GENDER PERSPECTIVES OF TWIN TRANSITION IN AGRICULTURE AND FOOD SECTOR COMPANIES: EMPIRICAL EVIDENCE FROM SERBIA

Mihailo Paunović[1], Dijana Štrbac[2], Lazar Živković[3]

**Corresponding author E-mail: mihailo.paunovic@ien.bg.ac.rs*

ARTICLE INFO

Original Article

Received: *28 June 2024*

Accepted: *30 August 2024*

doi:10.59267/ekoPolj2403895P

UDC 305:338.439(497.11)

Keywords:

twin transition, digitalisation, gender, agriculture, food

***JEL**: O13, M21, Q01*

ABSTRACT

This paper investigates the gender perspectives in the twin transition of companies in Serbia's agriculture and food sector, focusing on their adoption of information and communication technologies (ICT) and green/environmental activities. Using primary data from computer-assisted telephone interviews, a comprehensive survey was conducted among sector companies. Statistical analysis included descriptive statistics and non-parametric tests to compare differences between groups. The results highlight the significant impact of gender diversity on digitalisation adoption. However, disparities emerge in the green transition, particularly in waste reduction through recycling, raw material reuse, and supplier selection based on environmental criteria. No gender-specific differences were found in reducing harmful emissions or using eco-friendly packaging. This study enhances understanding of gender dynamics in the agri-food sector's twin transformation and highlights how gender perspectives influence digital and environmental practices. The findings inform policymakers and businesses on promoting gender-sensitive strategies for sustainable development and economic growth in Serbia and beyond.

Introduction

The "twin transition" concept originates from the European Green Deal and highlights the intertwined nature of digital and green transitions (European Commission, 2019).

1 Mihailo Paunović, Ph.D., Research Associate, Institute of Economic Sciences, Zmaj Jovina 12, 11000 Belgrade, Serbia, Phone: +381 2623 578, E-mail: mihailo.paunovic@ien.bg.ac.rs, ORCID ID (https://orcid.org/0000-0002-3183-9971)

2 Dijana Štrbac, Ph.D., Research Associate, Institute of Economic Sciences, Zmaj Jovina 12, 11000 Belgrade, Serbia, Phone: +381 2623 578, E-mail: dijana.strbac@ien.bg.ac.rs, ORCID ID (https://orcid.org/0000-0003-1972-5493)

3 Lazar Živković, Ph.D., Research Associate, Institute of Economic Sciences, Zmaj Jovina 12, 11000 Belgrade, Serbia, Phone: +381 2623 578, E-mail: lazar.zivkovic@ien.bg.ac.rs, ORCID ID (https://orcid.org/0000-0003-2405-2692)

Even though the digital and green transformations are interconnected, their dynamics and characteristics are different. The green transition requires a strong political and societal push driven by the public interest. On the other hand, the digital transformation is primarily market-driven. Advances in digital technologies have created enormous opportunities for innovative businesses, but this has often exploited regulatory gaps and caused inequalities (Brunori, 2022). These two concepts, while distinct, influence each other and are essential for everyone. They highlight the reciprocal relationship between digital advancements and sustainability efforts. Although the twin transition began within the European Union (EU), it has global relevance, reflecting the need for countries worldwide to address both digital and sustainable development simultaneously (Morten, 2023).

The twin transition in companies is a significant step towards integrating sustainability and technological advancements into their operations and strategies. The digital transformation plays a crucial role in promoting green technology innovation within companies (Xue et al., 2022; Zhang et al., 2022; Chen & Hao, 2022; Sun & Guo, 2022). Moreover, the integration of environmental responsibility into digital transformation efforts can lead to more cost-effective and efficient green innovation, satisfying both internal and external stakeholders (Sun & He, 2023). There is also a positive impact of digital transformation on total factor productivity, especially in heavily polluting enterprises, by increasing green technology innovation and corporate social responsibility (Su et al., 2023).

In the twin transition, agriculture and food processing are crucial sectors, identified alongside energy and mobility as key areas requiring profound transformation to achieve sustainability goals (European Environment Agency, 2021). The Farm to Fork strategy emphasizes this necessity by highlighting the significant contributions of agricultural systems to greenhouse gases, biodiversity loss, pollution, and water scarcity, as well as the food system's vital role in human well-being (Brunori, 2022). The twin transition in agriculture involves simultaneous changes in both production and consumption that can facilitate a shift towards sustainability and diversification in the agrifood system (Magrini et al., 2018).

The use of digital technologies in agriculture contributes to faster integration into the global economy, increases efficiency, promotes innovation and identifies new ways to improve supply chain management (Deichmann, Goyal & Mishra, 2016; Radić et al., 2022). The digitalisation of agriculture has been instrumental in improving agricultural productivity, promoting sustainable development, and achieving sustainability goals (Zhou et al., 2022; Zhong & Qi, 2022). Additionally, the transformation of agriculture from traditional to digital, ecological and intelligent practices can reduce resource wastage and environmental pressure, ultimately enhancing overall factor productivity in green agriculture (Hong et al., 2023). Improved management practises, higher productivity, lower costs, minimised environmental impact and improved product quality can be achieved through the introduction of digital innovations (Bolfe et al., 2020). Digital agriculture not only enhances agricultural productivity, but also addresses food security, climate protection, and resource management (Nasirahmadi & Hensel, 2022). Although digitalisation in agriculture has

a transformative impact across the agro-food systems, there are different challenges in establishing data systems and technologies. These include data ownership and control, development of technologies and data security (Rotz, et al., 2019).

In the context of the twin transition in the agri-food sector, gender dynamics play an important role in shaping agricultural productivity, sustainability and adaptation to climate change. Understanding the intersection of gender and these transformations is critical to promoting gender equality, improving agricultural outcomes and fostering inclusive development. The participation of women in agriculture is recognised as a key factor in increasing agricultural productivity and sustainability. Studies have shown that if women had equal access to productive resources as men, they could significantly increase yields on their farms, highlighting the potential for gender equality to drive agricultural productivity gains (Doss, 2017). The inclusion of women in agri-food value chains can help reduce the gender gap and empower women through measures such as equal payment, maternity rights and female-specific training (Malanski et al., 2022). Furthermore, addressing gender dimensions in agriculture is essential for enabling communities to effectively adapt to climate change, as traditional gender analyses may not fully capture the norms and roles that underlie gender dynamics in specific socio-cultural contexts (Jost et al., 2015).

Agriculture stands as a cornerstone of the Serbian economy, constituting a significant sector that contributes approximately 7.5% to gross value added (GVA) and employs 15% of the labour force during the period from 2015 to 2020. When combined with the food, beverage, and tobacco industries, agriculture collectively represents approximately 19% of total exports (Ministry of Agriculture, Forestry and Water Management, 2022). The agri-food sector has been identified as a priority in the Smart Specialisation Strategy of the Republic of Serbia, focusing on key areas such as high-tech agriculture, value-added food products, and sustainable food production chains (Ministry of Education, Science and Technological Development, 2020). The agri-food sector in Serbia is undergoing a transformation driven by digitalisation and green transition initiatives. Digital technologies, such as digital marketing, online sales, and search engine optimization, are significantly impacting the performance of companies in the agricultural sector in Serbia (Mihailović et al., 2024). This can be observed especially in the autonomous province of Vojvodina, where digital technologies are being adopted in agriculture, leading to higher productivity and the establishment of the digital agricultural sector (Vukadinović et al., 2022). Despite recognising ICT as crucial for the sustainable development of agriculture, Serbia still lags behind EU countries, mainly due to limited financial resources and insufficient educational background of agricultural producers (Jurjević et al., 2019). Environmental responsibility is increasingly recognized as crucial within Serbian agri-food companies. Recent research conducted in the Serbian economy indicates that companies in the agri-food sector demonstrate above-average commitment to environmental orientation and strategy (Milić, 2021). This underscores the need to further develop environmental practices within these companies to better align with societal expectations and enhance sustainability efforts.

While the Serbian agri-food sector is undergoing a significant transformation driven by digitalisation and green initiatives, it remains unclear to what extent this transformation

includes a gender perspective. Unequal access to resources and opportunities between men and women in agriculture is a significant barrier to achieving comprehensive sustainability and productivity goals. In addition, the insufficient involvement of women in digital and green initiatives hinders the potential to maximize the growth and sustainability of the sector.

The literature exploring technological transformation from a gendered perspective is notably sparse, especially in specific workplace contexts. Previous studies highlight that men adopt new agricultural production technologies at higher rates and more quickly than women (Ragasa, 2012). These gender differences are evident across a wide range of technologies, from basic agricultural tools to advanced digital agriculture technologies and ICT (Peterman et al., 2014). Despite these disparities, the impact of management structures in agricultural companies on ICT adoption remains under researched. This gap in the literature prevents a comprehensive understanding of how technological advances intersect with gender roles and inequalities, influencing agricultural productivity, sustainability efforts and adaptation strategies. Addressing this gap is important for advancing gender equality, improving agricultural outcomes and fostering inclusive development within the digital and green transitions.

The main objective of this study is to examine the gender perspectives related to the twin transition of enterprises in the agriculture and food sector in the Republic of Serbia, with a focus on the adoption of ICT and engagement in green/environmentally friendly activities. Specifically, the paper aims to determine whether there are significant differences between agri-food companies with women in their management structures and those managed exclusively by men in the key dimensions of the twin transition.

Materials and methods

In line with the main objective of the study, observed companies in the agri-food sector were categorised into two groups depending on whether they have women in management positions. The first group consists of companies that have women in management, while the second group consists of companies whose management is made up exclusively of men.

The level of ICT adoption was assessed by surveying organisations on their use of tools such as Enterprise Resource Planning (ERP) software, Customer Relationship Management (CRM) software, cloud service and the Internet of Things (IoT). The variable for the use of ICT was created based on the data collected. It ranges from 0 to 4, depending on how many of these technologies a company uses (0 – uses none of these four technologies; 4 – uses all four technologies).

In order to assess the use of renewable energy sources, the companies surveyed were asked whether they use any of the following energy sources: solar panels (or cells), biomass (including wood and waste), biogas plants, heat pumps (geothermal energy). The variable for the use of renewable energy sources ranges from 0 to 3, depending on whether a company uses none, one or more of these energy sources (0 – uses none of these energy sources; 3 – uses three of them). It should be noted that none of the companies surveyed use all four renewable energy sources.

Using a five-point Likert scale (1 - not at all; 2 - little; 3 - somewhat; 4 - to a large extent; 5 - to a great extent), the companies assessed the extent of progress in processes related to the more efficient use of energy and resources. They assessed the extent to which they have made progress in the following processes in the last three years: (1) reducing emissions of harmful gases/substances, (2) reducing waste by recycling and returning raw materials to the production chains, (3) using environmentally friendly or smart packaging and (4) selecting suppliers according to environmental criteria.

Following the main objective of the study and the definition of the variables, three research questions (RQ) are posed:

RQ1: Are there differences in the use of ICT between companies run by women and those run by men?

RQ2: Are there differences in the use of renewable energy sources between companies run by women and those run by men?

RQ3: Are there differences between women-led and men-led companies in the extent of progress in processes related to more efficient use of energy and resources?

The statistical analysis included descriptive statistics and non-parametric tests to compare the differences between two groups: companies that have women in management and companies whose management consists exclusively of men.

Sample description

The population for the sample selection includes all active companies in Serbia that have submitted the financial report for 2020 and whose main activity corresponds to the agriculture and food sector. The agriculture and food sector includes the following economic activities according to the Statistical Classification of Economic Activities in the European Community (NACE Rev. 2): crop and animal production and related activities (01), manufacture of food products (10) and manufacture of beverages (11) (Eurostat, 2008). Enterprises with fewer than 5 employees were excluded from the population due to their oversimplified management structures, so that the population thus defined consisted of 3,008 enterprises.

Stratified random sampling was chosen as the sampling method because it ensures that each subgroup of the population is adequately represented in the sample. The stratification was based on the two-digit economic activity of NACE Rev. 2 and took into account the regions (Vojvodina, Belgrade, South and East Serbia, Šumadija and West Serbia) and company sizes (5-20, 21-50, 51-250 and 251-500 employees). The survey sample (gross sample) consisted of 639 companies from the agricultural and food sector.

The number of companies that took part in the survey consists of 446 (69.8% sample fulfilment) companies from the agricultural and food sector. The survey was conducted using the CATI (Computer Assisted Telephone Interviewing) method and the survey period was set from June to July 2022. *Table 1* shows the structure of the population for sample selection, the gross sample size and the final (net) sample size by NACE Rev. 2 two-digit economic activity.

Table 1. The population for the sample selection, gross sample size and net sample size

NACE 2-dig	Activity	Population	Gross sample	Net sample
01	Crop and animal production and related activities	575	396	261
10	Manufacture of food products	2302	225	170
11	Manufacture of beverages	131	18	15
Total	Agriculture & Food	3008	639	446

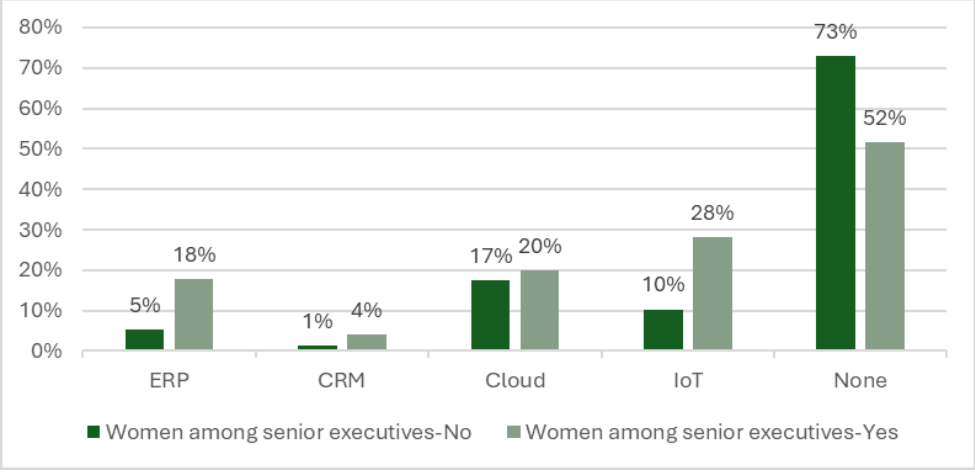
Source: Author's research

Regarding the regional distribution of the final (net) sample, 52% of the companies are from Vojvodina, 15% from Belgrade, 15% from South and East Serbia and 15% from Šumadija and West Serbia. Of the companies included in the final sample, 37% have between 5-20 employees, 29% between 21-50 employees, 29% between 51-250 employees and 5% between 251-500 employees.

Results and discussion

Figure 1 shows the percentage of surveyed companies that use ICT, including ERP software, CRM software, cloud service and the IoT. A comparison of ICT use in companies run by women and men shows that companies with women in management use ICT to a greater extent than companies whose management consists exclusively of men. Specifically, 18% of companies managed by women use ERP, while only 5% of companies managed by men use this software. The same is true for CRM software, cloud service and IoT. Despite these findings, a significant proportion of surveyed companies, comprising 73% led by men and 52% led by women, reported not using any of these technologies. This disparity in ICT adoption between male and female-led companies highlights potential differences in managerial strategies and priorities concerning technological investments.

Figure 1. The use of ICT tools



Source: Author's research

Table 2 contains descriptive statistics for companies that have women in management positions and for companies that do not have women in management positions for variables: ICT adoption, Use of renewable energy sources, Reduction of emissions of harmful gases / substances, Reduction of waste through recycling, Use of environmentally friendly or smart packaging, and Selection of suppliers based on environmental criteria.

Table 2. Descriptive statistics with the Shapiro-Wilk test of normality

Twin transition	Women among senior executives	N	Mean	Std. Deviation	Shapiro-Wilk	
					Statistic	Sig.
ICT adoption	No	155	0.34	0.63	0.59	0.00
	Yes	291	0.70	0.87	0.76	0.00
Use of renewable energy sources	No	155	0.15	0.41	0.41	0.00
	Yes	291	0.26	0.56	0.51	0.00
Reduction of emissions of harmful gases / substances	No	155	2.85	1.19	0.90	0.00
	Yes	291	2.90	1.35	0.89	0.00
Reduction of waste through recycling	No	155	3.03	1.12	0.92	0.00
	Yes	291	3.33	1.37	0.88	0.00
Use of environmentally friendly or smart packaging	No	155	2.26	1.26	0.85	0.00
	Yes	291	2.53	1.43	0.85	0.00
Selection of suppliers based on environmental criteria	No	155	2.17	1.17	0.84	0.00
	Yes	291	2.58	1.35	0.87	0.00

Source: Author's research

The Shapiro-Wilk test for normality is significant for each of the subsamples ($p<0.01$), which means that the data are not normally distributed. Since the normality assumption is necessary for parametric tests, the non-parametric Mann-Whitney test is used to determine whether there are significant differences between companies managed by women and those managed by men with regard to the application of these six criteria (*Table 3*).

Table 3. Mann-Whitney Test

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
ICT adoption	17314.50	29404.50	-4.60	0.00
Use of renewable energy sources	20852.00	32942.00	-1.95	0.05
Reduction of emissions of harmful gases / substances	22012.50	34102.50	-0.43	0.67
Reduction of waste through recycling	19092.50	31182.50	-2.74	0.01
Use of environmentally friendly or smart packaging	20458.50	32548.50	-1.67	0.09

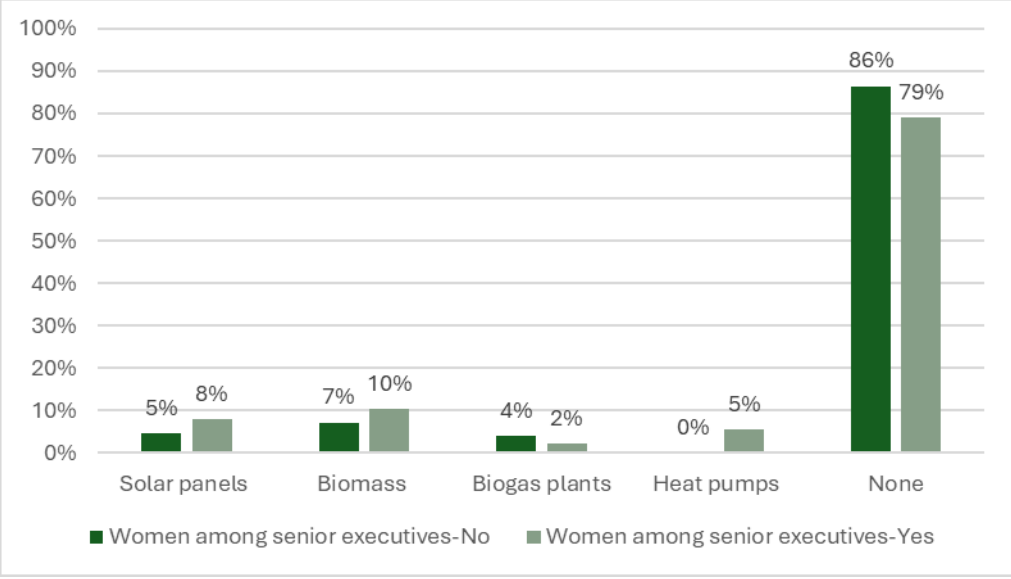
	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Selection of suppliers based on environmental criteria	18653.00	30743.00	-3.11	0.00

Source: Author's research

The result of the Mann-Whitney test is significant ($p<0.05$) for the variable ICT adoption, which means that companies with women in management use ICT to a greater extent (M=0.70) than companies whose managers are only men (M=0.34). While the previous literature often suggests that women entrepreneurs in the agri-food sector tend to implement fewer IoT technologies (Ragasa 2012; Peterman et al., 2014), these results reveal the opposite trend in Serbia. The presence of women in management structures within agri-food companies increases the likelihood of adopting ICT technologies. This finding suggests that gender-inclusive management practices can significantly enhance technological adoption and integration, challenging conventional narratives and underscoring the critical impact of women's leadership in driving technological advancement.

Figure 2 shows the percentage of companies that use renewable energy sources such as solar panels (or cells), biomass (including wood and waste), biogas plants and heat pumps (geothermal). As with ICT, the companies are categorised into two groups depending on whether they have women in management positions.

Figure 2. The use of renewable energy sources



Source: Author's research

A comparison of the use of renewable energies in companies shows that companies with women in management make greater use of solar panels, biomass and heat pumps than companies whose management consists exclusively of men. The opposite is only true for biogas plants: 4% of male-managed companies compared to 2% of female-managed companies stated that they use this renewable energy source. However, most of the companies surveyed stated that they do not use any of the renewable energy sources mentioned: 86% of male-managed companies and 79% of female-managed companies stated this.

The result of the Mann-Whitney test is significant (p=0.05) for the variable Use of renewable energy sources (*Table 3*), which means that companies with women in management use renewable energy sources to a greater extent (M=0.56) than companies whose managers are only men (M=0.41) (*Table 2*). This finding, similar to the results observed with ICT adoption, underscores the positive impact of gender diversity in leadership on sustainable practices within agri-food companies. The increased use of renewable energy sources by companies led by women suggests that gender-inclusive management not only fosters technological adoption but also promotes greater environmental responsibility.

Respondents rated various statements on a five-point Likert scale about the extent of progress in processes related to the more efficient use of energy and resources in their companies. *Table 4* shows the percentage structure of the respondents' assessments (1 - not at all; 2 - little; 3 - somewhat; 4 - to a large extent; 5 - to a great extent).

Table 4. The percentage structure of the respondents' assessments

Progress in processes related to the more efficient use of energy and resources	Women among senior executives	1	2	3	4	5	Significant progress (4+5)
Reduction of emissions of harmful gases / substances	No	18%	17%	33%	25%	7%	32%
	Yes	24%	12%	28%	23%	13%	36%
Reduction of waste through recycling	No	9%	25%	30%	26%	10%	36%
	Yes	16%	10%	24%	25%	25%	50%
Use of environmentally friendly or smart packaging	No	36%	28%	17%	12%	7%	19%
	Yes	37%	13%	22%	16%	12%	28%
Selection of suppliers based on environmental criteria	No	37%	28%	23%	6%	6%	12%
	Yes	32%	15%	27%	16%	10%	26%

Source: Author's research

The findings indicate that in the past three years, a higher proportion of companies led by women have reported significant advancements in processes aimed at enhancing energy and resource efficiency. Specifically, 36% of women-led companies, compared to 32% of men-led

companies, noted substantial progress in reducing emissions of harmful gases and materials. The same applies to reducing waste through recycling and returning raw materials to the production chain (50% of women-led companies compared to 36% of men-led companies), using environmentally friendly or smart packaging (28% of women-led companies compared to 19% of men-led companies) and selecting suppliers according to environmental criteria (26% of women-led companies compared to 12% of men-led companies).

The Mann-Whitney test is used to determine whether there are statistically significant differences in mean values between two groups in terms of the extent of progress in processes related to the more efficient use of energy and resources. The results of the test are significant ($p<0.05$) for the reduction of waste through recycling and the selection of suppliers based on environmental criteria (*Table 3*). Companies with women in management (M=3.33) advanced in the past three years to a larger extent in reducing waste through recycling than companies whose managers are only men (M=3.03). In addition, in the past three years women-led companies (M=2.58) made a larger progress in selecting suppliers based on environmental criteria than men-led companies (M=2.17) (*Table 2*). On the other hand, statistical differences between women-led and men-led companies were not found ($p>0.05$) in terms of the extent of progress in reducing emissions of harmful gases/substances or in the use of environmentally friendly or smart packaging (*Table 3*).

These results suggest that while women-led companies are particularly effective in implementing practices that promote waste reduction and environmentally conscious supplier selection, both women-led and men-led companies need to increase their focus on reducing harmful emissions and adopting environmentally friendly packaging solutions. The significant advancements by companies with women in their management structures in certain sustainability practices highlight the potential for gender-inclusive leadership to drive broader environmental initiatives within the agri-food sector.

Conclusion

This study has explored the interconnected dynamics between gender diversity, technology adoption and sustainability practices within the agri-food sector. It highlights the significant role of gender diversity in the adoption of ICT and sustainability practices in agri-food companies in Serbia. The presence of women in leadership positions within this sector positively influences the dynamics of the twin transition. Companies led by women demonstrate more robust utilisation of ICT tools and stronger commitment to sustainable practices compared to those led exclusively by men.

A study of 446 companies from the agricultural and food sector in Serbia concluded that companies run by women are more committed to the introduction of ICT and environmental sustainability than companies run exclusively by men. In particular, the statistical analysis showed that companies with women in management positions use ICT tools such as ERP, CRM software, cloud services and IoT to a greater extent than companies whose managers are only men. In terms of the green transition, there are statistically significant results between male and female-led companies in reducing waste through recycling and

in selecting suppliers according to environmental criteria. On the other hand, no statistical differences were found between the two groups of companies in terms of the extent of progress in reducing emissions of harmful gases/substances or in the use of environmentally friendly or smart packaging.

The findings not only highlight the enhanced performance of women-led companies in these areas but also emphasise the importance of gender-inclusive management structures for fostering technological innovation and sustainability. The research findings have important implications for both business leaders and policymakers. Promoting gender diversity in leadership positions can enhance companies' technological capabilities and sustainability performance. By actively promoting gender diversity, companies can improve their competitiveness, operational efficiency and reputation among stakeholders.

The research suggests policy instruments that support women's leadership and measures that aim to reduce barriers to female leadership in the agri-food sector. Policymakers can use these findings to advocate for initiatives that promote inclusive growth and create a favourable business environment.

While the study provides valuable insights into the relationship between gender diversity, ICT adoption and sustainability practices, further research is needed to examine additional factors influencing this dynamic. Future studies can build on these findings to investigate the mechanisms through which gender diversity enhances ICT use and sustainability efforts, as well as explore the long-term impacts of these practices on agricultural productivity and inclusive development. Additionally, research could delve deeper into the organisational mechanisms and leadership strategies that promote greater ICT adoption and sustainability performance in women-led firms and track the long-term impact of gender diversity on business performance and societal contributions within the agri-food sector.

Acknowledgements

The research presented in this paper was funded by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia under contract number 451-03-66/2024-03/200005. The database used in this research is the result of the project Velika Mala Privreda (Big Small Business Project) funded by the United States Agency for International Development (USAID) and implemented by ACDI/VOCA, J.E. Austin Associates, CEVES, and the Divac Foundation.

Conflict of interests

The authors declare no conflict of interest.

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