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Business Leadership in the Adoption of Eco-Innovation in Manufacturing: Evidence from Firm-Level Microdata

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Abstract: *With growing global concern about climate change, manufacturing, especially in emerging markets, faces increasing pressure to adopt sustainable practices. A key response is eco-innovation, involving cleaner technologies, greener production methods, and business models with reduced environmental impact. This research examines the role of business leadership in the adoption of eco-innovation in manufacturing. The analysis relies on microdata from the 2023 Community Innovation Survey conducted by the Statistical Office of Serbia, covering the period 2020–2022. Descriptive statistics and one-way ANOVA are employed to examine differences across sub-sectors, firm size, and technology intensity, as well as the influence of factors such as regulations, incentives, market demand, costs, and reputational considerations. The results show that business leadership plays a key role in driving eco-innovation, particularly when motivated by reputational benefits and cost pressures. In contrast, firm size and technological intensity have no significant effect, while differences across manufacturing sub-sectors are more pronounced. Firms are driven by energy and material costs, regulatory compliance, and reputational gains, whereas government incentives and green public procurement have limited influence due to weak and inconsistent policies. These findings highlight the strategic importance of leadership-driven decision-making in eco-innovation adoption, informing both business practice and policy design for the green transition in emerging economies.*

Keywords: business leadership, eco-innovation, firm-level drivers, green transition, innovation adoption, manufacturing sector, reputational considerations, sustainability.
JEL Classification: Q55, O03, Q56.

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INTRODUCTION

In recent years, growing concern about climate change and environmental damage has pushed countries to move toward greener and more sustainable economies. This shift, often called the green transition, is especially important for the manufacturing sector, which plays a major role in pollution and the use of natural resources (European Commission, 2020a; International Energy Agency, 2023). According to the International Energy Agency (2023), industry accounts for around 25% of global CO_2 emissions, underscoring the urgent need for deep decarbonization.

To achieve the internationally agreed climate target of zero greenhouse gas emissions by 2050, in line with the Paris Agreement, the manufacturing industry will need to change significantly by adopting cleaner technologies, improving energy efficiency, and switching to renewable energy sources. A key enabler of this change is eco-innovation, which involves new or improved products, processes, or business models that reduce environmental impact.

The European Union's green transition agenda, which aims to make Europe the first climate-neutral continent by 2050, is driving substantial changes in the regulatory and economic environment. Serbia, as a country aspiring to EU membership, must align its industrial practices with these sustainability goals to secure both economic and environmental progress.

In this context, the Green Agenda for the Western Balkans provides a roadmap for Serbia's integration into the EU's green transition, with specific focus on decarbonization, sustainable agriculture, and reducing pollution, making it a crucial framework for the country's economic and environmental alignment with EU standards (European Commission, 2020b).

The Agenda promotes environmental sustainability and opens up new economic opportunities for Serbia by encouraging investment in green technologies and fostering regional cooperation on climate-related initiatives. A recent systematic review of green growth and innovation in the Global South emphasizes that industrial policies promoting eco-innovation can deliver both environmental and competitiveness benefits but also highlights that empirical evidence from emerging and transition economies remains limited (Herman, 2023). This reinforces the importance of generating new firm-level insights for countries like Serbia.

Serbia's manufacturing sector is predominantly composed of small and medium-sized enterprises, many of which are export-oriented (Trajković & Stošić Mihajlović, 2021). Despite this outward orientation, the sector continues to grapple with significant obstacles, including the need for modernization of production technologies, improvements in infrastructure, and more reliable access to financial resources (Majstorović et al., 2020). In recent years, increasing attention has been placed on eco-innovation and sustainability, spurred by tightening environmental regulations and international market pressures, with the goal of boosting competitiveness and supporting long-term development.

Building on the above discussion, this paper aims to provide new empirical evidence to address two central research questions:

- How do company size, technological intensity, and industry sub-sector influence the likelihood of introducing eco-innovations in the Serbian manufacturing sector?
- Which firm-level factors, including regulatory pressure, financial incentives, market demand, cost-related drivers, and reputational considerations, are most strongly associated with the adoption of eco-innovation? In addition, the study explores how business leadership shapes strategic decisions related to eco-innovation, particularly in contexts where environmental commitment strengthens firm reputation, stakeholder trust, and market positioning.

Moreover, growing attention has been paid to the role of reputational considerations in motivating firms to engage in eco-innovation. In an increasingly sustainability-conscious marketplace, companies are aware that adopting environmentally responsible practices enhances their public image, strengthens customer loyalty, and improves relationships with regulators and investors. The reputational dimension of eco-innovation is particularly relevant for manufacturing firms in transition economies, such as Serbia, where participation in global supply chains often depends on demonstrating compliance with international environmental standards and corporate social responsibility principles. Thus, alongside regulatory and cost-related drivers, reputational motivations may represent a powerful and strategic incentive for green transformation.

This paper makes several significant contributions to the existing literature on eco-innovation. First, it provides new empirical evidence on the adoption of environmentally beneficial innovations in the manufacturing sector of an emerging economy – a context that has received limited attention in prior studies. Second, it applies firm-level microdata from the 2023 Community Innovation Survey, allowing for a detailed sectoral analysis and the identification of key drivers of eco-innovation adoption.

Third, the paper offers insights into the relative influence of structural firm characteristics (such as size and technological intensity) versus contextual and motivational factors (such as cost pressures, regulation, and reputation) in shaping eco-innovation decisions.

Finally, by focusing on the Serbian case within the broader EU accession and Green Agenda framework, the study contributes to a better understanding of the challenges and opportunities of the green transition in non-EU countries, offering policy-relevant findings for similar economies in the Western Balkans and beyond.

LITERATURE REVIEW

Conceptual Foundations of Eco-Innovation

Eco-innovation is a concept that has attracted considerable attention in both academic and practical spheres due to its potential to address environmental challenges while fostering economic growth. The diverse definitions of eco-innovation are reflected in the wide range of terms and concepts used. Researchers use various terms for it, such as environmental innovation, eco-innovation, green innovation, and sustainable or sustainability-oriented innovation (Pichlak & Szromek, 2021).

It is generally defined as any innovation that leads to a reduction in environmental impact, regardless of whether this outcome was the original intention of the innovation or not (Vieira & Radonjič, 2020). This definition emphasizes the dual nature of eco-innovation, which can manifest itself either as incremental improvements to existing processes or as radical innovations that fundamentally change the way products are developed and produced (Arranz et al., 2020).

The literature suggests that eco-innovation is not merely a technical or product-based phenomenon; it also involves organizational changes and the adoption of new management practices that contribute to environmental sustainability (Bucheli-Calvache et al., 2023). For instance, Kemp and Pearson (2007) characterize eco-innovation as production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resource use (including energy use) compared to relevant alternatives.

This definition underscores the importance of integrating eco-innovation into the strategic framework of firms, as it can lead to enhanced competitive advantages and market opportunities (Dzhunushalieva & Teuber, 2024).

The European Commission (2013) specified eco-innovation as "all forms of innovation, technological and non-technological, that create business opportunities and benefit the environment by preventing or reducing their impact, or by optimizing the use of resources". OECD (2010) emphasizes that eco-innovation can be analyzed based on its target, mechanism, and impact. The target represents the main focus of eco-innovation, which can be a product, process, marketing method, or organization. The mechanisms imply the novelty level and nature of eco-innovation.

The impact includes the effect of eco-innovation on the environmental conditions. Eco-innovation can also be understood as the integration of environmental considerations into the innovation process, leading to the development of new products, services, and business models that are environmentally friendly (Pichlak & Szromek, 2021).

This definition highlights the transformative potential of eco-innovation, suggesting that it is not merely about improving existing products but also about rethinking and redesigning business practices to align with sustainability objectives.

Losacker et al. (2023) provide evidence from patent licensing data in China that eco-innovation diffusion is strongly influenced by the geography of technology adoption, with locally specialized and innovative regions more likely to adopt homegrown green technologies, underscoring the role of spatial and systemic factors in shaping eco-innovation pathways. The integration of sustainability into the core of innovation processes is a critical aspect that distinguishes eco-innovation from traditional innovation.

Determinants of Eco-Innovation

In recent years, eco-innovation has become a dynamic and expanding research field, reflecting growing academic and policy interest in the intersection between sustainability and innovation. According to Hu et al. (2024), the number of publications on eco-innovation has grown significantly, progressing through phases of budding, steady development, and rapid expansion. Their combined scientometric and meta-analytic study confirms that the determinants of eco-innovation remain a long-standing research focus, with particular attention given to firm-level innovation capability, environmental regulation, and the enabling role of government policies.

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Numerous studies have explored the drivers and barriers of eco-innovation, often highlighting firm-level, sectoral, and institutional characteristics. A meta-analytic review conducted by Bitencourt et al. (2020), which synthesized findings from 71 studies and over 220,000 observations, identified several key antecedents of eco-innovation, including company capabilities, environmental regulations, market turbulence, access to information, R&D investment, and firm size.

Their analysis also confirmed a positive relationship between eco-innovation and firm performance, with notable variations across national contexts. For instance, the link between eco-innovation and competitiveness appeared stronger in countries with lower Human Development Index scores, suggesting that firms in environmentally challenged or economically constrained regions may derive greater strategic benefits from sustainability-oriented innovations.

The influence of company size on the introduction of eco-innovation reveals various dynamics between firm characteristics and their capacity to adopt environmentally sustainable practices. Generally, larger firms are found to have a greater propensity to engage in eco-innovation compared to their smaller counterparts. This trend can be attributed to several factors, including resource availability, economies of scale, and organizational capabilities that larger firms possess (Doran & Ryan, 2014; Triguero et al., 2015).

Larger companies typically have more substantial financial resources, which enable them to invest in research and development activities aimed at eco-innovation. This financial backing allows them to undertake more extensive projects that may involve higher risks and longer payback periods, which smaller firms might be unable to afford (Sichoongwe, 2023).

Moreover, larger firms often benefit from established R&D departments and specialized personnel who can focus on developing eco-innovative products and processes (Ahmed et al., 2023). This structural advantage facilitates a more systematic approach to innovation, allowing larger firms to integrate eco-innovation into their core business strategies effectively.

In contrast, small and medium-sized enterprises (SMEs) often face significant barriers to eco-innovation, primarily due to limited financial resources and a lack of specialized knowledge (Klement, 2023; Brogi & Menichini, 2021). However, it is crucial to note that SMEs can also exhibit high levels of innovation, particularly in niche markets where they can leverage their agility and responsiveness to consumer demands (Zhang & Walton, 2016).

Findings from Kenya suggest that SMEs may even be more proactive in adopting eco-design targets compared to larger companies, highlighting that firm size does not always determine the degree of eco-innovation uptake (Andersen et al., 2022). The entrepreneurial spirit inherent in many SMEs can lead to innovative solutions that larger firms may overlook due to their more bureaucratic structures (Hansen & Klewitz, 2012).

Previous studies have shown that a company's economic sector plays a critical role in shaping how it responds to environmental challenges and opportunities when introducing eco-innovation. Different sectors exhibit varying levels of eco-innovation adoption due to distinct regulatory environments, market demands, technological capabilities, and competitive pressures. One of the primary determinants of eco-innovation is the regulatory framework that governs specific sectors. Industries that are heavily regulated, such as the automotive and energy sectors, often face stringent environmental standards that compel firms to innovate to comply with regulations (Giraldo, 2024).

For instance, the automotive industry has seen significant advancements in eco-innovation, particularly in the development of electric and hybrid vehicles, driven by regulatory pressures to reduce emissions (Maldonado-Guzmán & Garza-Reyes, 2020).

Market demand also plays a crucial role in shaping eco-innovation within different sectors. Industries that cater to environmentally conscious consumers, such as the tourism and hospitality sectors, are more likely to adopt eco-innovative practices to enhance their competitive advantage (Ahmed et al., 2023; Lopes & Basso, 2023). Conversely, sectors that do not face significant consumer pressure for sustainability may lag in adopting eco-innovative practices, as the perceived benefits may not justify the costs involved (Leitao et al., 2020). Firms with higher technological capabilities are more likely to engage in eco-innovation, as these capabilities enable them to innovate processes, products, and services that reduce environmental impacts (Valdez-Juarez & Castillo-Vergara, 2021; Hojnik et al., 2017).

One of the primary reasons that technological capability influences eco-innovation is that it allows firms to effectively gather and analyze information related to environmental performance. Companies with advanced technological infrastructures can better identify inefficiencies and areas for improvement, leading to more effective eco-innovative strategies (Urbaniec et al., 2021).

For instance, firms that invest in digital technologies and data analytics are better equipped to monitor their environmental impact and optimize their resource use, which is essential for developing eco-innovative solutions (Valdez-Juárez & Castillo-Vergara, 2021).

Another important yet sometimes underexplored driver of eco-innovation is corporate reputation. The pursuit of a positive environmental image can serve as a strategic motivation for firms to innovate sustainably (Vieira & Radonjič, 2020). Reputational gains arise when eco-innovation signals environmental responsibility to customers, investors, and policymakers, thereby improving a firm's legitimacy and competitive standing (Doran & Ryan, 2014).

Studies in various contexts demonstrate that companies utilize eco-innovation to differentiate themselves and establish trust among environmentally conscious stakeholders (Bonzanini Bossle et al., 2016; Ahmed et al., 2023).

Particularly in export-oriented sectors, firms may adopt eco-innovation not only to comply with environmental regulations but also to enhance brand value and meet the sustainability expectations of foreign partners. This reputational mechanism is especially relevant in emerging and transition economies, where building credibility in international markets can significantly influence growth and competitiveness.

The factors and drivers of eco-innovation in manufacturing are diverse and interrelated, reflecting the complex landscape of environmental sustainability and technological advancement. One of the primary drivers of eco-innovation is regulatory pressure. Existing regulations often compel firms to adopt eco-innovative practices to comply with environmental standards and avoid penalties. For example, manufacturing firms in the automotive and chemical industries face strict emissions standards, prompting them to innovate in cleaner technologies and processes (Ryszko, 2017). Financial considerations also play a crucial role in the eco-innovation landscape. Firms that can access grants, subsidies, or low-interest loans for sustainable projects are more likely to pursue eco-innovative practices.

However, as Bugge et al. (2024) emphasize, transformative change requires more than financial incentives. Without strong integration into local innovation systems, even well-funded initiatives risk remaining detached "tech-push" projects with limited long-term impact in developing and transition economies. Conversely, financial constraints can hinder innovation efforts, particularly for SMEs that may lack the resources to invest in new technologies (Del Rio et al., 2017).

The competitive landscape within specific industries can drive eco-innovation. Firms operating in highly competitive markets may be more inclined to adopt eco-innovative practices as a means of differentiation and cost reduction (Ganapathy et al., 2014). Finally, the socio-economic context in which firms operate can influence their approach to eco-innovation. Factors such as regional environmental policies, cultural attitudes towards sustainability, and economic conditions can shape the drivers and barriers to eco-innovation (Rama et al., 2022).

METHODOLOGY

This research draws on microdata from the 2023 Community Innovation Survey (CIS) conducted by the Statistical Office of Serbia, covering the period from 2020 to 2022. The data was provided directly by the Statistical Office of the Republic of Serbia, which administered the survey as part of the harmonized CIS cycle in accordance with Eurostat guidelines. Data collection was carried out using standardized questionnaires distributed to enterprises and compiled through structured data processing.

The sample includes 955 manufacturing companies across diverse sub-sectors. The data was collected using a stratified sampling method to ensure representation across different industry divisions, company sizes, and regions of Serbia. The focus of the study is limited to the manufacturing sector due to its central role in the development and implementation of eco-innovations, as well as its high environmental impact compared to other sectors. To explore the adoption of eco-innovations, companies are categorized by size, technological intensity, and manufacturing sub-sectors.

Table 1 provides an overview of manufacturing classifications based on company size and sub-sectors. To make the analysis more accessible, individual NACE divisions were further summarized into broader sub-sectors, which group together related industries. For example, food and beverages include NACE codes 10 and 11, textiles and leather bring together NACE codes 13, 14, and 15, while chemicals and pharmaceuticals combine NACE codes 20 and 21.

Similarly, metals cover NACE codes 24 and 25, and electrical and machinery integrate NACE codes 26–30. This grouping provides a clearer overview of the sectoral structure while still reflecting the diversity of Serbia's manufacturing industry. The classification of manufacturing by technological intensity is based on the OECD taxonomy of economic activities, which uses R&D intensity as a criterion (Galindo-Rueda & Verger, 2016). Certain NACE divisions, such as the manufacture of tobacco products and the manufacture of coke and refined petroleum products, were excluded due to their highly specific regulatory environments and limited relevance for broader eco-innovation analysis. These sectors are also characterized by relatively low participation in innovation surveys and distinct production structures that may not be comparable to the rest of the manufacturing sector.

Table 1. Classification of Manufacturing Companies by Size and Manufacturing Sub-Sectors

Company size		
Classification		**Number of employees**
Micro		1–9
Small		10–49
Medium		50–249
Large		250 or more
Manufacturing Sub-sector Grouping Based on NACE Rev. 2 Codes		
NACE Rev. 2 Code	**NACE Rev. 2 Division**	**Subsectors**
10	Manufacture of food products	Food and Beverages
11	Manufacture of beverages	
13	Manufacture of textiles	Textiles and Leather
14	Manufacture of wearing apparel	
15	Manufacture of leather and related products	
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Wood and Paper
17	Manufacture of paper and paper products	
20	Manufacture of chemicals and chemical products	Chemicals and Pharmaceuticals
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	
22	Manufacture of rubber and plastic products	Rubber and Plastics
23	Manufacture of other non-metallic mineral products	
24	Manufacture of basic metals	Metals
25	Manufacture of fabricated metal products, except machinery and equipment	
26	Manufacture of computer, electronic, and optical products	Electrical and Machinery
27	Manufacture of electrical equipment	
28	Manufacture of machinery and equipment n.e.c.	
29	Manufacture of motor vehicles, trailers, and semi-trailers	
30	Manufacture of other transport equipment	
31	Manufacture of furniture	Furniture
12	Manufacture of tobacco products	Not included in the research paper
18	Printing and reproduction of recorded media	
19	Manufacture of coke and refined petroleum products	

Source: authors' classification.

The dependent variables in this analysis (Table 1) reflect the extent to which firms engaged in various eco-innovation activities during the reference period. Specifically, they capture the reported implementation of practices aimed at enhancing environmental performance across multiple dimensions of production and resource use.

The eco-innovation activities considered in this study are based on the definitions used in the CIS and include reduction of energy consumption or CO_2 emissions; reduction of material or water use per unit of output; mitigation of soil, noise, water, or air pollution; substitution of hazardous or polluting materials with more environmentally friendly alternatives; replacement of fossil energy sources with renewables; and recycling of waste, water, or materials for internal use or resale.

The statistical analyses were performed using SPSS software, including descriptive statistics and a one-way ANOVA to examine and compare the adoption of eco-innovations across different industry sectors, company size categories, and technological intensity levels. The one-way ANOVA (Analysis of Variance) is a statistical method used to test whether there are statistically significant differences between the means of three or more independent groups. The test is based on the principle of partitioning the total variability in the data into the variability between groups and within groups, with the F-statistic calculated as the ratio of these two sources of variation:

In the context of this study, ANOVA is particularly suitable because the variables of interest (industry sector, company size, and technological intensity) consist of multiple categorical groups, and the objective is to determine whether the average level of eco-innovation adoption differs significantly among them.

By applying ANOVA, it is possible to assess not only the descriptive trends but also the statistical robustness of observed differences, thereby providing stronger evidence for analyzing sectoral and firm-level variations in eco-innovation practices.

Additional analyses were conducted to determine the importance of various factors in driving enterprises' decisions to introduce innovations with environmental benefits. The following factors were examined: existing environmental regulations; existing environmental taxes, charges, or fees; environmental regulations or taxes expected in the future; government grants, subsidies, or other financial incentives for environmental innovations; current or expected market demand for environmental innovations; improving the enterprise's reputation; voluntary actions or initiatives for environmental good practice within the sector; high cost of energy, water, or materials; and the need to meet requirements for public procurement contracts.

RESULTS

The structure of the research sample, derived from the CIS questionnaire, is presented in Table 2. It combines data on company size, technological intensity, and manufacturing sub-sectors, providing a comprehensive overview of the surveyed firms.

In terms of company size, small enterprises represent the largest group (37%), followed by medium-sized (32%) and large firms (25%), while micro-enterprises account for the remaining 6%. With respect to technological intensity, most firms operate within the low- and mid-low-tech categories, which together comprise almost 70% of the sample. Specifically, low-tech companies account for 45% and mid-low-tech for 24%, while mid-high-tech firms make up 23%, and high-tech firms only 8%. This distribution is consistent with previous findings, which note that more than two-thirds of Serbian industry consists of low- and medium-low-tech companies (Klarin et al., 2016).

Table 2. Structure of the Research Sample by Company Size, Technological Level, and Subsector

Category	Subcategory	Number of Companies	Percentage, %
Company size	Micro (1–9 employees)	57	6
	Small (10–49 employees)	352	37
	Medium (50–249 employees)	306	32
	Large (250+ employees)	240	25
Technological level	High-tech	74	8
	Mid-high tech	219	23
	Mid-low tech	230	24
	Low tech	432	45
Subsectors	Food and Beverages (NACE 10–11)	129	15
	Textiles and Leather (NACE 13–15)	112	13
	Wood and Paper (NACE 16–17)	65	7
	Chemicals and Pharmaceuticals (NACE 20–21)	50	6
	Rubber and Plastics (NACE 22)	102	12
	Metals (NACE 24–25)	122	14
	Electrical and Machinery (NACE 26–30)	243	28
	Furniture (NACE 31)	45	5

Source: authors' calculations based on data from the Community Innovation Survey (2023).

As demonstrated in Table 2, the breakdown by sub-sector shows that Electrical and Machinery is the most represented group (28% of the sample), followed by Food and Beverages (15%) and Metals (14%). Smaller but still notable sub-sectors include Rubber and Plastics (12%), Textiles and Leather (13%), and Chemicals and Pharmaceuticals (6%), while Furniture and Wood and Paper account for 5% and 7%, respectively.

The results of the one-way ANOVA revealed no statistically significant differences in the adoption of eco-innovations across the four technological intensity groups for any of the variables studied (Table 3). Although it was anticipated that firms with higher technological intensity would exhibit greater eco-innovation adoption due to their stronger R&D capabilities and access to resources, the lack of significant variation suggests that, within the Serbian context, technological intensity alone may not be a determining factor in driving ecological innovation practices.

Table 3. Results of One-Way ANOVA Test for the Technological Intensity Groups

ANOVA						
		Sum of Squares	***df***	**Mean Square**	***F***	**Sig.**
Reduced energy use or CO2 ‘footprint’ (i.e., reduced total CO2 emission)	Between Groups	3.938	3	1.313	2.158	**0.091**
	Within Groups	578.591	951	0.608		
	Total	582.530	954			
Reduced material or water use per unit of output	Between Groups	2.610	3	0.870	1.445	**0.228**
	Within Groups	572.787	951	0.602		
	Total	575.397	954			
Reduced soil, noise, water, or air pollution	Between Groups	4.147	3	1.382	2.391	**0.067**
	Within Groups	549.717	951	0.578		
	Total	553.864	954			
Replaced a share of materials with less polluting or hazardous substitutes	Between Groups	2.717	3	0.906	1.798	**0.146**
	Within Groups	479.011	951	0.504		
	Total	481.728	954			
Replaced a share of fossil energy with renewable energy sources	Between Groups	1.770	3	0.590	1.766	**0.152**
	Within Groups	317.724	951	0.334		
	Total	319.493	954			
Recycled waste, water, or materials for own use or sale	Between Groups	1.399	3	0.466	0.857	**0.463**
	Within Groups	517.874	951	0.545		
	Total	519.273	954			
Protection of biodiversity	Between Groups	0.527	3	0.176	0.411	**0.745**
	Within Groups	406.265	951	0.427		
	Total	406.792	954			

Note: df = degrees of freedom; F = f-statistic; Sig = significance.

Source: authors' calculations based on data from the Community Innovation Survey (2023).

This contrasts with recent findings from Mexico, where technological capability was found to significantly influence eco-innovation among SMEs (Valdez-Juárez & Castillo-Vergara, 2021), highlighting that other factors may play a more critical role in shaping eco-innovation efforts across industries (Table 3). The second part of the analysis examined whether company size influences the adoption of ecological innovations. While the descriptive statistics indicate that larger companies are more likely to adopt eco-innovations than smaller ones, the results of the one-way ANOVA showed no statistically significant differences between company sizes in the Serbian context (Table 4).

Table 4. Results of One-Way ANOVA Test for Company Size

ANOVA						
		Sum of Squares	***df***	**Mean Square**	***F***	**Sig.**
Reduced energy use or CO2 ‘footprint’ (i.e., reduced total CO2 emission)	Between Groups	1.302	3	0.434	0.710	**0.546**
	Within Groups	581.228	951	0.611		
	Total	582.530	954			
Reduced material or water use per unit of output	Between Groups	0.264	3	0.088	0.146	**0.932**
	Within Groups	575.132	951	0.605		
	Total	575.397	954			
Reduced soil, noise, water, or air pollution	Between Groups	0.675	3	0.225	0.387	**0.762**
	Within Groups	553.189	951	0.582		
	Total	553.864	954			
Replaced a share of materials with less polluting or hazardous substitutes	Between Groups	0.588	3	0.196	0.388	**0.762**
	Within Groups	481.140	951	0.506		
	Total	481.728	954			
Replaced a share of fossil energy with renewable energy sources	Between Groups	1.942	3	0.647	1.939	**0.122**
	Within Groups	317.551	951	0.334		
	Total	319.493	954			
Recycled waste, water, or materials for own use or sale	Between Groups	1.664	3	0.555	1.019	**0.383**
	Within Groups	517.610	951	0.544		
	Total	519.273	954			
Protection of biodiversity	Between Groups	0.571	3	0.190	0.446	**0.720**
	Within Groups	406.220	951	0.427		
	Total	406.792	954			

Note: df = degrees of freedom; F = f-statistic; Sig = significance.

Source: authors' calculations based on data from the Community Innovation Survey (2023).

In Table 4, this result contrasts with much of the existing literature, which generally supports a positive relationship between firm size and eco-innovation. For example, Sichoongwe (2023), Poussing & Le Bas (2013) and Triguero et al. (2017) emphasize that larger firms are more likely to adopt eco-innovation due to their better R&D capabilities, better access to financial resources and higher risk tolerance compared to SMEs.

However, the findings are consistent with some studies that challenge this relationship. Research by Wagner (2008) and Bernauer et al. (2007) suggests that company size is not always a decisive factor for eco-innovation. These studies find that other factors such as networking, collaboration with universities, supplier relationships and organizational practices such as training have a greater impact on eco-innovation than firm size. De Marchi (2012) also emphasises the role of external collaboration and networks for knowledge sharing, which in some contexts can outweigh the impact of firm size.

The analysis of ecological innovation adoption across different industry sectors revealed significant differences, with the Textiles and Leather sub-sector showing notably higher levels of eco-innovation compared to the Electricals and Machinery and Furniture sub-sectors (Table 5). This suggests that sector-specific factors play an important role in driving ecological innovation.

Table 5. Results of One-Way ANOVA Test for Manufacturing Subsectors

ANOVA					
Eco innovations					
	Sum of Squares	***df***	**Mean Square**	***F***	**Sig.**
Between Groups	5.908	7	0.844	2.957	0.005
Within Groups	245.463	860	0.285		
Total	251.371	867			

Multiple Comparisons Dependent Variable: Eco-innovations Tukey HSD						
					95% Confidence Interval	
(I) Sectors	**(J) Sectors**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**Lower Bound**	**Upper Bound**
Textiles and Leather	Food and Beverages	0.07553	0.06900	0.958	-0.1341	0.2852
	Wood and Paper	0.13673	0.08330	0.725	-0.1164	0.3898
	Chemicals and Pharmaceuticals	0.08196	0.09087	0.986	-0.1941	0.3581
	Rubber and Plastics	0.16010	0.07312	0.359	-0.0621	0.3823
	Metals	0.15065	0.06991	0.381	-0.0618	0.3631
	Electrical and Machinery	**0.22205***	0.06102	0.007	0.0367	0.4074
	Furniture	**0.31219***	0.09429	0.022	0.0257	0.5987
*. The mean difference is significant at the 0.05 level.						

Note: df = degrees of freedom; F = f-statistic; Sig = significance; Std. Error=standard error.
Source: Authors' calculations based on data from the Community Innovation Survey (2023).

While previous studies have demonstrated that eco-innovation adoption varies across broad sectors such as manufacturing, services, or tourism, there is far less evidence regarding differences within the various sub-sectors of manufacturing itself (Table 5). In this respect, the findings provide an important contribution by showing that even within the manufacturing industry, eco-innovation uptake is not uniform but shaped by sub-sector characteristics. For policymakers, this implies that efforts to stimulate eco-innovation need to be designed with sector-specific characteristics in mind, rather than relying solely on firm size or technological intensity. Additional attention and targeted support should be directed toward sub-sectors that are slower to adopt green practices to strengthen their sustainability performance (Table 6).

Table 6. Average Importance of Factors Driving Eco-Innovation in Serbian Enterprises (score 0-3)

Driver of eco-innovation	**Mean value**
Existing environmental regulations	1.67
Existing environmental taxes, charges, or fees	1.47
Environmental regulations or taxes expected in the future	1.49
Government grants, subsidies, or other financial incentives for environmental innovations	0.96
Current or expected market demand for environmental innovations	1.17
Improving your enterprise's reputation	1.71
Voluntary actions or initiatives for environmental good practice within your sector	1.26
High cost of energy, water, or materials	1.76
Need to meet requirements for public procurement contracts	0.83

Source: authors' calculations based on data from the Community Innovation Survey (2023).

Additional analysis revealed that the primary drivers for adopting eco-innovation in the Serbian manufacturing sector are the high costs of energy, water, and materials, as well as the desire to improve the company's reputation and comply with existing environmental regulations when introducing eco-innovation (Table 6). This indicates that eco-innovation is not only a response to external pressure but also a result of leadership decisions aimed at strengthening long-term competitive positioning. This pattern is consistent with the findings of Bonzanini Bossle et al. (2016), who argue that eco-innovation is frequently adopted in response to normative and regulatory pressures rather than proactive environmental strategies. The strong influence of cost-related factors also reflects broader trends observed in the literature, which highlight resource efficiency and operational savings as dominant motivations for eco-innovation, particularly in contexts characterized by nascent innovation systems and limited institutional support for environmental policy (Horbach et al., 2012).

Among the non-regulatory and non-cost factors, improving corporate reputation stands out as the second most influential driver of eco-innovation (mean value 1.71), just behind the cost-related factor. This finding highlights that Serbian manufacturers increasingly view environmental responsibility as part of their strategic positioning rather than merely as compliance. A strong reputation for sustainability can open access to new markets, attract business partners, and improve stakeholder relations. Given Serbia's ongoing integration into European value chains, firms that demonstrate credible environmental practices can gain reputational advantages that translate into economic benefits.

In contrast, government financial incentives and requirements related to public procurement appear to have a relatively limited influence. This can be attributed to the current lack of comprehensive and targeted policy instruments in Serbia that actively promote or reward green innovation. The relatively low scores assigned to these factors underscore a broader policy gap, the absence of consistent and accessible support mechanisms for companies investing in environmentally beneficial innovations. Similar patterns have been observed in other transition economies, where the absence of long-term green policy frameworks weakens the effectiveness of public support instruments (Triguero et al., 2013).

CONCLUSIONS

The findings reveal that neither firm size nor technological intensity exerts a significant effect on the extent of eco-innovation adoption within Serbia's manufacturing industry. By contrast, notable variations emerge across individual sub-sectors, with textiles and leather enterprises exhibiting comparatively higher levels of eco-innovation than those operating in the electrical and machinery or furniture production sectors.

The main drivers for adopting eco-innovation are high costs of energy, water, or materials; the desire to improve corporate reputation; and compliance with existing environmental regulations. The prominence of reputational motivations suggests that firms are increasingly recognizing environmental performance as integral to their market identity and competitiveness. This confirms that business leadership plays a strategic role in promoting eco-innovation, especially in contexts where regulatory and financial incentives are insufficient. These findings have important implications for policymakers seeking to promote sustainable practices in Serbia's manufacturing sector. They also provide benchmarks for other emerging and transition economies and contribute to a broader understanding of effective green transition strategies.

The main policy conclusion is that sector-specific policies are needed to address the significant differences in the uptake of eco-innovation across industries. Policymakers should focus on providing targeted incentives, subsidies, and technical support to lagging manufacturing sectors while promoting best practices from more advanced sectors. The finding that companies are motivated by regulatory compliance suggests that tightening environmental regulations and improving enforcement could lead to greater diffusion of eco-innovation. Policymakers could also enhance regulatory frameworks by introducing stricter environmental standards that encourage sustainable practices.

Furthermore, the study underscores the need for stronger government incentives to facilitate Serbia's transition to a green economy, in line with international sustainability goals. The importance of high costs related to energy, water, and materials as key drivers suggests that cost-reduction initiatives could further encourage eco-innovation. Policies such as tax incentives, grants, or access to low-interest loans for adopting resource-efficient technologies would make it easier for firms to invest in sustainability. Given that reputation is another motivating factor, governments should implement programs like eco-certifications and public recognition to reward companies for adopting green practices, creating further incentives.

Long-term monitoring and adaptation of innovation programs should ensure that policies evolve alongside technological advancements and sectoral needs, allowing for continuous improvement in eco-innovation practices. Policymakers and industry associations could also harness reputational incentives by promoting voluntary eco-certifications, public awards, and green labelling schemes that recognize environmentally responsible firms. Such visibility mechanisms can amplify the reputational rewards of eco-innovation and encourage broader participation across the manufacturing sector.

AR&P

The research has several limitations, including reliance on the Community Innovation Survey 2023 data, which may not fully capture all relevant trends in eco-innovation. Second, the analysis is limited to firms operating in Serbia. While this single-country focus enables an in-depth examination of eco-innovation dynamics in the national manufacturing sector, it limits the generalizability of the findings to other countries with different institutional, economic, and policy contexts.

Future research could benefit from comparative studies across multiple countries to assess whether the observed patterns hold in various environments. The analysis also focuses primarily on a limited set of drivers, potentially overlooking the role of firm-level R&D capacity, access to international markets, managerial capabilities, and the influence of supply chains or regional ecosystems.

Building on this research, future studies could examine eco-innovation trends over several years to better understand how companies respond to changing economic and regulatory environments. The inclusion of other sectors and the use of mixed methods, such as interviews or case studies, could provide a more comprehensive understanding of the specific challenges and motivations for adopting eco-innovation. In addition, comparing the Serbian case with that of similar countries could help to identify common patterns and develop more effective policy approaches.

Author Contributions

Conceptualization: L. Ž., D. Š.; data curation: L. Ž., D. Š.; formal analysis: L. Ž., D. Š.; funding acquisition: L. Ž., D. Š.; investigation: L. Ž., D. Š.; methodology: L. Ž.; project administration: L. Ž., D. Š.; resources: L. Ž., D. Š.; software: L. Ž., D. Š.; supervision: L. Ž.; validation: D. Š.; visualization: L. Ž., D. Š.; writing-original draft preparation L. Ž., D. Š.; writing-review and editing: L. Ž., D. Š.

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Conflicts of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data that support the findings of this study are derived from the 2023 Community Innovation Survey (CIS) conducted by the Statistical Office of the Republic of Serbia for the reference period 2020–2022. The survey is part of the harmonized CIS cycle coordinated by Eurostat, following its methodological guidelines and standards. The microdata used in this analysis are not publicly available due to confidentiality restrictions imposed by the Statistical Office of the Republic of Serbia. Access to anonymized firm-level data was granted to the authors under a formal request and data use agreement for research purposes.

Informed Consent Statement

Not applicable.

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