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Exploring the Relationship Between Digital Transformation and Sustainable Development Goals in Slovenian SMEs

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Abstract

Digital transformation is increasingly recognized as an important enabler of sustainable development and competitiveness in small- and medium-sized enterprises (SMEs). However, evidence on how different dimensions of digital transformation relate to the achievement of Sustainable Development Goals (SDGs) remains limited. This study explores the relationship between digital transformation and selected Sustainable Development Goals (SDGs) using an explanatory sequential mixed-methods design, in which quantitative findings informed the subsequent qualitative exploration and interpretation of managerial perspectives. The quantitative phase combined data from Eurostat's ICT Usage Survey (2020–2024), including 60 sustainability-related indicators, with an analysis of the relationship between the Digital Economy and Society Index (DESI) and selected SDG indicators across 27 EU member states using Spearman's rank correlation. The quantitative analysis suggests that Slovenia performs close to the EU average in overall digitalization, while significant associations were identified between digitalization and SDG 9. The qualitative phase consisted of semi-structured interviews with managers from ten Slovenian SMEs from different sectors. The findings indicate that managers perceive digital technologies, process digitalization, data-driven decision-making, and employee digital competencies as important contributors to sustainability-related outcomes, particularly in relation to SDG 8, SDG 9, SDG 12, and SDG 13. The study contributes to the literature on sustainability-oriented digital transformation in SMEs by integrating quantitative benchmarking with managerial perspectives. The findings highlight the importance of organizational capabilities, digital competencies, and strategic alignment in translating digital transformation initiatives into sustainability-related outcomes. The results provide practical implications for SMEs and policymakers seeking to support sustainable and digitally enabled business development.

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1. Introduction

As digital technology continues to embed and influence everyday life, its social and environmental impacts need to be addressed seriously [1]. Digital technologies become deeply embedded in organizational processes; their environmental, social, and governance implications require increasing attention within sustainability research, highlighting the need to align technological innovation with broader sustainability objectives and societal well-being. Recent conceptual research further argues that technology is becoming increasingly central to sustainability and should be recognized as an explicit component of contemporary sustainability frameworks, as digital infrastructures increasingly shape environmental, social, and economic outcomes [2]. The rapid technological progress of recent decades has fundamentally reshaped business operations across all industries. For small- and medium-sized enterprises (SMEs), digital transformation is no longer merely a driver of competitiveness but a prerequisite for long-term resilience, environmental responsibility, and sustainable growth. In September 2015, the UN announced the 17 Sustainable Development Goals (SDGs) as a basis for the 2030 Agenda for Sustainable Development [3]. In the context of the European Green Deal and the UN 2030 Agenda for Sustainable Development, digitalization plays a dual role: it enhances operational efficiency while simultaneously enabling more sustainable production, consumption, and governance models. Recent studies further argue that technology should be viewed not merely as an enabler of sustainability but as an increasingly important dimension of sustainability itself [4].

Despite the strategic importance of digital transformation, Slovenian SMEs continue to face significant barriers in its implementation, including limited digital competences, constrained financial resources, fragmented access to technological solutions, and insufficient strategic guidance [3,4]. These constraints not only slow down digital adoption but also hinder these SMEs from contributing effectively to key Sustainable Development Goals (SDGs), particularly “Decent Work and Economic Growth” (SDG 8), “Industry, Innovation and Infrastructure” (SDG 9), “Responsible Consumption and Production” (SDG 12), and “Climate Action” (SDG 13).

Large companies and the SME sector are experiencing these changes in completely different ways [5]. Understanding how digital transformation contributes to sustainability objectives is therefore essential for identifying the mechanisms through which SMEs specifically can overcome these challenges and enhance their contribution to sustainable development.

The flexibility that characterizes many SMEs can also hinder their ability to fully adopt digital tools, which are increasingly vital in today’s business landscape [6]. Consequently, a growing body of research has shifted its focus from the economic benefits of digitalization towards its potential contribution to sustainable development. Exploring these relationships is particularly important for SMEs, as digital technologies may help in simultaneously addressing both competitiveness and sustainability challenges.

1.1. Research Aim and Objectives

Despite the growing importance of digital transformation and sustainability, limited empirical evidence exists regarding how different dimensions of digital transformation are associated with the achievement of Sustainable Development Goals, particularly in small- and medium-sized enterprises. Previous studies have examined the relationship between digitalization and sustainability from different perspectives, including the role of digital technologies in sustainable business models [7], the contribution of Industry 4.0 technologies to sustainable development [8], and the potential of digital transformation to support sustainability transitions in European SMEs [9]. However, most studies have focused on conceptual frameworks, specific technologies, or individual sectors. Relatively little research has combined managerial perspectives with large-scale digitalization and sustainability indicators at both enterprise and country levels. Furthermore, the mecha-

nisms through which specific dimensions of digital transformation contribute to sustainability outcomes remain insufficiently understood. Recent research has increasingly emphasized that digital transformation and Industry 4.0 technologies play a central role in supporting sustainability transitions, particularly through innovation, resource efficiency, and circular economy practices in SMEs. The results reveal an emerging yet still modest pattern of I4.0 adoption. IoT stands out as the most widely used technology, followed by big data and integrated systems. While medium and larger enterprises are more likely to implement advanced technologies such as robotics, simulation, or AI, even microenterprises are actively adopting accessible solutions—especially IoT and cloud computing—for applications such as energy monitoring and basic data management. Nevertheless, overall technological deployment remains limited, and integration across all stages of the product life cycle is still rare [10]. To address this gap, the present study integrates quantitative analyses based on Eurostat ICT indicators, DESI data, and SDG indicators with qualitative evidence from SME managers, providing a multi-level assessment of the relationship between digital transformation and sustainability.

Accordingly, in this study, we employ a mixed-methods research design that integrates quantitative analyses based on Eurostat ICT indicators, DESI data, and SDG indicators and qualitative evidence from semi-structured interviews with SME managers. Digital transformation is conceptualized as a multidimensional phenomenon comprising digital technologies, business processes, data utilization, employee competencies, and strategic orientation.

The aim of this research is to explore the relationship between different dimensions of digital transformation and the achievement of Sustainable Development Goals in the context of SMEs while assessing Slovenia's position within the broader European digitalization and sustainability landscape.

To achieve this aim, the study pursues the following objectives:

- To examine the statistical association between digitalization, measured through the Digital Economy and Society Index (DESI), and selected sustainability indicators across EU member states.
- To benchmark Slovenian enterprises against the EU averages across selected digital adoption indicators and identify their key strengths and weaknesses.
- To analyze SME managers' perceptions regarding the relationship between digital transformation and the achievement of Sustainable Development Goals.

The present study contributes to the existing literature in several important ways. First, it combines quantitative evidence from Eurostat, DESI, and SDG datasets with qualitative insights from SME managers. Second, it provides a multidimensional perspective on digital transformation by examining digital technologies, business processes, data utilization, employee competencies, and strategic orientation. Third, it links macro-level statistical evidence with firm-level perceptions, enabling a more comprehensive exploration of the relationship between digitalization and sustainable development. Finally, it offers practical insights for policymakers and SME managers seeking to support sustainable digital transformation.

Slovenia was selected as a theoretically relevant case rather than a convenience sample. SMEs represent more than 99% of all Slovenian enterprises and play a dominant role in employment and value creation. Furthermore, Slovenia is simultaneously undergoing digital and sustainability transitions similar to those observed across many EU member states, making it a suitable context for examining the relationship between digital transformation and sustainability-related outcomes in SMEs. As a small open economy with a strong SME sector and digitalization levels close to the EU average, Slovenia provides a useful setting for exploring challenges and opportunities that may also be relevant to SMEs in other European contexts.

1.2. Research Questions

In the context of ongoing digital and sustainable transformations, SMEs are increasingly adopting a wide range of digital technologies, which are progressively demonstrating their strategic value [8,11]. Digitalization has become a key driver of organizational performance, operational efficiency, and long-term competitiveness [12,13], while also enabling more sustainable business practices [9,11]. In this regard, digital transformation contributes to broader sustainability objectives by supporting more efficient resource use, fostering innovation, and enabling environmentally and socially responsible business models [9,14]. Existing studies further indicate that advanced digital tools, including artificial intelligence, can enhance decision making and support SMEs in achieving competitive advantages [15,16].

In this research, digital transformation is conceptualized as a multidimensional process encompassing digital technologies, business processes, data utilization, employee competencies, and strategic orientation [13,17]. The research examines how the integration of digital tools, supported by AI and data-driven approaches, contributes to sustainable digital transformation in micro-, small-, and medium-sized enterprises. By integrating managerial perceptions with benchmarking evidence derived from Eurostat ICT indicators, the present study enables a comparison between firm-level experiences and broader digitalization trends, thereby supporting a more nuanced assessment of the relationship between digital transformation and sustainability objectives [13,16–18]. Based on the literature review and the exploratory objective of this study, the research was guided by the following overarching research question:

RQ: What associations can be identified between digital transformation and sustainability-related outcomes, and how do SME managers in Slovenia perceive and explain these relationships?

To explore this question, the qualitative component focused on five key dimensions of digital transformation identified in the literature:

- Adoption of digital technologies (e.g., AI, IoT, cloud computing);
- Digitalization of business processes;
- Data-driven decision-making and the use of digital data resources;
- Digital competencies of employees;
- Integration of digitalization into organizational strategy.

These dimensions served as thematic areas for the semi-structured interviews and subsequent qualitative analysis. Rather than testing predefined hypotheses, the study sought to explore how managers perceive the role of different digital transformation dimensions in supporting sustainability-related outcomes within SMEs. The findings should therefore be interpreted as exploratory and intended to generate insights and directions for future research rather than to confirm causal relationships.

The present study is closely aligned with the objectives of the Special Issue *Achieving Sustainability: Role of Technology and Innovation*. Recent research increasingly recognizes that technological innovation, digital transformation, and organizational capabilities play a critical role in supporting sustainability transitions by improving resource efficiency, strengthening innovation capacity, enabling data-driven decision-making, and facilitating more sustainable business practices [9,11,14]. However, limited evidence exists regarding how these mechanisms are perceived and implemented within SMEs and how managerial perspectives correspond with broader sustainability indicators. By integrating quantitative analyses of digitalization and sustainability indicators with qualitative insights from SME managers, this study contributes to a better understanding of how technology and innovation support sustainability-related outcomes in SMEs. In doing so, it directly addresses the intersection of digital transformation, innovation, and sustainable

development, which represents a central theme of this Special Issue. Recent contributions to this Special Issue further emphasize that sustainability transitions require an integrated perspective combining technological innovation, organizational transformation, and responsible governance. While digital technologies create new opportunities for improving resource efficiency, innovation capacity, and circular business practices, their sustainability outcomes ultimately depend on how organizations implement these technologies within broader organizational and societal contexts [1,2]. Building on these perspectives, the present study investigates how SME managers perceive the relationship between digital transformation and sustainability and complements existing conceptual work with empirical evidence from Slovenia.

The remainder of the study is structured as follows: Section 2 presents the theoretical background and literature review. Section 3 describes the research methodology, including the mixed-methods design, data sources, and analytical procedures. Section 4 presents the results of the qualitative interviews, the Eurostat benchmarking analysis, and the DESI–SDG correlation analysis. Section 5 discusses the findings in relation to the existing literature and highlights their implications for SMEs and policymakers. Finally, Section 6 concludes the study, outlines its limitations, and suggests directions for future research.

2. Literature Review

Small- and medium-sized enterprises (SMEs) play a central role in the European economy. According to European Commission [5], SMEs account for approximately 99% of all enterprises in the European Union and generate more than half of its economic value added. Their importance is even more pronounced in Slovenia, where the business structure is dominated by micro-, small-, and medium-sized enterprises. Consequently, achieving the objectives of both digital and sustainable transitions largely depends on the ability of SMEs to adopt digital technologies and integrate sustainability principles into their business models. As argued by Bican and Brem [8], digital transformation represents an important opportunity for SMEs to strengthen their competitiveness while simultaneously contributing to broader sustainability objectives.

2.1. Digital Transformation

The term “digital transformation” describes the use of different types of digital technologies to bring about substantial changes in the properties of an organization [3]. Digitalization, meaning the use and integration of digital technologies in physical production processes, is a key component of the Fourth Industrial Revolution, or Industry 4.0 [19]. For manufacturing SMEs to be able to compete on a global scale, they need to be more flexible, adaptive to new changes, and highly responsive, which the adoption of Industry 4.0 allows [20]. More precisely, technologies like IoT, artificial intelligence (AI), machine learning (ML), and robotics help SMEs to achieve better work efficiency through the automation of business processes [21,22].

Beyond the adoption of digital technologies, digital transformation is increasingly understood as a socio-technical process involving the interaction between technological, organizational, and human factors. The socio-technical systems perspective originated from the work of Trist and Bamforth [23] and was subsequently developed by Bostrom and Heinen [24], who argued that organizational performance depends on the joint optimization of social and technical systems rather than on technological change alone. From this perspective, technologies, organizational structures, business processes, managerial practices, and employee competencies are interdependent elements that collectively influence organizational outcomes.

This perspective is particularly relevant for SMEs, where digital transformation often extends beyond technology adoption and requires organizational adaptation, employee

learning, and strategic alignment. Consequently, sustainability-related outcomes cannot be explained solely by the implementation of digital technologies but must also consider how these technologies are embedded within organizational processes and practices.

The socio-technical perspective provides the theoretical foundation for the present study. It informs the examination of digital transformation as a multidimensional phenomenon encompassing digital technologies, business processes, data utilization, employee competencies, and strategic orientation. It also supports the mixed-methods design adopted in this research, as both quantitative indicators and managerial perceptions are necessary to understand the complex interactions between technological and organizational dimensions of digital transformation and their relationship with sustainability-related outcomes and Sustainable Development Goals. However, the adoption of Industry 4.0 in Slovenian SMEs is still limited [25].

Previous research has shown that the successful implementation of digital technologies in SMEs depends not only on technological investments but also on organizational capabilities, digital skills, data integration, managerial support, and the broader business environment [12,13]. This issue is particularly relevant in Slovenia, where SMEs account for 99.6–99.8% of all enterprises, employ approximately two-thirds of the workforce, and generate more than 60% of total turnover, making them the backbone of the national economy [25]. Consequently, the success of both the digital and sustainable transitions in Slovenia largely depends on the ability of SMEs to develop the organizational and technological capabilities required for effective digital transformation.

Industry 4.0 readiness can be measured using different measurement models. Some of the most popular models are as follows: Digital Readiness Assessment Maturity (DREAMY), which includes the technological and cultural aspects in the assessment; the Smart Manufacturing Readiness Level model, which determines companies' readiness for changes; the Industry 4.0 Maturity Model (I4.0-MM), which identifies companies' strengths and weaknesses [26]; the Digital Maturity Readiness Model, which is valuable in recognizing the significance of operations alongside traditional dimensions like strategy, product, leadership and technology [27]. The susceptibility of an SME to external factors is a result of its reliance on diverse resources, including materials, workforce, financial capital equipment, knowledge, and market opportunities for its products or services [27,28].

2.2. Sustainable Development Goals

Sustainability is commonly defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. In the business context, sustainability is typically conceptualized through three interrelated dimensions—economic, environmental, and social sustainability—which together form the foundation of the Triple Bottom Line approach [28]. The Sustainable Development Goals (SDGs), also known as the Global Goals, were introduced by the United Nations in 2015 as a universal framework for addressing major global challenges, including poverty, inequality, environmental degradation, and climate change [3]. The 17 SDGs provide a shared agenda for governments, businesses, and civil society organizations, aiming to promote sustainable development by 2030.

The SDGs offer a comprehensive framework for evaluating progress across economic, social, and environmental dimensions. However, implementation pathways and progress levels vary considerably across regions and sectors, reflecting differences in local contexts, priorities, and development challenges [29]. Consequently, while the SDGs provide a common language and set of indicators for measuring sustainability performance, their achievement requires context-specific approaches and solutions.

Digital transformation has increasingly been recognized as an important enabler of sustainable development. Through the adoption of information and communication technologies (ICTs), organizations can improve resource efficiency, optimize business processes, enhance decision-making, and support innovation. As a result, digitalization has the potential to contribute to economic and social development while reducing environmental impacts, thereby supporting progress toward several SDGs and broader sustainability objectives [30].

2.3. *The Impact of Digitalization on Sustainable Development Goals*

In “Analysing Associations Between Digitalization and the Accomplishment of the Sustainable Development Goals” [31], Pérez-Martínez et al. [32], analyzed the relationship between digital transformation and the SDGs for the member states of the European Union. The results show that, in general, digital transformation contributes positively to sustainable development outcomes, especially in the areas related to health, innovation, infrastructure, and institutional development; it is important to note that the study shows that these benefits are not equal across countries. Lastly, they show that digitalization is not alone in its influence on whether a country achieves an impact in terms of the SDGs; this success also depends on broader social, governance, and policy frameworks. This provides evidence of the need for context-specific strategies in increasing the influence of digital transformations on sustainable development [33].

To achieve more sustainable performance, many enterprises are adopting different digital solutions [34]. The rapid development of digital technologies, especially ICTs, has had an enormous influence on both societies and economies. ICT is improving people’s quality of life by providing easier access to information, social connection, education, and healthcare, in addition to affecting other aspects of life [32]. In the business environment, it has been used by both manufacturing companies and service companies [35]. ICT implementation is becoming absolutely crucial for companies to achieve a competitive advantage in the market; importantly, the introduction of digital technologies is much easier for large companies than for smaller enterprises [36,37].

Bansal [38] conceptualized corporate sustainability as the ability of firms to address short-term economic, environmental, and social needs while safeguarding long-term benefits in these dimensions. Under the guidance of sustainable development principles, firms are expected to pursue not only economic growth, but also the balanced integration of their economic, environmental, and social objectives. Ozturk et al. [39] found that digitalization and SME development create a mutually reinforcing relationship that contributes positively to sustainable development and environmental sustainability.

Recent studies documenting the concrete environmental impacts of digitalization reveal the depth of its transformation. Research by Chopra and Chen [40,41] may reflect the mechanisms through which digital solutions reduce ecological footprints, whether by optimizing industrial processes or replacing physical activities with virtual alternatives. Previous studies based on EU member states have reported positive associations between business digital transformation and performance related to SDG 8, SDG 9, and SDG 13 [41].

Despite the growing adoption of artificial intelligence (AI), the literature directly examining the relationship between AI and the achievement of Sustainable Development Goals (SDGs) at the firm level remains limited. The existing research has primarily focused on the environmental implications of AI, including its potential to improve energy efficiency, reduce emissions, support green development, and stimulate green innovation [42,43]. While these studies provide valuable insights into the sustainability potential of AI, evidence regarding its broader contribution to the achievement of SDGs in business settings remains scarce. Vărzaru [44] argues that higher levels of digital development are associated with improved sustainability performance and emphasizes the strategic role of digital technologies in supporting eco-

nomic, environmental, and social sustainability objectives. The study further emphasizes that digitalization should be viewed not only as a technological transformation but also as a key enabler of sustainable development policies and practices.

The existing literature increasingly suggests that digital transformation can contribute to sustainable development, although its effects depend on the organizational, technological and institutional context. Pérez-Martínez et al. [32] show that digitalization is positively associated with the achievement of several SDGs in EU member states, particularly in areas related to innovation, infrastructure and institutional development. Similarly, Chatzistamoulou [11], Bonilla et al. [9], and George et al. [14] emphasize that digital technologies can support sustainable business models, improve resource efficiency, and strengthen innovation capacity. However, these studies also indicate that digitalization alone is not sufficient; its sustainability effects depend on how technologies are embedded into business processes, managerial capabilities, and broader policy frameworks.

This is particularly relevant for SMEs, which often face the challenges that come with limited financial, technological, and human resources. Prior studies suggest that digital transformation in SMEs should therefore be understood as a multidimensional process involving technologies, data use, business processes, employee competencies, and strategic orientation. Recent research also highlights the potential of AI to support energy efficiency, emissions reduction, green innovation, and sustainability-oriented decision making; however, evidence on the direct relationship between AI and SDG achievement at the firm level remains limited [43]. Despite the growing body of research, limited evidence exists that simultaneously combines quantitative sustainability indicators and managerial perspectives when examining the relationship between digital transformation and sustainable development in SMEs. This gap provides the motivation for the present study.

3. Materials and Methods

3.1. Research Design

Small and medium-sized enterprises (SMEs) represent the primary focus of this study due to their central role in the European economy and their increasing involvement in digital transformation processes. At the same time, SMEs face specific challenges related to limited resources, varying levels of digital maturity, and growing expectations regarding sustainable development. These characteristics make SMEs a particularly relevant context for examining the relationship between digital transformation and the achievement of Sustainable Development Goals (SDGs).

This study employed an explanatory sequential mixed-methods design. The quantitative phase was conducted first and consisted of benchmarking analyses based on Eurostat ICT Usage Survey data, complemented by an examination of associations between the Digital Economy and Society Index (DESI) and selected SDG indicators. The purpose of this phase was to identify broader patterns related to digital transformation and sustainability performance. The qualitative phase followed in the form of semi-structured interviews with SME managers. Semi-structured interviews were selected as the primary qualitative research method because they enable the in-depth exploration of managerial perceptions while maintaining a sufficient degree of comparability across respondents through a common interview structure [44,45]. The method is particularly suitable for exploratory studies investigating complex and multidimensional phenomena such as digital transformation and sustainable development, where contextual understanding and expert judgement are essential [44]. Unlike standardized surveys, semi-structured interviews allow respondents to elaborate on their experiences, provide examples from practice, and explain mechanisms that may not be captured through predefined response categories [45].

The interviews explored how managers perceive the relationship between digital transformation and sustainability-related outcomes and provided additional insights into

the mechanisms underlying the patterns identified in the quantitative analysis. Given the exploratory nature of this study, the qualitative component was designed to identify key dimensions of digital transformation, explore managerial perceptions of their relationship with the SDGs, and provide a deeper understanding of the mechanisms linking digitalization and sustainability. The findings from the interviews were subsequently compared with the results of the benchmarking and correlation analyses, enabling triangulation between firm-level perceptions and macro-level statistical evidence.

The research approach combined three complementary components:

- A structured literature review examining the relationship between digital transformation and sustainable development;
- A quantitative analysis based on secondary data sources, including Eurostat ICT Usage Survey data, DESI indicators, and SDG indices;
- A qualitative analysis based on semi-structured interviews with SME managers.

The quantitative component complemented managerial perceptions with objective and comparable evidence derived from large-scale European datasets. The Eurostat ICT Usage Survey was selected because it represents one of the most comprehensive and standardized sources of enterprise-level digitalization data across European countries. The benchmarking analysis enabled a comparative assessment of Slovenia's position relative to the EU average across selected digital adoption indicators and supported the identification of key digitalization strengths and gaps. In addition, DESI–SDG correlation analysis was employed to investigate whether broader patterns of digitalization are associated with sustainability outcomes at the European level.

Spearman's rank correlation was selected because it is robust to non-normal distributions, outliers, and ordinal relationships, making it particularly suitable for analyzing composite indicators such as DESI and SDG indices [46,47]. The combination of quantitative and qualitative methods enabled methodological triangulation and strengthened the overall validity of the research findings by integrating managerial perspectives with objective statistical evidence.

3.2. Quantitative Data Collection and Analysis

The quantitative analysis was based on secondary data obtained from the Eurostat ICT Usage Survey for Enterprises, the Digital Economy and Society Index (DESI), and the Sustainable Development Goals (SDG) Index [47–50]. These sources were selected because they provide harmonized and comparable indicators of digitalization and sustainability across European countries.

The Eurostat ICT Usage Survey database contains a comprehensive set of indicators related to the adoption and use of digital technologies by enterprises. For the purposes of this study, data covering the period 2020–2024 were extracted and analyzed. From the full Eurostat ICT Usage Survey dataset comprising 558 indicators, a subset of 60 indicators was selected for detailed analysis. The selection was informed by the literature review and focused on dimensions of digital transformation potentially relevant to sustainability-related outcomes. The selected indicators covered ten thematic categories: artificial intelligence, cloud computing, ICT training, enterprise resource planning systems, e-invoicing, cybersecurity, e-commerce, digital customer services, environmental sustainability of ICT, and digital intensity indicators.

The benchmarking analysis was conducted to position Slovenia within the broader European digitalization landscape and to provide contextual information for interpreting the qualitative findings. Rather than evaluating individual firms, the benchmarking compared Slovenia's performance with that of other EU member states across selected ICT adoption indicators. For each indicator, country-level values were extracted from the Eu-

rostat ICT Usage Survey database and compared using EU averages, percentile rankings, and gap analysis. This approach enabled the identification of areas in which Slovenia performs above or below the broader European pattern and provided a quantitative context for exploring how SME managers perceive digital transformation and sustainability-related outcomes.

An unweighted country mean was used to ensure that each EU member state contributed equally to the benchmarking analysis. The objective of the study was not to estimate the average level of digitalization across all European enterprises, but rather to compare Slovenia with the distribution of EU member states. Using weighted averages based on population size, GDP, or number of enterprises would have disproportionately increased the influence of larger economies and reduced the comparability of country-level digitalization patterns. This approach is consistent with benchmarking methodologies used in European digitalization monitoring frameworks, including DESI and the European Innovation Scoreboard [50,51].

To further explore the relationship between digitalization and sustainability outcomes, an additional analysis was conducted using DESI scores and selected SDG indicators. Four SDG dimensions were included: SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). These dimensions were selected because previous research suggests plausible links between digital transformation, innovation, productivity, resource efficiency, and environmental performance [33,43].

Associations between DESI scores and SDG indicators were examined using Spearman's rank correlation coefficient. Spearman's method was selected because DESI and SDG indices are composite indicators whose distributions may not satisfy the assumptions required for parametric testing. Compared with Pearson's correlation, Spearman's method is more robust to non-normal distributions, outliers, and monotonic relationships [50,51]. Correlations were calculated for all 27 EU member states for the years 2022 and 2024, and statistical significance was assessed using a two-tailed test with a significance threshold of $\alpha = 0.05$. All quantitative analyses were conducted using Python 3.12, with the pandas and scipy libraries used for data processing and statistical analysis. Visualizations were produced using matplotlib. The complete analytical workflow was implemented in a reproducible Jupyter Notebook 4.x environment using publicly available datasets [47–51].

3.3. Qualitative Data Collection and Analysis

Qualitative data were collected through semi-structured interviews with managers of micro, small, and medium-sized enterprises in Slovenia between January and March 2026. A purposive sampling strategy was employed to ensure diversity in terms of industry, company size, organizational structure, and digital maturity. The sample included ten SMEs operating in manufacturing, services, ICT, tourism, retail, artificial intelligence implementation, e-commerce, printing, and food-related industries. The objective was not statistical representativeness but the exploration of diverse managerial perspectives regarding digital transformation and sustainability.

The interviewees were primarily company directors, with one project manager directly involved in digital transformation initiatives. All participants occupied decision-making positions and had direct responsibility for planning, implementing, or managing digital transformation activities within their organizations. This ensured that the collected data reflected both operational experience and strategic perspectives on the relationship between digitalization and sustainability-related objectives. Detailed characteristics of the participating companies are presented in Appendix A (Table A1).

Semi-structured interviews were selected because they enable the in-depth exploration of managerial perceptions while maintaining sufficient comparability across respondents through a common interview structure [44,45]. The interview protocol was developed based on the literature on digital transformation, Industry 4.0, SME digital maturity, sustainable digital transformation, and the Sustainable Development Goals (SDGs). To ensure consistency across interviews and reduce the risk of leading questions, all participants were asked the same core questions using a standardized interview guide, while allowing additional probing questions for clarification when necessary.

The interview protocol consisted of six thematic sections:

- Respondent and company characteristics;
- Assessment of digital maturity, including technology adoption, process digitalization, employee competencies, and digital strategy;
- Perceived relationships between digital transformation and SDGs;
- Mechanisms through which digitalization contributes to sustainability-related outcomes;
- Barriers and challenges associated with digital transformation;
- Strategic implications of digitalization for sustainable development.

Barriers to digital transformation were explicitly addressed in the interview protocol through a dedicated thematic section focusing on obstacles and risks associated with digitalization and sustainability integration. In addition, references to barriers also emerged during broader discussions of digital maturity, organizational readiness, and sustainability-related outcomes. Particular attention was devoted to six dimensions of digital transformation identified in the literature: digital technologies, digitalized business processes, data-driven decision-making, digital competencies, and digital strategy. Respondents were asked to discuss how these dimensions contribute to sustainability-related objectives and Sustainable Development Goals, as well as the perceived timing, strength, and nature of these contributions. To enhance transparency and replicability, Table A2 presents the thematic structure of the interview protocol together with representative examples of the core questions used in each thematic section. The complete interview guide is provided in Appendix A (Table A2).

Interviews were conducted individually at company premises and lasted between 45 and 90 min. All interviews were recorded with participants' consent and subsequently transcribed for analysis. Interview transcripts were analyzed using thematic analysis following the approach proposed by Braun and Clarke [52]. The analysis combined deductive and inductive coding procedures. Initially, five coding categories were derived from the literature review and interview protocol: digital technologies, digitalized business processes, data-driven decision-making, digital competencies, and digital strategy. Subsequently, additional themes emerging from the data were identified through iterative coding and comparison across interviews. The analysis focused on identifying recurring perceptions regarding the contribution of digital transformation to sustainability-related outcomes and SDGs.

The coding process was conducted in two stages. First, a deductive coding framework was developed based on the literature review and interview protocol. Five initial coding categories were defined: digital technologies, digitalized business processes, data-driven decision-making, digital competencies, and digital strategy. These categories reflected the main dimensions of digital transformation examined in the study.

In the second stage, inductive coding was used to identify additional concepts and patterns emerging from the interview data. Through iterative comparison of coded segments across interviews, several recurring themes were identified, including innovation and competitiveness, resource efficiency, organizational readiness, barriers to digital transformation, and the adoption of advanced technologies. The final thematic structure

was developed through repeated review and refinement of codes and themes following the procedures proposed by Braun and Clarke [52]. The qualitative findings were subsequently compared with the quantitative benchmarking and DESI–SDG correlation results, enabling methodological triangulation and a more comprehensive interpretation of the relationship between digital transformation and sustainability in SMEs.

3.4. Ethical Considerations

The study was conducted in accordance with general ethical principles for social science research, including voluntary participation, informed consent, confidentiality, and anonymity of respondents. Prior to each interview, participants were informed about the purpose of the study, the intended use of the collected data, and their right to withdraw from the research at any stage without consequences. All interview participants provided informed consent for participation and audio recording. To protect confidentiality, company representatives are not identified individually in the manuscript, and interview findings are reported in aggregated form. The collected data were used exclusively for research purposes and stored securely by the research team. According to the institutional regulations applicable to the authors at the time of data collection, formal approval from an ethics review board was not required because the study involved voluntary interviews with adult professionals in their professional capacity and did not collect sensitive personal data. No vulnerable groups were involved in the research.

To enhance the credibility of the findings, a standardized interview protocol was used across all interviews, and thematic analysis was conducted systematically following the approach proposed by Braun and Clarke [52]. Nevertheless, as the study relies on self-reported managerial perceptions, the findings should be interpreted as perceived rather than objectively verified relationships between digital transformation and sustainability-related outcomes.

4. Results

4.1. Quantitative Findings

The quantitative analysis was conducted in two stages. First, a benchmarking analysis based on Eurostat ICT Usage Survey indicators was performed to provide a broader overview of digital transformation patterns and Slovenia's position relative to other EU member states. Second, associations between the Digital Economy and Society Index (DESI) and selected Sustainable Development Goal (SDG) indicators were examined to explore potential relationships between digitalization and sustainability outcomes. The benchmarking analysis was intended to provide a contextual overview of Slovenia's digitalization performance relative to other EU member states. The results do not represent an assessment of individual enterprises but rather illustrate broader national patterns in the adoption of digital technologies and practices. These findings served as a quantitative point of reference for the subsequent qualitative analysis. The benchmarking results indicate that Slovenia performs relatively well in several dimensions of business digitalization, particularly ICT training, employment of ICT specialists, electronic invoicing, mobile device provision, and the use of external ICT services. At the same time, lower levels of adoption were observed for certain advanced digital technologies, including selected applications of artificial intelligence, robotics, and digital customer support solutions. Furthermore, the results highlight opportunities for further improvement in areas related to resource efficiency and the environmental sustainability of digital activities. Rather than providing a comprehensive assessment of national digital performance, the benchmarking analysis was intended to establish an empirical context for examining the relationship between digital transformation and sustainability. Detailed indicator-level benchmarking

results are presented in Appendix A.2. To further investigate the relationship between digital transformation and sustainability outcomes, Spearman's rank correlation coefficients were calculated between DESI scores and selected SDG indicators (SDG 8, SDG 9, SDG 12, and SDG 13) for 2022 and 2024. The results are presented in Table 1, while detailed visualizations are provided in Appendix A.2.

Table 1. Spearman's correlation coefficients between DESI and SDG indices for 27 EU member states (2022 and 2024). Significance level $\alpha = 0.05$. Green shading indicates statistically significant results.

SDG	Spearman ρ	p -Value	Significant
Year 2022			
SDG 8	0.1184	0.5728	No
SDG 9	0.6400	0.0005	Yes
SDG 12	−0.5723	0.0028	Yes
SDG 13	−0.3792	0.0615	No
Year 2024			
SDG 8	0.0792	0.7066	No
SDG 9	0.6523	0.0004	Yes
SDG 12	−0.5853	0.0021	Yes
SDG 13	−0.4108	0.0413	Yes

Table 1 summarizes the associations between DESI and selected SDG indicators for 2022 and 2024. Statistically significant associations were identified for SDG 9 (Industry, Innovation and Infrastructure) and SDG 12 (Responsible Consumption and Production) in both years. A statistically significant association was also observed for SDG 13 (Climate Action) in 2024. No statistically significant associations were identified for SDG 8 in either year or for SDG 13 in 2022. The observed patterns were broadly consistent across both reference years. However, given the exploratory nature of the study, the limited sample of 27 EU member states, and the use of bivariate correlation analysis, the results should be interpreted as indicative associations rather than evidence of causal or generalizable relationships. Detailed visualizations are presented in Appendix A.2.

4.2. Qualitative Findings

The thematic analysis revealed that managers generally perceive digital transformation as an important contributor to sustainability-related outcomes, particularly within the economic and environmental dimensions of sustainable development. Across the interviews, four recurring themes emerged: innovation and competitiveness, resource efficiency, digital competencies, and organizational readiness. Innovation was identified as the most frequently discussed benefit of digital transformation. Interviewees consistently associated digital technologies with improved competitiveness, process modernization, and the ability to develop new products and services. These perceptions were most linked to SDG 9 (Industry, Innovation and Infrastructure) and SDG 8 (Decent Work and Economic Growth).

Resource efficiency emerged as a second major theme. Respondents emphasized that digital tools, automation, and data-driven decision-making can support the optimization of business processes, reduce material consumption, and improve operational efficiency. These perceptions were primarily associated with SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action). Several participants highlighted that digital technologies enable more accurate monitoring of resource use and facilitate more informed operational decisions.

A third recurring theme concerned employee digital competencies. Managers repeatedly emphasized that successful digital transformation depends not only on technology

adoption but also on employee skills, training, and organizational learning. Interviewees frequently described digital competencies as a prerequisite for innovation and effective use of digital technologies, particularly in relation to SDG 8 and SDG 9.

Barriers to digital transformation were discussed by most interview participants. The most frequently mentioned challenges included insufficient digital competencies, resistance to organizational change, limited data availability, and unclear strategic direction. While financial constraints were also acknowledged, respondents more often emphasized organizational and human factors as key obstacles to successful digital transformation and sustainability integration. The adoption of advanced technologies such as artificial intelligence, robotics, and blockchain was found to be relatively limited. Most participating firms reported using artificial intelligence primarily for marketing, communication, and administrative support rather than for core production processes. These findings suggest that the adoption of advanced digital technologies remains uneven across the participating SMEs, despite a general recognition of their strategic importance.

Overall, the findings indicate that managers primarily associate digital transformation with innovation, operational efficiency, and resource optimization. Economic sustainability was the most frequently discussed dimension, followed by environmental sustainability, particularly in relation to resource efficiency, waste reduction, and improved monitoring of resource consumption. In contrast, social sustainability received considerably less attention. Issues such as employee well-being, social inclusion, job quality, and broader societal impacts of digital transformation were mentioned only occasionally. This finding suggests that the social dimension remains comparatively underexplored in both managerial practice and existing research, highlighting a potential direction for future studies on digital transformation and sustainable development in SMEs. Table 2 summarizes the main themes identified through thematic analysis and illustrates their relationship with the SDGs most frequently mentioned by the interview participants.

Table 2. Main themes emerging from the qualitative analysis and their relationship to selected SDGs.

Description of the Finding	Illustrative Evidence from Interviews	Related SDGs	Theme
Managers associated digital transformation with process modernization, improved competitiveness, and the development of new products and services.	Interviewees emphasized that digital tools support innovation, improve responsiveness, and enable more efficient business development.	SDG 8, SDG 9	Innovation and competitiveness
Digital tools, automation, and data-driven decision-making were linked to more efficient use of resources, reduced waste, and improved operational control.	Respondents described digitalization as useful for monitoring resource use, optimizing processes, and reducing unnecessary material or energy consumption.	SDG 12, SDG 13	Resource efficiency
Employee skills, training, and digital literacy were identified as prerequisites for successful digital transformation.	Managers emphasized that technology adoption is limited when employees lack the necessary digital skills or confidence.	SDG 8, SDG 9	Digital competencies
Strategic alignment, managerial commitment, and openness to change were described as important conditions for digital transformation.	Respondents highlighted the role of leadership, internal coordination, and willingness to adapt business processes.	SDG 8, SDG 9, SDG 12	Organizational readiness
Barriers included insufficient digital competencies, resistance to change, limited data availability, unclear strategic direction, and financial constraints.	These challenges were discussed by the majority of participants and appeared both in response to direct interview questions and during broader discussions of digital maturity.	Cross-cutting	Barriers to digital transformation
Advanced technologies such as AI, robotics, and blockchain were recognized as strategically important but were adopted unevenly across participating SMEs.	AI was most often reported in marketing, communication, and administrative support rather than in core production or operational processes.	SDG 8, SDG 9, SDG 12	Uneven adoption of advanced technologies
Economic and environmental aspects of sustainability were discussed more frequently than social sustainability.	Participants focused mainly on efficiency, innovation, and resource optimization, while issues such as job quality, inclusion, and broader social impacts were mentioned less often.	SDG 8	Limited attention to social sustainability

4.3. Integration of Quantitative and Qualitative Findings

The integration of quantitative and qualitative findings enabled a more comprehensive understanding of the relationship between digital transformation and sustainability-related outcomes. While the quantitative analysis identified broad patterns and statistically significant associations between digitalization and selected SDGs, the qualitative interviews provided contextual explanations and managerial perspectives that helped interpret these findings. Table 3 presents a joint display of the key quantitative and qualitative findings, highlighting areas of convergence, complementarity, and potential divergence, together with their integrated interpretation.

The negative association observed between digitalization and SDG 12 should not be interpreted as evidence that digital transformation reduces sustainability performance. Rather, it suggests that countries with higher levels of digitalization do not necessarily achieve stronger performance in indicators related to responsible consumption and production. One possible explanation is that highly digitalized economies also tend to be more affluent and consumption-intensive, which may negatively affect certain SDG 12 indicators despite improvements in technological efficiency. The qualitative findings provide additional context, as managers frequently emphasized resource optimization, waste reduction, and process efficiency at the organizational level. This suggests that while digitalization may contribute positively to resource efficiency within firms, these benefits may not automatically translate into improved sustainability outcomes at the national level.

The joint display demonstrates how qualitative findings complement and contextualize the quantitative results. While the quantitative analysis identified broad patterns and associations, the qualitative interviews provided insights into the organizational mechanisms, managerial perceptions, and contextual factors that may explain these patterns. Together, the findings suggest that digital transformation contributes to sustainability primarily through innovation, organizational capabilities, and resource optimization, while highlighting the continuing importance of digital competencies and strategic alignment.

Table 3. Joint display of quantitative and qualitative findings and their integrated interpretation.

Quantitative Finding	Qualitative Finding	Integrated Interpretation
Significant positive association between DESI and SDG 9 in 2022 and 2024	Managers consistently emphasized innovation, process modernization, and technological development as key benefits of digital transformation.	Both data sources suggest that innovation and organizational modernization represent important mechanisms linking digital transformation and sustainability-related outcomes.
Significant negative association between DESI and SDG 12 in 2022 and 2024	Managers emphasize resource efficiency and waste reduction	Digitalization may improve efficiency at the firm level but does not necessarily reduce overall consumption patterns at the national level.
Significant association between DESI and SDG 13 in 2024, but not in 2022	Environmental benefits were discussed primarily in terms of resource monitoring and operational efficiency.	The relationship between digitalization and climate-related outcomes appears less consistent and may depend on contextual factors beyond enterprise-level digital transformation
Slovenia performs relatively well in ICT training and employment of ICT specialists.	Managers repeatedly identified employee digital competencies as a prerequisite for successful digital transformation.	Both data sources highlight the importance of human capital and digital skills as enabling factors for digital transformation and sustainability.
Limited adoption of advanced digital technologies, particularly AI applications.	Most firms reported using AI primarily for marketing, communication, and administrative support rather than core business processes.	The findings suggest that AI adoption among SMEs remains uneven and concentrated in selected business functions despite its perceived strategic importance.
No statistically significant association was identified between DESI and SDG 8.	Managers frequently associated digital transformation with competitiveness and business growth.	While managers perceive economic benefits from digital transformation, these perceptions were not reflected in statistically significant macro-level associations.
Social sustainability received limited attention in interviews	Social sustainability received limited attention in interviews	Managers primarily associated digital transformation with economic performance, innovation, and resource efficiency, while social outcomes were discussed less frequently, suggesting an imbalance in how sustainability is perceived and operationalized within SMEs.

5. Discussion

5.1. Integration of Quantitative and Qualitative Results

The integration of quantitative and qualitative evidence suggests that digital transformation is perceived as a multidimensional process that may contribute to sustainability through innovation, resource efficiency, and organizational capability development. While the quantitative analysis identified significant associations between digital transformation and selected SDGs, the qualitative findings provided contextual insights into how managers interpret these relationships within their organizations. The strongest convergence between the two data sources was observed in relation to innovation and organizational development. The positive association identified for SDG 9 was consistent with managers' emphasis on process modernization, technological innovation, and digital infrastructure as key drivers of competitiveness and long-term development. Similarly, resource optimization emerged as a recurring theme in the interviews and was reflected in the quantitative associations observed for SDG 12.

The findings also highlight the importance of employee competencies and organizational readiness. Managers consistently emphasized digital skills, training, and managerial commitment as critical enabling factors for successful digital transformation. These observations suggest that the benefits of digital technologies depend not only on technological adoption but also on organizational capabilities and human capital development. Overall, the integrated findings indicate that SMEs perceive digital transformation primarily through its economic and operational benefits, while social dimensions of sustainability receive comparatively less attention.

5.2. Comparison with Previous Research

The significant positive association identified between digital transformation and SDG 9 (Industry, Innovation and Infrastructure) is consistent with previous studies emphasizing the role of digital technologies in supporting innovation, technological modernization, and competitiveness. Similar findings were reported by Pérez-Martínez et al. [32] and Vărzaru [44], who identified positive relationships between digital development, innovation capacity, and sustainability performance. The qualitative findings of the present study further support this interpretation, as managers consistently associated digital transformation with innovation, process modernization, and the development of new products and services.

The significant negative association observed between digitalization and SDG 12 suggests that higher levels of digitalization do not automatically translate into stronger performance in responsible consumption and production at the national level. While digital technologies may improve efficiency, productivity, and resource management within organizations, highly digitalized economies are often also characterized by higher levels of production, consumption, and material use. Consequently, the sustainability benefits of digitalization may be partially offset by broader economic and behavioral patterns. This finding highlights the importance of complementing digital transformation initiatives with policies and organizational practices specifically targeting sustainable consumption and resource use.

The association between digital transformation and SDG 13 (Climate Action) was less consistent across the two reference years and should therefore be interpreted with caution. Although a statistically significant association was identified in 2024, the corresponding relationship in 2022 did not reach the significance threshold. Consequently, the findings do not provide sufficient evidence to draw firm conclusions regarding the relationship between digitalization and climate-related outcomes.

No statistically significant association was observed between DESI and SDG 8 in either reference year. Therefore, the results do not provide sufficient evidence to support a relationship between digitalization and economic growth outcomes at the aggregate country level.

The findings support a socio-technical understanding of digital transformation because both data sources indicate that sustainability-related outcomes depend on more than the adoption of digital technologies alone. The qualitative interviews consistently emphasized the importance of employee competencies, organizational readiness, managerial commitment, and strategic alignment as prerequisites for realizing the benefits of digital technologies. Similarly, the quantitative results suggest that digitalization is associated with sustainability-related outcomes only in certain dimensions, indicating that technology adoption alone is insufficient to explain sustainability performance. Together, these findings support the socio-technical perspective, which views organizational outcomes as emerging from the interaction between technological, organizational, and human factors rather than from technology implementation in isolation.

5.3. Theoretical Contribution

This study contributes to the existing literature in several ways. First, it extends previous research by examining digital transformation as a multidimensional phenomenon encompassing technological adoption, organizational capabilities, employee competencies, data utilization, and strategic orientation rather than focusing solely on technological implementation. Second, by combining quantitative benchmarking with qualitative managerial perspectives, the study provides a more comprehensive understanding of how SMEs perceive the relationship between digital transformation and sustainability. Third, the findings suggest that organizational capabilities and digital competencies are important factors associated with the successful translation of digital transformation initiatives into sustainability-related outcomes, highlighting the relevance of socio-technical perspectives for understanding digital transformation processes.

From a theoretical perspective, the study contributes to the growing literature on digital transformation and sustainability by supporting the view that sustainability-related outcomes cannot be explained solely through technology adoption. Instead, the findings suggest that organizational capabilities, employee competencies, managerial commitment, and strategic alignment represent important contextual factors shaping how digital technologies are translated into sustainability-related outcomes. While the exploratory nature of the study does not allow causal inferences, the results provide empirical support for socio-technical perspectives that emphasize the interaction between technological, organizational, and human dimensions of digital transformation.

The study also contributes to the broader digital transformation literature by providing empirical evidence that the relationship between digitalization and sustainability is not uniform across different sustainability dimensions. While positive associations were identified for innovation-related outcomes, the findings indicate that digitalization alone does not automatically translate into improvements in all areas of sustainable development. This observation supports recent calls in the literature for a more nuanced understanding of digital transformation as a context-dependent and multidimensional process rather than a universally positive driver of sustainability.

Finally, the study contributes to the sustainability literature by integrating macro-level sustainability indicators with firm-level managerial perspectives. The findings suggest that sustainability-related outcomes in SMEs are shaped not only by technological capabilities but also by organizational and strategic factors. Furthermore, the comparatively limited attention devoted to social sustainability by interview participants highlights a potentially underexplored area within both digital transformation and sustaina-

bility research, indicating an important avenue for future theoretical and empirical development.

5.4. Practical Implications

The findings provide several practical implications for both policymakers and SME managers. For policymakers, a differentiated approach to digital transformation support is recommended. Enterprises with lower levels of digital maturity should be supported primarily through basic digitalization measures, including digital skills development, ICT training programs, and support for the adoption of core digital tools such as e-invoicing, cloud solutions, and digital customer service platforms. Given the identified weaknesses of Slovenian enterprises in e-commerce adoption and digital customer interaction, targeted support measures in these areas could generate substantial benefits.

For enterprises with higher levels of digital maturity, policy measures should focus on accelerating the adoption of advanced technologies, including artificial intelligence, IoT solutions, advanced data analytics, and digitally integrated supply chains. Innovation incentives, pilot projects, and technology demonstration programs may help bridge the gap between digital experimentation and large-scale implementation.

The findings also suggest that digital transformation policies should not focus exclusively on technology adoption. Employee digital competencies, process optimization, and data-driven decision making emerged as equally important dimensions associated with sustainability outcomes. Therefore, future support programs should combine technological investments with organizational and managerial capability development.

For SME managers, the results highlight that sustainable digital transformation should be approached as a strategic business process rather than a technology project. The strongest sustainability benefits were associated with process digitalization, employee competencies, and innovation-oriented digital initiatives.

5.5. Limitations and Future Research

Several limitations should be acknowledged. First, the quantitative analysis relied on country-level DESI and SDG indicators and employed bivariate correlation analysis. As a result, the findings identify associations rather than causal relationships. Furthermore, the analysis was based on a relatively small sample of 27 EU member states, which limits the robustness and generalizability of the statistical results. The benchmarking analysis was based on an unweighted average of EU member states, ensuring equal representation of countries but not accounting for differences in economic size, number of enterprises, or sectoral structure. In addition, data availability varied across some ICT indicators.

Second, the qualitative component was based on a purposive sample of ten Slovenian SMEs, including seven micro and small enterprises and three medium-sized enterprises. Although the sample reflects the dominant structure of the Slovenian business sector, the objective was not statistical representativeness but rather the exploration of diverse managerial perspectives across different industries and levels of digital maturity. Consequently, the findings should be interpreted as exploratory and analytically transferable rather than statistically generalizable.

Third, the qualitative findings are based on self-reported managerial perceptions and may therefore be influenced by social desirability bias. Although participation was voluntary and responses were anonymized, no formal assessment of social desirability was conducted, and interview responses were not systematically verified against internal company records or external performance data. The findings should therefore be interpreted as perceived rather than objectively validated relationships between digital transformation and sustainability-related outcomes.

Future research should employ larger samples, longitudinal research designs, and firm-level datasets to better understand the mechanisms linking digital transformation and sustainability performance. Particular attention should be devoted to identifying causal pathways, examining sector-specific differences, and exploring the role of social sustainability, which emerged as comparatively underrepresented in both managerial perceptions and existing research. Further studies could also investigate how different levels of digital maturity influence sustainability outcomes over time and explore decision-support approaches that help SMEs align digital transformation initiatives with sustainability objectives.

6. Conclusions

This study explored the relationship between digitalization and the achievement of Sustainable Development Goals in SMEs using a mixed-methods research design. Quantitative analyses based on Eurostat ICT Usage Survey data and the relationship between DESI and selected SDG indicators across EU member states were complemented by semi-structured interviews with managers of Slovenian SMEs, enabling a broader exploration of sustainability-related outcomes associated with digital transformation.

The benchmarking analysis suggested that Slovenian enterprises perform close to the EU average in overall digital adoption. Strengths were observed in areas such as e-invoicing and ICT-related training, while comparatively lower levels of adoption were identified in e-commerce and customer-oriented digital services. These findings provide contextual insights into the digital maturity of Slovenian SMEs and the challenges associated with more advanced forms of digital transformation.

The DESI–SDG analysis identified statistically significant associations between digitalization and selected sustainability indicators, particularly SDG 9. At the same time, the results suggest that digitalization alone may not automatically translate into improved environmental sustainability outcomes, highlighting the complexity of the relationship between technological development and sustainability.

The qualitative findings suggest that SME managers perceive digital transformation as an important contributor to innovation, operational efficiency, organizational adaptability, and resource optimization. The interviews further indicate that employee digital competencies, organizational readiness, and strategic alignment are important factors associated with the successful implementation of digital transformation initiatives.

The study contributes to the literature by integrating macro-level sustainability indicators, enterprise digitalization measures, and managerial perspectives within a single analytical framework. By combining quantitative and qualitative approaches, the research provides exploratory insights into how digitalization is perceived and associated with sustainability-related outcomes in SMEs.

Despite its limitations, the study highlights the importance of viewing digital transformation not merely as a technological process but as a multidimensional organizational phenomenon shaped by the interaction of technologies, business processes, data utilization, employee competencies, and strategic capabilities. Consistent with a socio-technical perspective, the findings suggest that sustainability-related outcomes are influenced not only by technology adoption but also by the organizational and human factors that support its implementation.

Future research should further investigate sector-specific pathways and potential mechanisms linking digitalization and sustainability-related outcomes using larger samples, longitudinal designs, and firm-level data. Such studies could contribute to a deeper understanding of how digital transformation supports sustainable development across different organizational contexts.

Overall, the findings suggest that the sustainability-related benefits of digital transformation depend not only on the adoption of digital technologies but also on how these technologies are embedded within organizational processes, supported by employee competencies, and aligned with strategic objectives. These observations should be interpreted as exploratory insights that provide a foundation for future research rather than as evidence of causal relationships.

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Institutional Review Board Statement: No personal or sensitive data were collected or discussed during the interviews. All participants were informed in advance about the purpose of the research, and that their responses would be anonymized and presented exclusively in aggregated form. Participation was entirely voluntary. In line with the established institutional framework and standard research practice at the University of Ljubljana, such research, without interventions, without collection of personal or sensitive data, and ensuring full anonymization, does not fall within the category requiring formal ethical approval.

Informed Consent Statement: Verbal informed consent was obtained from the participants. Verbal consent was obtained rather than written because the study involved minimal risk, participation was voluntary, and no personally identifiable or sensitive data were collected.

Data Availability Statement: The original data presented in the study are openly available: <https://ec.europa.eu/eurostat/web/interactive-publications/digitalisation-2025> (11. November 2025). <https://digital-strategy.ec.europa.eu/en/policies/desi> (4. November 2025). <https://dashboards.sdgindex.org/explorer> (11. November 2025). https://github.com/ivoh644/SDG_DESI. <https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/des> (4. November 2025).

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial intelligence
SMEs	Small- and medium-sized enterprises
UN	United Nations
SDG	Sustainable Development Goals
ICT	Information and Communication Technology
DESI	Digital Economy and Society Index
EU	European Union
GDP	Gross Domestic Product
SLO	Slovenia
IoT	The Internet of Things
SCM	Supply chain management

Appendix A

Appendix A.1. Characteristics of the Interviewed SMEs and Interview Structure

Table A1. Characteristics of the interviewed SMEs, respondents, and assessed digital maturity levels.

Respondent	Sector	Main Activity	Company Size	Position of Respondent	Digital Maturity
R1	Manufacturing	Metal processing and industrial constructions	Medium	CEO	High
R2	Manufacturing	Wood-processing machinery manufacturing	Medium	CEO	High
R3	ICT Services	Digitalization and IT solutions	Small	CEO	High
R4	Retail	Mobile devices and telecommunications equipment	Small	CEO	Medium
R5	Tourism	Travel and tourism services	Small	CEO	Low
R6	Services	Vending and automated beverage distribution	Medium	Project Manager	Medium
R7	Manufacturing	Printing and graphic production	Small	CEO	Medium
R8	ICT Services	Artificial intelligence implementation and consulting	Micro	CEO	High
R9	E-commerce	Global online retail (optics)	Small	CEO	High
R10	Consumer Goods	Cosmetics, honey products, and spirits	Micro	CEO	Medium

Table A2. Interview structure.

Research Objective	Example Questions	Related Digitalization Dimension	Thematic Area
Characterize respondents and organizations	What is your role in the organization? What is the size and main activity of your company?	Context	Respondent and Company Profile
Assess the current level of digitalization	To what extent does your company use modern digital technologies, AI, cloud computing, and data analytics? How would you assess the overall digital maturity of your organization?	Technology, Processes, Data, Strategy	Digital Maturity Assessment
Identify SDGs perceived as most influenced by digitalization	Which Sustainable Development Goals are most affected by digitalization in your organization?	All dimensions	Digitalization and SDGs
Evaluate the perceived contribution of specific digitalization factors	How do productivity, innovation, digital infrastructure, resource consumption, waste reduction, CO ₂ reduction, and employee competencies contribute to SDG achievement?	Technology, Processes, People	Impact of Digitalization Parameters
Identify how digitalization influences sustainability outcomes	Which mechanisms contribute most to sustainability outcomes: process optimization, digital tools, data analytics, or employee competencies?	Technology, Processes, Data, Competencies	Mechanisms of Impact
Examine links between specific technologies and individual SDGs	Which SDGs are influenced by AI, IoT, cloud computing, blockchain, process automation, digital supply chains, digital competencies, and digital strategy?	Technology, Processes, Competencies, Strategy	Impact Areas by SDG
Assess whether impacts are direct or indirect and their timing	Are the impacts of digitalization on SDGs direct or indirect? Do they occur in the short, medium, or long term?	All dimensions	Nature and Time Horizon of Impact

Assess perceived magnitude of influence	How strong is the impact of each digitalization dimension on SDG achievement?	All dimensions	Strength of Impact
Identify obstacles to digital transformation and sustainability integration	What barriers hinder digitalization and sustainability integration (e.g., lack of knowledge, financial constraints, employee resistance, lack of data, unclear strategy)?	All dimensions	Barriers and Risks
Evaluate managerial perceptions of the digitalization–sustainability relationship	Do some SDGs depend more on digitalization than others? Can digitalization also have negative sustainability effects?	Strategy	Strategic Assessment
Assess overall relationship between digitalization and sustainability	To what extent do you agree that digitalization has a direct and significant impact on SDG achievement?	All dimensions	Overall Evaluation

Appendix A.2. Figures of Quantitative Analysis

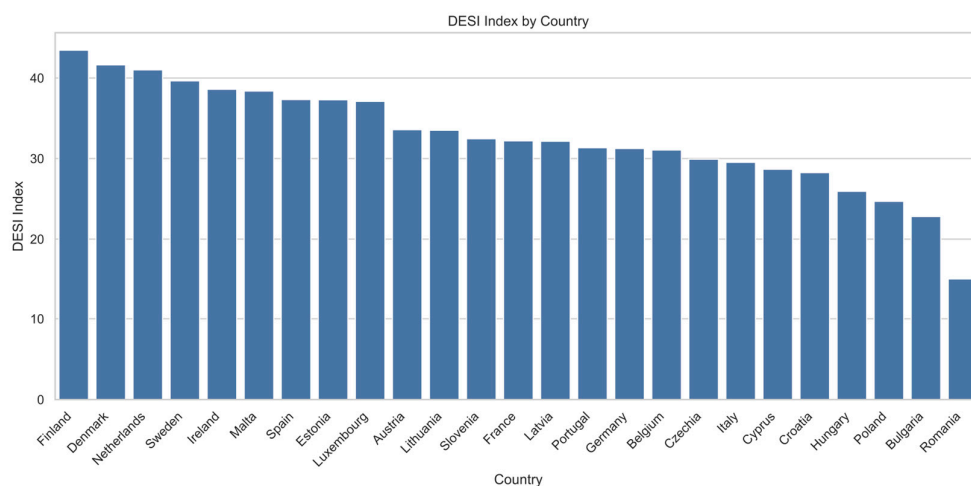


Figure A1. DESI scores for all 27 EU member states (2022). Countries are ranked from highest to lowest DESI score.

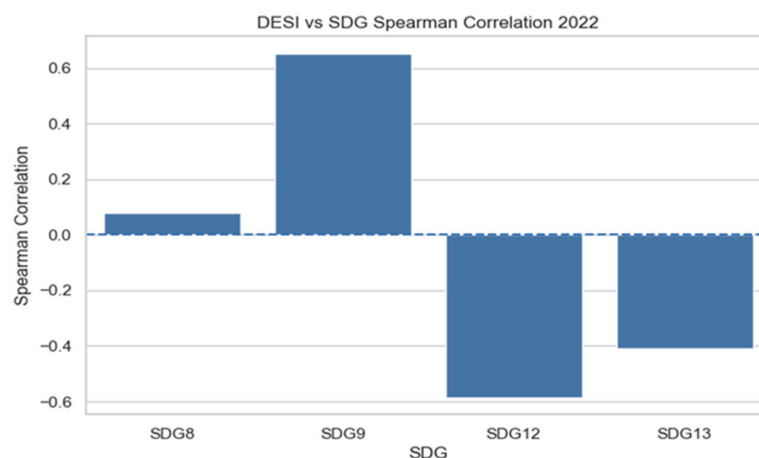


Figure A2. Spearman's correlation coefficients between DESI and each of the four SDG sub-indices in 2022. Blue bars indicate positive correlations; the dashed line marks zero. Dotted horizontal line represents the zero-correlation reference line, indicating the threshold between positive and negative Spearman correlation values.

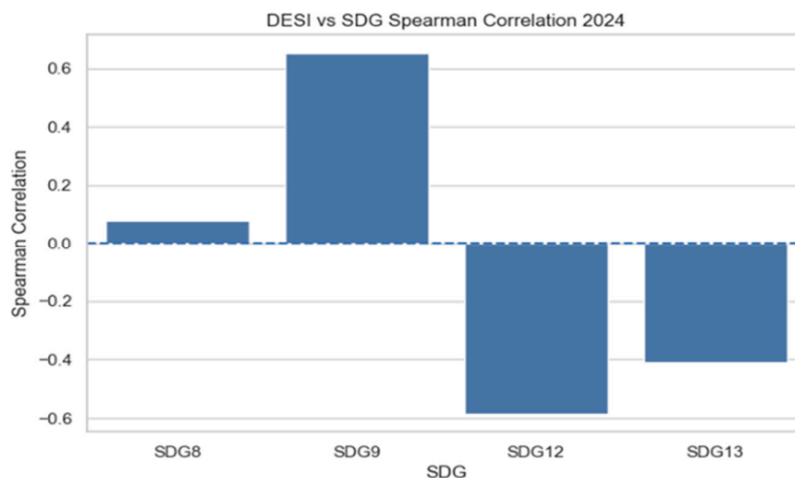


Figure A3. Spearman's correlation coefficients between DESI and each of the four SDG sub-indices in 2024. Blue bars indicate positive correlations; the dashed line marks zero. Dotted horizontal line represents the zero-correlation reference line, indicating the threshold between positive and negative Spearman correlation values.



Figure A4. SDG sub-index scores (SDGs 8, 9, 12, 13) for all 27 EU member states in 2022. Each panel shows country-level variation in the respective sustainability dimension.

Rank Relationships (Spearman Perspective) — Year 2022

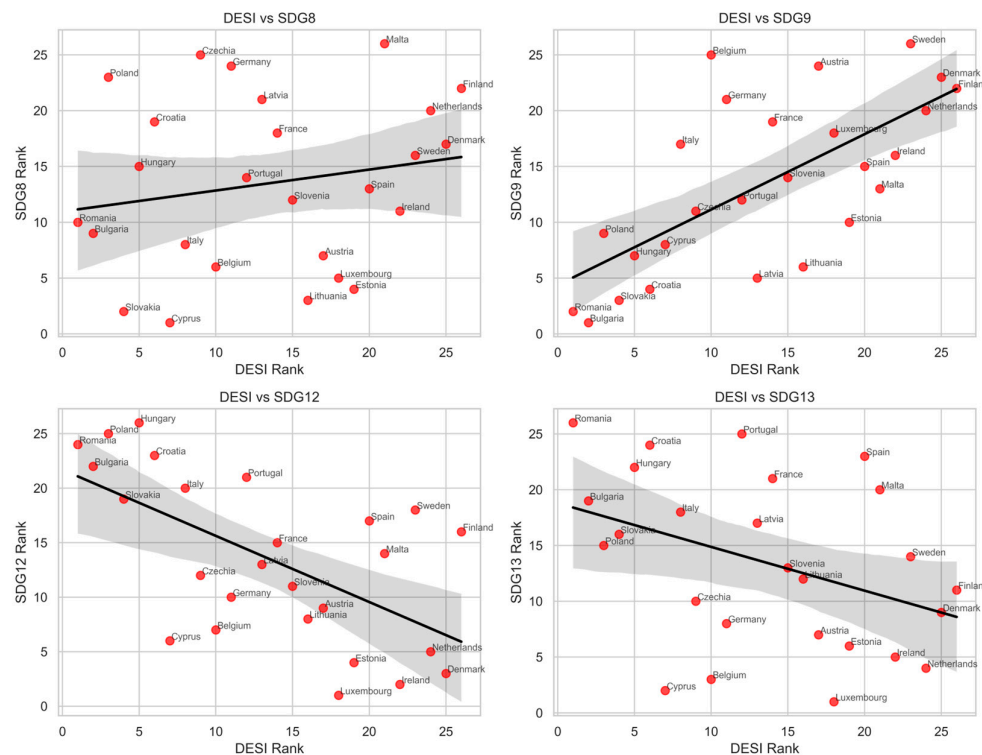


Figure A5. Rank-order scatter plots of DESI rank vs. SDG rank for all four sub-indices in 2024. Results are consistent with 2022, confirming the temporal robustness of the observed associations. Relationships between DESI ranks and SDG ranks across EU Member States in 2024. Red dots represent individual countries. The black line shows the overall trend in the rank relationship, and the shaded area represents the 95% confidence interval. The figure is intended for visual interpretation, while statistical associations were evaluated using Spearman's rank correlation coefficient (ρ).

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