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Digital Transformation and Innovation: The Influence of Digital Technologies on Turnover from Innovation Activities and Types of Innovation

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Abstract: In today's competitive and globalized world, innovation is essential for organizational survival, offering a means for companies to address environmental impacts and social challenges. As innovation processes accelerate, managers need to rethink the entire value-creation chain, with digital transformation emerging as a continuous process of organizational adaptation to the evolving societal landscape. The research question focuses on how digital technologies—such as artificial intelligence, Big Data, cloud computing, industrial and service robots, and the Internet of Things—influence innovation-driven revenues among enterprises within the European Union (EU). The paper examines, using neural network analysis, the specific impact of each digital technology on innovation revenues while exploring how these technologies affect various types of social innovation within organizations. Through cluster analysis, the study identifies patterns among EU countries based on their digital technology adoption, innovation expenditures, and revenues and the proportion of enterprises engaged in innovation activities. The findings highlight the central role of digital technologies in enhancing innovation and competitiveness, with significant implications for managers and policymakers. These results underscore the necessity for companies to strategically integrate digital technologies to sustain long-term competitiveness in the rapidly evolving digital landscape of the EU.

Keywords: innovation; social innovation; digital transformation; digital technologies; artificial intelligence; Big Data; cloud computing; industrial and service robots; Internet of Things

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1. Introduction

Digitalization is critical in optimizing production processes, enhancing communication between business partners, and reducing operational costs in the current global economy. It allows companies to use real-time data to make informed decisions, automate repetitive processes, and improve efficiency. However, merely implementing new technologies does not guarantee success. Companies must fundamentally rethink their business models to fully leverage the potential offered by digital transformation [1].

The transition to innovation-based business models entails a profound shift in how companies deliver value to their customers [2]. In an increasingly digitalized world, the ability to innovate and quickly adapt to technological changes becomes a key determinant of long-term success [3]. Digital transformation has fundamentally redefined how companies approach innovation. Digital technologies have opened new possibilities for innovation by facilitating global collaboration, democratizing access to knowledge and resources, and providing powerful tools for analysis and experimentation. Companies that efficiently integrate these technologies into their innovation processes will remain competitive and have the potential to redefine industries and create value in previously unimaginable ways. In the digital era, the ability to innovate quickly and efficiently increasingly equates to the

ability to adopt and adapt to digital transformation [4]. Digital transformation in the context of innovation involves adopting new technologies and transforming organizational culture. Successful companies encourage a mindset of continuous experimentation, tolerance of failure, and rapid learning, all facilitated and amplified by digital tools.

Social innovation has recently gained increasing recognition as a powerful tool for driving social progress. It has become a critical component of public policy and corporate strategy as organizations across sectors seek to address our time's social and environmental challenges. The essence of social innovation lies in its ability to reimagine existing social structures and relationships, enabling communities and organizations to respond more effectively to societal needs [5].

Developing an organizational culture that supports social innovation is essential for long-term success. These actions encourage collaboration and exchanging ideas among employees, the company, and external partners. Innovation managers must create an environment where employees feel free to experiment and take risks without fearing failure. Adopting clear and structured processes for managing ideas and innovation projects can enhance efficiency and reduce the time from conception to implementation [6]. Companies can respond more effectively to changes in the external environment and capitalize on emerging opportunities by promoting flexible and adaptable management [7].

The COVID-19 crisis in 2020 significantly accelerated social innovation across EU countries, with digital technologies playing a crucial role in enabling organizations to respond effectively to the challenges posed by the pandemic. The crisis highlighted the importance of adaptability, collaboration, and technology in driving social innovation, setting the stage for a more resilient and digitally enabled future.

This paper aims to comprehensively analyze how digital technologies, such as artificial intelligence (AI), Big Data (BD), cloud computing (CC), industrial and service robots (ISR), and the Internet of Things (IoT), influence the generation of innovation-driven revenues from innovation activities and the types of social innovation within the EU. The research addresses existing gaps by examining the specific impact of each digital technology on companies' innovation revenues, which has been underexplored in previous studies. The originality of this paper lies in its application of artificial neural network analysis to evaluate the individual effects of these technologies and in its use of cluster analysis to categorize EU countries based on their adoption levels of digital technologies, innovation expenditures, and engagement in innovation activities.

The paper begins with an introduction that outlines the critical role of digital transformation in today's global economy and the necessity for companies to rethink their business models to harness the potential of digital technologies. A literature review and hypothesis development section explores previous research on digital technologies and innovation, formulating hypotheses. The materials and methods section details the research design, selected data, and methods used in the study. The results section presents the findings from the artificial neural networks and cluster analyses. The discussion section explores the implications of these findings for innovation management and competitiveness in the EU. Finally, the conclusion summarizes the key insights and suggests directions for future research.

2. Literature Review and Hypotheses Development

2.1. The Role of Digital Transformation in Enhancing Innovation Performance

In recent years, digital technologies have revolutionized how companies manage their operations and innovate in products and services [8]. AI has advanced data processing and decision-making automation, bringing significant benefits in optimizing operations and improving efficiency. BD has provided valuable insights into operational performance and customer preferences, supporting the personalization of products and services. IoT has connected equipment and devices into an integrated digital ecosystem, improving the monitoring and management of physical assets. CC has enabled real-time resources and data access, facilitating rapid decision-making and process optimization. ISR enhances efficiency

and precision in production lines and operational processes, reducing costs and production times. These technologies have led to continuous innovation in production methods and management models in the manufacturing sector and increased enterprises' innovation capabilities [1]. By integrating these advanced technologies, companies can remain competitive and achieve long-term advantages in a rapidly changing global market [8].

The organization's digital transformation may be the most challenging aspect, but it is also crucial for sustaining long-term innovation. Digital transformation is a comprehensive process through which organizations leverage digital technologies to alter their operations, business models fundamentally, and approaches to value creation. Digital transformation is not merely about adopting new technologies; it requires a strategic shift in how organizations generate value, engage with customers, and sustain a competitive advantage in an increasingly digital marketplace [9]. This shift often leads to innovative organizational changes, redefining traditional business practices and creating new growth opportunities.

Value creation, deeply intertwined with digital transformation and innovation, refers to the process through which organizations deliver products or services that hold significant customer value [10]. In the context of digital transformation, value creation is often enhanced through the innovative application of digital technologies, which can lead to improved customer experiences, streamlined operations, and the development of new business models.

Digital transformation involves restructuring internal processes, adopting new agile and collaborative work methods, and developing the workforce's digital skills. A digitally transformed organization can quickly adapt to changes, experiment with new ideas, and continuously learn from market feedback. Digital transformation facilitates access to new markets and business opportunities, and adopting digital technologies can significantly improve employee productivity. Automating repetitive tasks and implementing digital collaboration tools allow staff to focus on higher-value activities, thus stimulating innovation and creativity within the organization [11].

Digital transformation does not only involve adopting new technologies; it also requires a fundamental change in organizational culture. Enterprises must encourage a mindset oriented towards innovation, agility, and continuous learning to fully leverage the potential of digital transformation. In the current global market context, digital transformation is no longer an option but a prerequisite for enterprises wanting to remain relevant and competitive. Companies that embrace this change and invest in digital technologies are better positioned to face future challenges and seize emerging opportunities in an increasingly digitalized economy [12].

Digital transformation represents not merely an incremental improvement of existing technologies but a radical change in how production and operations are conceived and executed, integrating digital technologies into all aspects of the value chain [1]. Automating production processes eliminates human errors and allows companies to operate continuously, thus increasing production capacity and reducing the time needed to bring products to market [13]. At the same time, optimizing resources using advanced algorithms can lead to significant savings in raw materials and energy, contributing to the long-term sustainability of operations.

Another essential aspect of digital transformation is the ability to collect and analyze data in real-time, providing companies with valuable information to make quick and informed decisions, anticipate and prevent problems before they arise, and rapidly adapt processes to the dynamic demands of the market [3]. This agility and responsiveness become major differentiators in a highly competitive global business environment [14].

Implementing digital technologies in companies' operational processes brings multiple benefits. These include increased efficiency, reduced costs, improved customer experience, and innovation ability [8]. In a world where adaptation to specific customer needs is essential, advanced technologies allow for the small-scale but efficient production of a limited series of customized products without compromising costs or quality [15]. This ability to offer personalized solutions meets customer demands and creates opportunities to explore

new market segments and develop closer customer relationships [16]. Companies that quickly adapt their digital infrastructure to meet market demands will have a significant competitive advantage [1].

Adopting digital technologies allows firms to offer more efficient and personalized solutions, quickly adapting to changing market needs [17]. Performance-based business models can provide customers guaranteed service or efficiency, significantly increasing customer satisfaction and loyalty [15]. At the same time, using artificial intelligence and BD can provide companies with detailed insights into customer behavior and preferences. CC and the IoT facilitate connectivity and access to data from any location, allowing continuous global monitoring and the optimization of operations [14]. Companies that invest in these technologies can develop innovative business models that improve efficiency, reduce costs, generate new revenue streams, and create sustainable long-term value [1].

In many cases, companies that focus solely on adapting their products or services through digitalization without fully exploring the innovative potential of digital technologies risk overlooking transformation opportunities [18]. Instead of using collected data to develop new product lines or personalized services, some firms may only enhance existing functionalities, limiting growth and innovation potential [1]. Using digital transformation solely to support current products can stagnate innovation, as the firm fails to adapt to new market demands and rapid technological changes [19]. On the other hand, firms that adopt a holistic approach to digital transformation and integrate new technologies into all aspects of their business model are more likely to innovate and ensure sustainable long-term growth. Therefore, real success in the digital age requires more than just digitalizing existing products; it involves fundamentally rethinking the entire business model and how technology creates new and sustainable value.

Digital transformation can drive the creation of new revenue flows or increase existing flows for companies [20]. Digital technologies transform how companies generate revenues and manage and optimize operations, supporting continuous innovation and sustainable growth [21]. Iansiti and Lakhani [14] also show that innovations based on digital technologies improve operational efficiency and create new revenue sources and business models that can radically transform industries. In a dynamic and globalized business environment, companies that embrace and invest in digital transformation have the potential to significantly differentiate themselves from the competition and lead the market through continuous innovation [1].

The paper proposes an initial hypothesis regarding the role of digital technologies in improving innovation performance:

Hypothesis H1. *Digital technologies positively influence revenues from innovation activities in the EU countries*.

2.2. The Influence of Digital Technologies on Types of Innovation

Using digital technologies in innovation enables companies to significantly reduce the time needed to develop and launch new products. Technologies like AI can analyze large amounts of data to identify market trends and consumer preferences, providing companies with valuable insights to develop products that better meet market demands. Digital collaboration tools (such as CC) facilitate communication and coordination among geographically dispersed product development teams, allowing faster and more efficient innovation. Integrating IoT technologies into existing products can add new functionalities and enhance user experience by providing connected and personalized services. These advancements improve operational efficiency and create opportunities to differentiate products in the market and build stronger customer relationships. Companies can better navigate the complexity and dynamics of the global market by leveraging digital technologies, thereby ensuring a competitive advantage and sustainable long-term growth [22].

Innovation, a central theme in discussions about digital transformation, is defined by Schumpeter as the introduction of new combinations of resources that result in new

products, processes, markets, or organizational structures [23]. Schumpeter emphasizes that innovation is the primary driver of economic development and competitive superiority. Drucker highlights that innovation extends beyond technological advancements, including new ways of creating value through business processes and entrepreneurial practices [24]. Drucker views innovation as a crucial tool for entrepreneurs, enabling them to capitalize on change and transform it into an opportunity.

Within the broader framework of innovation, it is essential to distinguish between technological and social innovations. Technological innovations involve technological advancements and processes that enhance efficiency or result in new products. Schumpeter's theory primarily focuses on this type of innovation, considering it the backbone of economic progress. On the other hand, social innovations aim to improve social practices, relationships, or structures, often addressing societal needs or challenges. Mulgan underscores that social innovations emerge from efforts to meet social needs in ways not always driven by market forces, thereby contributing to societal well-being and sustainability [5]. This distinction is crucial for understanding the multilayered nature of innovation, which can simultaneously drive economic growth and foster social progress.

Adopting innovation-based strategies allows companies to respond swiftly to market changes and technological advancements [25]. In fast-paced technological sectors, continuously launching new products and improving existing ones is crucial for maintaining competitiveness and relevance. Process innovations can significantly reduce production times and costs, enabling companies to offer competitively high-quality products. Flexibility and adaptability are significant in a globalized business environment, where customer demands and preferences change rapidly. Companies can quickly adjust the production volume and type to meet variable demand by optimizing supply chains and adopting lean production methods. Innovation-based strategies enhance operational efficiency and create opportunities for expansion and growth in new markets [25]. These strategies can foster an organizational culture focused on social innovation and continuous improvement.

Ferreira et al. [26] investigated why companies opt for implementing digital technologies and the impact of digitalization on innovation and performance. They revealed that the main reasons for companies' digital transformation include the desire to remain competitive in a rapidly changing business environment, the need to improve operational efficiency, and the aspiration to meet the continuously evolving demands of customers better. Regarding the impact on innovation, the research of Ferreira et al. [26] demonstrated that adopting digital technologies boosts companies' capacity to innovate. Integrating digital tools into research and development processes allows for better data collection and analysis, facilitating the rapid identification of new market opportunities and accelerating innovation cycles.

Product, process, and industry-level innovations are strongly stimulated by digital technologies, which not only positively influence individual company development but also catalyze a profound transformation of the entire economic ecosystem, fostering collective integration and progress [27].

At the product level, digital technologies enable unprecedented personalization and the continuous improvement of functionalities. Using AI and IoT in consumer products allows real-time adaptation to user needs and preferences, creating unique experiences and added value. This fact increases customer satisfaction and opens new market opportunities and business models based on personalized services. Digital goods and service innovations radically transform how consumers interact with products and services [28]. These innovations meet existing needs more efficiently and create new market demands and opportunities [29].

Within a company, innovation extends beyond developing new products to encompass how operations and internal processes are managed [30,31]. Implementing advanced process management practices can improve workflow efficiency, reduce wait times, and improve production quality. This action is essential in a dynamic business environment, where the ability to respond quickly to market changes and customer demands can make the

difference between success and failure [32]. Dynamic capabilities enable organizations to be proactive and anticipate changes rather than merely reacting when they occur. Adaptability is fundamental in digitalization and globalization, where rapid and frequent changes occur. Therefore, developing and strengthening dynamic capabilities should be a strategic priority for any organization aiming to remain competitive and thrive in the long term [33]. In this context, innovation is a tool for increasing efficiency and a fundamental mechanism for survival and success in a constantly changing business environment.

Regarding process innovations, digital technologies have catalyzed a profound transformation of how companies operate [34]. Automation based on artificial intelligence and machine learning optimizes supply chains, improves production efficiency, and reduces human errors [35,36]. Ben and Hikkerova [37] argued that the opportunities offered by digital technologies enable the implementation of continuous innovation processes and capabilities, highlighting the transformative potential of digital technologies in redefining how organizations approach innovation. Companies can create a virtuous cycle of improvement and adaptation, essential for long-term success in an ever-changing economic landscape, by adopting a continuous innovation mindset supported by digital tools and processes.

Innovation capability contributes to maintaining long-term competitiveness as it allows organizations to adapt to market changes and proactively respond to emerging customer needs. Companies that invest in developing innovation capability can introduce new products and services and improve internal processes, thereby increasing operational efficiency and reducing costs [38]. An organizational culture that promotes creativity, collaboration, and continuous learning supports this ability to transform knowledge and ideas into practical and valuable solutions. Thus, innovation capability is a competitive advantage and a strategic necessity in a business environment characterized by rapid and complex changes. Organizations that can continuously transform knowledge and ideas into new solutions will prosper and lead the industry in the future.

Innovations in organizational practices may represent digital technologies' most subtle yet profound impact [39,40]. The effect of digital transformation on organizational practices is as significant as innovation at the product, service, or process level [20,41]. Companies need to reconfigure their internal structures to support new technologies and processes. Digital transformation can also radically alter supply and distribution chains [42]. Another area where digital transformation has a strong influence is customer relationships. Collaborative digital platforms enable closer and more personalized customer interactions, providing superior user experiences and services tailored to individual preferences. Thus, digital transformation is not just a technological trend but a fundamental change in how companies operate, innovate, and create value [43,44]. Its impact extends to all levels of the organization and can determine a company's long-term success or failure. This action requires a well-thought-out strategy and rigorous implementation to maximize benefits and minimize associated risks [31].

Analyzing the impact of digitalization on types of innovation is essential for understanding how companies can improve their innovation capabilities [45,46]. Previous research has shown that effectively integrating digital technologies can strengthen a company's position in innovation, facilitating product and service development, improving processes, and modifying organizational practices [21,47].

This paper proposes a second hypothesis regarding the influence of digital technologies on different types of innovation:

Hypothesis H2. *Digital technologies positively influence all types of innovation, with the most significant impact on process innovations, communication, and logistics chains.*

2.3. The Relationship among Digital Technologies, Innovation Expenditures and Revenues, and the Percentage of Innovating Enterprises in the EU

Integrating innovations in digital technologies into organizational strategies and operations is not just an option but an imperative necessity for sustainability and competitiveness

in the digital era [48]. These innovations provide the tools to navigate the increasing complexity of the business environment, respond swiftly to changes, and create value more sustainably and responsibly [49]. In this context, organizations that invest significantly in innovation activities and successfully embrace and efficiently integrate these digital innovations position themselves best to thrive in the uncertain and dynamic future that lies ahead [11]. The findings of Zhang et al. [27] highlight the critical importance of digital transformation as an innovation driver for existing companies, especially in the face of market and technological uncertainty. These firms can maintain their relevance and competitiveness and become innovation leaders in their industry by embracing digital transformation, transforming the challenges of uncertainty into opportunities for growth and market differentiation [50].

Implementing modern digital technologies, such as AI, BD, IoT, CC, and ISR, enables companies to accelerate the innovation cycle and bring products that better meet customer demands to market. Firms that can rapidly integrate new technologies into their operational processes also gain a significant competitive advantage, as they can respond more efficiently to market changes and technological advancements [51]. Innovations help companies react to market changes and allow them to anticipate and influence these changes. Innovative firms can launch products that create new market segments or change consumer behaviors, setting new standards in the industry. Adopting digital technologies and generating innovations are interdependent processes that ensure companies' survival in a competitive environment [52]. The ability to continuously innovate and quickly adapt to new technologies becomes a critical differentiator in the long-term success of any organization.

2.3.1. Internet of Things

In the organizational environment, the IoT revolutionizes production and logistics processes. Sensors integrated into industrial machinery allow for real-time performance monitoring, the anticipation of maintenance needs, and the optimization of energy consumption, improving operational efficiency, reducing costs, and minimizing downtime [28]. The IoT is more than a mere technological innovation; it catalyzes a fundamental transformation of how we interact with the world around us. From enhancing operational efficiency in industry to revolutionizing daily life, the IoT creates a more innovative, connected, and potentially more sustainable world [53]. As technology evolves, its impact on society and the economy will deepen, opening new frontiers for innovation and progress.

Incorporating the IoT into innovation management strategies enables a significant transformation in how companies conduct their activities and make decisions. The IoT allows for the real-time monitoring and control of production processes, reducing downtime and improving operational efficiency [54]. Data collected from various devices can be analyzed to identify patterns and trends that can lead to process optimization and the development of new products and services [55]. IoT technology is increasingly important in industrial and commercial innovation [4]. Smart and interconnected devices become essential to modern business infrastructures, facilitating greater flexibility and adaptability to market changes.

2.3.2. Cloud Computing

CC is more than a mere technological innovation; it is a transformative factor for modern supply chains and, by extension, the entire global business landscape [56]. CC enables companies to build more resilient, efficient, and responsive supply chains by facilitating increased visibility, improving collaboration, reducing costs, and enhancing agility [57]. As CC evolves, its impact on how companies operate and compete globally becomes more pronounced, redefining the fundamentals of supply chain management in the digital era [35].

Adopting CC offers companies significant opportunities to optimize operations and improve innovation capacity. Integrating CC into decision-making processes is particularly important, as it allows rapid access to relevant data and advanced analytical tools [58].

Thus, companies can respond more efficiently and quickly to changes in the business environment and adjust their innovation strategies to adapt to new realities. CC contributes to innovative companies' competitiveness and long-term success by improving information flow and reducing the time needed to transform ideas into products and services [4].

2.3.3. Artificial Intelligence

Integrating AI into production processes represents a paradigm shift in the manufacturing industry. AI optimizes existing processes and prepares the ground for more innovative, flexible, and sustainable production models by enhancing efficiency, precision, and adaptability [59]. In addition to operational benefits, AI fosters product innovation. Companies can create products customized and optimized for specific consumer needs using AI algorithms in the design and development phases. This action improves customer satisfaction and creates opportunities for new business models based on customized and on-demand production [48]. As technology continues to evolve, its impact on product design, manufacture, and distribution will expand, redefining the fundamentals of industrial production in the digital era [60]. AI can lead to more informed strategic decisions and the development of products and services that better meet market needs [61].

2.3.4. Big Data

BD is more than just a collection of information; it is a transformative tool that redefines how we understand the world. BD can potentially address some of the most pressing challenges of modern society, from climate change to social inequalities, by facilitating more informed decisions, more efficient communication, improved coordination, and more precise actions [62]. BD's impact on organizing and managing society will extend as data analysis technologies evolve, opening new possibilities for innovation and progress [28].

In the manufacturing industry, BD enables a detailed analysis of production processes, identifying areas for cost savings and increasing productivity [63]. In the healthcare industry, BD transforms medical care. Healthcare providers can personalize treatments and intervene more promptly in emergencies by collecting and analyzing real-time data on patient behaviors [64]. The ability to effectively collect, analyze, and utilize large volumes of data gives companies and medical institutions the advantage of responding quickly and efficiently to emerging challenges and opportunities [4].

2.3.5. Industrial and Service Robots

ISR can learn and optimize complex tasks through trial and error without explicit programming. They allow for unprecedented flexibility and adaptability in production lines, making mass customization and small-batch production highly efficient [65]. The capability of ISR to autonomously learn and optimize complex tasks represents not just an incremental improvement in industrial automation but a fundamental transformation of how we conceive and operate production systems [66]. This technology prepares the ground for brilliant and adaptive factories capable of responding quickly and efficiently to changes in the business environment and continuously innovating production processes [67].

Using digital technologies, such as AI, BD, the CC, and ISR, plays a decisive role in shaping the innovative capacities of EU countries. Capello and Lenzi [68] examined regional innovation patterns in the EU. Their research identified five distinct types of innovative regions, offering a nuanced perspective on innovation disparities at the national and regional levels within the EU. Similarly, Szopik-Depczyńska et al. [69] grouped EU countries based on innovation indicators to investigate the degree of implementation of sustainable development goals. Żelazny and Pietrucha [70] investigated EU countries based on their performance in the digital economy and innovation, highlighting the close link between digitalization and the innovation capacity of enterprises. Regarding the percentage of innovating enterprises, Hollanders and Es-Sadki [71] used data from the European Innovation Scoreboard to group EU countries according to their innovation performance.

Hypothesis H3 is based on the premise that there are significant variations among EU countries regarding the adoption of digital technologies, innovation expenditures and revenues, and the percentage of innovative enterprises:

Hypothesis H3. *EU countries can be grouped into clusters based on digital technologies, innovation expenditures and revenues, and the percentage of innovative enterprises at the EU level.*

To test Hypothesis H3, we will use cluster analysis to identify homogeneous groups of EU countries that exhibit similar characteristics regarding digital technologies, innovation expenditures and revenues, and the percentage of innovative enterprises.

3. Materials and Methods

3.1. Research Design

The research design involves a quantitative analysis to evaluate the influence of digital technologies on the innovative performance of enterprises in the EU. The study employs panel data from Eurostat, providing a comparative perspective on digital technologies and innovation outcomes. Artificial neural and cluster analyses are the primary methods used to test hypotheses and identify patterns in digital technology adoption and innovation revenue generation.

The research stages begin with identifying research objectives and hypotheses. Data collection focused on relevant variables, including digital technologies (artificial intelligence, Big Data, cloud computing, industrial and service robots, the IoT), innovation expenditures, innovation revenues, and the percentage of innovative enterprises. The subsequent step involves data processing to ensure completeness and accuracy, along with normalization to ensure comparability across different variables and units of measurement.

Applying the research methods (artificial neural network analysis and cluster analysis) is followed by the analysis and interpretation of results to understand the individual influence of each digital technology on innovation revenues. The identified groups, through cluster analysis, are interpreted to identify common characteristics and significant differences, assessing the involvement and performance of each cluster in the European innovation context. Conclusions and recommendations are formulated based on the study's main findings summary. Figure 1 illustrates the research stages chart.

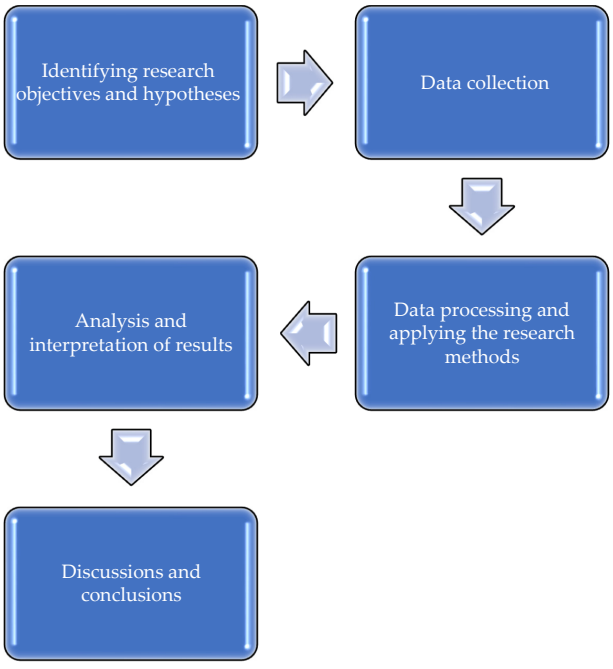

Figure 1. Research stages.

This systematic and well-structured approach ensures a comprehensive analysis of the impact of digital technologies on social innovation, providing valuable insights to guide EU policies and strategies.

3.2. Selected Variables

This empirical investigation selected variables from the Eurostat database, including indicators from 2020 and 2021. The sample size for this research comprises enterprises from all 27 EU member states, providing a broad and representative view of the European business landscape. The collected data reflect various aspects of digital technology use and the social innovation performance of enterprises in the European Union. The selected variables include the degree of digital technology adoption, encompassing AI, BD, the IoT, CC, and ISR use measurements. These technologies are essential for evaluating enterprises' digitalization and technological transformation.

Turnover from innovation activities (percentage of total turnover) is one of the primary variables, measuring the additional income enterprises generate from introducing new products, processes, or services. This variable assesses the direct economic impact of innovation on firms' financial performance. An investigation of the H2 Hypothesis implies variables defining types of social innovation: business process innovation, new or improved methods for producing goods or providing services, innovations in logistics, new business practices for organizing procedures or external relations, new methods of organizing work responsibility, decision-making or human resource management, new or improved processes for information processing or communication, new methods for accounting or other administrative operations, and new marketing methods for promotion, packaging, pricing, product placement, or after-sales services.

Business process innovations refer to implementing new or improved methods for producing goods or providing services, contributing to increased efficiency and competitiveness. Logistics innovations include improving the flow of goods and services and optimizing supply and distribution chains. New business practices for organizing procedures or external relations reflect innovations in how companies manage interactions with partners, customers, and other external entities. New methods for organizing work responsibilities, decision-making, or human resource management highlight changes in firms' internal structures to enhance efficiency and improve performance.

New or improved information-processing methods represent technologies and practices that enable more efficient data management and faster, more accurate communication within and outside the organization. Innovations in accounting or other administrative operations include improvements in financial and administrative processes to increase accuracy and operational efficiency. New marketing methods for promotion, packaging, pricing, product placement, or after-sales services represent innovative strategies companies adopt to attract and retain customers, adapting to the ever-changing market demands and preferences. These variables provide a comprehensive view of the diversity and complexity of social innovation activities within European enterprises. For each category, the study measures the percentage of enterprises implementing such innovations, offering a nuanced view of the adoption of social innovation across different business aspects.

Cluster analysis implies two additional variables characterizing innovation: expenditure on innovation activities and enterprises engaged in innovation activities. Expenditure on innovation activities represents the percentage of investments enterprises allocate for innovation, excluding research and development. These expenditures reflect firms' financial commitment to promoting and supporting innovation. The percentage of enterprises engaged in innovation activities is another essential variable, indicating the proportion of companies reporting innovative activities. This variable is important for understanding the degree of engagement and adoption of innovations within the European business environment.

The papers' approach focuses on percentages of enterprises adopting various technologies and innovations, allowing for meaningful comparisons across different EU countries.

This approach provides a normalized view of digitalization and social innovation trends across the European Union.

Table 1 presents the selected variables for research, the datasets, measures, and the data sources.

Table 1. Selected variables and measures.

Variable	Dataset	Measures	Sources
TIA	Turnover from innovation activities	Percentage of total turnover	[72]
AI	Artificial intelligence	Percentage of total enterprises	[73]
BD	Big Data	Percentage of total enterprises	[74]
CC	Cloud computing	Percentage of total enterprises	[75]
ISR	Industrial or service robots	Percentage of total enterprises	[76]
IoT	Internet of Things	Percentage of total enterprises	[77]
BPI	Business process innovation	Percentage of total enterprises	[78]
MPGS	New or improved methods for producing goods or providing services	Percentage of total enterprises	[78]
INOL	Innovations in logistics	Percentage of total enterprises	[78]
NBP	New business practices for organizing procedures or external relations	Percentage of total enterprises	[78]
DMHR	New methods of organizing work responsibility, decision making or human resource management	Percentage of total enterprises	[78]
IPC	New or improved methods for information processing or communication	Percentage of total enterprises	[78]
AAO	New methods for accounting or other administrative operations	Percentage of total enterprises	[78]
NMM	New marketing methods for promotion, packaging, pricing, product placement, or after-sales services	Percentage of total enterprises	[78]
EXPIA	Expenditure on innovation activities	Percentage of spending on innovation (excluding R&D)	[79]
ENTIA	Enterprises engaging in innovation activities	Percentage of total enterprises	[80]

Source: developed by the author based on [72–80].

Table 2 shows the descriptive statistics of selected variables.

Table 2. Descriptive statistics.

	N	Minimum	Maximum	Mean	Std. Deviation	Statistic	Kurtosis
TIA	27	3.8	42.4	13.019	7.4551	2.401	8.783
AI	27	0.5	8.8	2.696	2.0259	1.320	1.779
BD	27	2.7	28.7	12.367	7.4369	0.743	−0.655
CC	27	10.9	75.5	38.167	17.4141	0.580	−0.587
ISR	27	1.7	12.8	6.348	2.6523	0.258	−0.081
IoT	27	10.5	50.8	27.904	9.6311	0.734	0.552
BPI	27	5.7	67.5	43.333	14.6021	−0.567	−0.232
MPGS	27	2.9	39.4	22.596	8.7142	0.127	−0.111
INOL	27	2.8	37.7	14.507	7.4059	1.375	2.912
NBP	27	2.2	38.6	17.893	9.6370	0.758	0.199
DMHR	27	3.6	43.9	20.070	9.2456	0.639	0.556
IPC	27	3.6	62.0	25.126	11.7954	1.130	2.655
AAO	27	2.0	57.5	19.859	11.3124	1.665	4.038
NMM	27	3.3	34.8	17.274	7.7203	0.599	0.240
EXPIA	27	6.5	80.6	38.270	20.2318	0.007	−0.770
ENTIA	27	10.7	72.6	51.581	14.9758	−0.813	0.476

Source: authors' design using SPSS v.27.

3.3. Methods

The methods employed in this research to analyze the complex impact of digital technologies on the innovative performance of enterprises in the European Union were artificial neural network analysis (ANN) and cluster analysis.

The analysis of Artificial Neural Networks (ANNs) focused on evaluating the individual influence of digital technologies on innovation revenues and the types of innovation generated by these technologies. ANNs, mathematical models inspired by the functioning

of the human nervous system, are widely used in various fields to analyze and understand complex relationships in data. ANNs can effectively detect hidden patterns and trends in research data, offering significant insights into complex datasets [81]. This method was particularly useful in our study for identifying how each digital technology contributes to the innovative performance of enterprises within the European context. ANNs are powerful tools for pattern recognition, prediction, and classification tasks, making them invaluable in assessing the impact of digitalization on social innovation [82]. ANN enables highlighting the nuances of digital technology's role in driving innovation, revealing specific contributions that might not have been apparent through traditional statistical methods [83].

In the second empirical stage of the research, cluster analysis was employed to test Hypothesis H3. Specifically, the Ward method was utilized to group EU countries into homogeneous clusters based on their levels of digital technology adoption, innovation expenditures, revenues, and the percentage of innovative enterprises. The Ward method is a hierarchical clustering technique that aims to minimize the variance within each cluster, thereby enhancing the homogeneity of the formed groups [84]. This method is particularly effective in providing clear and distinct groupings, essential for accurately interpreting the complex relationships between digitalization and innovation across EU countries [85]. Applying the Ward method in this analysis was instrumental in identifying and clearly defining country groups based on their typical profiles concerning key innovation and digitalization variables [86]. This approach not only allowed us to categorize countries but also to highlight significant differences between clusters. These differences were crucial for a deeper interpretation of the implications for innovative performance in the EU, as they revealed varying levels of digital maturity and innovation potential across member states [87]. The insights from this cluster analysis are valuable for policymakers and businesses, as they underscore the importance of customized strategies in fostering innovation through digital technologies in diverse national contexts.

When applied using IBM SPSS v.27 software, these methods provide a comprehensive understanding of how digital technologies drive innovation across Europe. This dual approach—combining the predictive power of ANNs with the structural clarity offered by cluster analysis—yields a robust framework for analyzing the intersection of digitalization and innovation. The approach underscores the importance of leveraging sophisticated analytical tools in contemporary research to better understand the complex dynamics of innovation in the digital age [88].

4. Results

We used the MLP (multilayer perceptron) method in the artificial neural network analysis. MLP is a feed-forward artificial neural network comprising an input layer, one or more hidden layers, and an output layer [81]. It models complex relationships between variables and can learn and generalize from data. MLP can be configured so that the input layer represents the level of digital technology adoption. The hidden layer is responsible for capturing innovative behavior at the country level. This layer performs intermediate data transformations, capturing complex relationships between inputs and outputs. The activation function used in this layer is the hyperbolic tangent, which returns values in the range $(-1, 1)$, providing symmetric output scaling. The output layer reflects innovation revenues, and the activation function used is also the hyperbolic tangent. Figure 2 depicts the network diagram among variables.

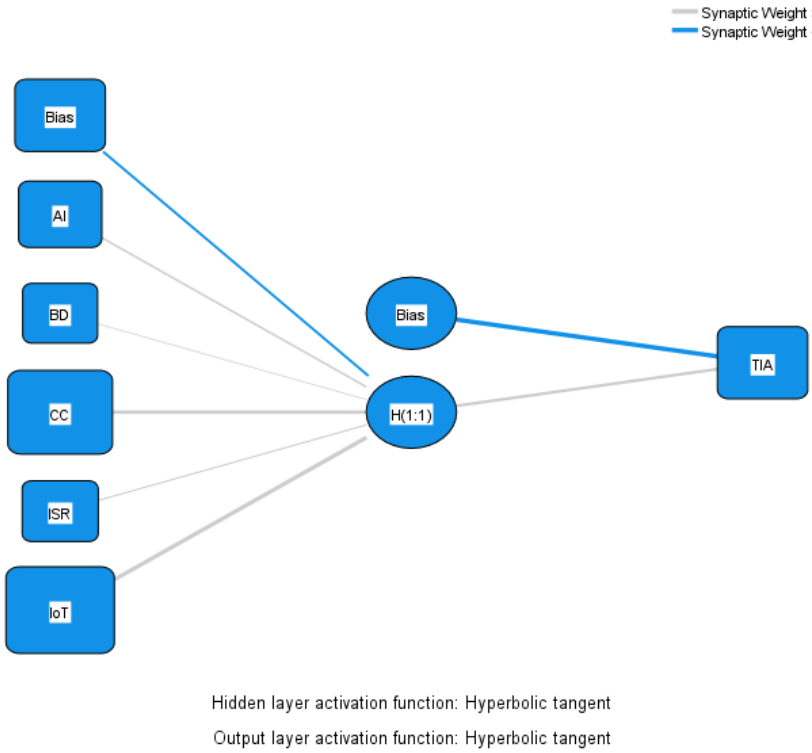

Figure 2. MLP model of the influences of digital technologies on turnover from innovation activities. Source: authors' design using SPSS v.27.

Table 3 encompasses the predictors for the input and hidden layer variables and their relationships.

Table 3. MLP model predictors for turnover from innovation activities.

Predictor		Predicted			
		Hidden Layer 1	Output Layer		
		H (1:1)	TIA	Importance	Normalized Importance
Input Layer	(Bias)	−0.376			
	AI	0.190		0.126	30.0%
	BD	0.046		0.031	7.3%
	CC	0.553		0.379	90.0%
	ISR	0.066		0.043	10.3%
	IoT	0.633		0.421	100.0%
Hidden Layer 1	(Bias)		−0.650		
	H (1:1)		0.408		

Source: authors' design using SPSS v.27.

Table 3 shows that AI has a moderate contribution, with an influence weight of 0.190 and a normalized importance of 30.0%. BD has the smallest contribution, with an influence weight of 0.046 and a normalized significance of 7.3%, suggesting a limited influence on innovation revenues. CC and the IoT have the most significant contributions, with influence weights of 0.553 and 0.633 and normalized importance of 90.0% and 100.0%, respectively, indicating a substantial impact on innovation revenues. ISR has a smaller yet not negligible contribution, with an influence weight of 0.066 and a normalized importance of 10.3%. The MLP model analysis provides valuable insights into the impact of digital technologies on innovation activities (TIAs). The results validate hypothesis H1, indicating that these technologies positively influence TIA, albeit with varying importance. The IoT stands out

as the most influential factor, closely followed by CC. Both technologies show significant and positive predictive coefficients, indicating a substantial contribution to innovation revenue growth. AI ranks third in importance, also demonstrating a positive, though more moderate, impact. ISR and BD, while positively influencing, play a less significant role in the model.

The model includes negative biases in both the input and the first hidden layers. These negative values suggest potential barriers or thresholds that must be overcome before digital technologies can fully exhibit their positive effects on innovation revenues. The MLP model data confirm the decisive role of digital technologies in fostering innovation and generating revenue, particularly highlighting the importance of the IoT and CC in this process. The results indicate the need to overcome specific obstacles to maximize the benefits of these technologies in innovation activities.

Another MLP model was employed to examine the correlation between digital technology adoption in EU member states and various forms of enterprise innovation. The model's architecture begins with an input layer that receives data on the extent of digital technology adoption across European Union countries. This information is processed and transmitted to the network's hidden layer. The hidden layer, representing innovative behavior at the country level, plays a crucial role in data processing and transformation. A hyperbolic tangent activation function activates the variables in this layer. After processing in the hidden layer, the output layer receives the information. This final layer produces the model results, represented in our case by various types of enterprise innovation (BPI, MPGS, INOL, NBP, DMHR, IPC, AAO, and NMM). The output layer uses a sigmoid activation function. The sigmoid function transforms inputs into a range between 0 and 1, allowing the model to capture complex and nonlinear relationships between input and output variables. Figure 3 depicts the network diagram among variables.

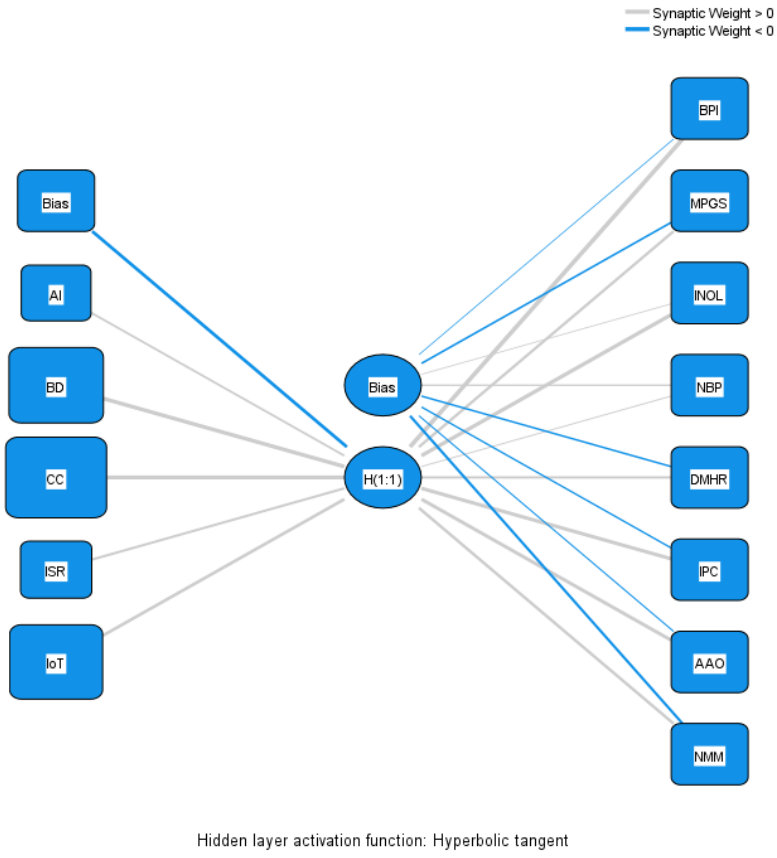

Figure 3. MLP model of the influences of digital technologies on types of innovation. Source: authors' design using SPSS v.27.

Table 4 encompasses the predictors for the input and hidden layer variables and their relationships.

Table 4. MLP model predictors for types of innovation.

Predictor		Predicted									Importance	Normalized Importance
		Hidden Layer 1	Output Layer									
		H (1:1)	BPI	MPGS	INOL	NBP	DMHR	IPC	AAO	NMM		
Input Layer	(Bias)	−1.272										
	AI	0.586									0.102	35.2%
	BD	1.549									0.252	86.5%
	CC	1.882									0.291	100.0%
	ISR	0.621									0.112	38.4%
	IoT	1.263									0.243	83.6%
Hidden Layer 1	(Bias)		−0.001	−0.574	0.034	0.193	−0.553	−0.537	−0.140	−0.624		
	H (1:1)		2.552	1.120	1.493	0.080	0.605	1.441	1.324	1.255		

Source: authors' design using SPSS v.27.

Analyzing the data from Table 4, we conclude that digital technologies positively influence all types of innovation, confirming the validity of Hypothesis H2. In particular, according to their normalized importance, CC, BD, and the IoT have the most significant influence on innovation. These technologies are fundamental for process innovation, communication, and logistics chains, as they have significant weights in hidden and output layers.

Process innovations (BPI), the communication domain (IPC), and logistics (INOL) are strongly influenced by the activation of the hidden layer, indicating that digital technologies play a decisive role in these areas. Process innovations (BPI) have the highest influence weight (2.552), suggesting a significant impact of digital technologies on this type of innovation. Thus, the data support the hypothesis that digital technologies positively and significantly impact various types of innovation, especially in processes, communication, and logistics, confirming that adopting these technologies is crucial for fostering innovation in enterprises.

Hypothesis H3 explores the possibility of grouping EU countries into homogeneous clusters based on adopting digital technologies, innovation expenditures and revenues, and the percentage of enterprises engaged in innovative processes. This clustering approach provides a comprehensive perspective on how European economies adopt and implement emerging technologies and innovations, reflecting innovation capacity and economic structure variations.

We aim to identify common patterns and regional particularities through cluster analysis, contributing to a deeper understanding of the European innovation landscape. The research evaluates the adoption of AI, BD, the IoT, CC, and ISR, correlating these variables with investments in innovation activities and their financial performance. The Ward method enabled the formation of homogeneous clusters using the squared Euclidian distance [84]. Figure 4 illustrates the dendrogram with three homogeneous clusters. These clusters are built using data corresponding to several key variables that capture innovation activities and digital technology adoption across enterprises in the European Union. The variables used to build these clusters include AI, BD, the IoT, CC, ISR, TIA, EXPIA, and ENTIA. The resulting three clusters likely represent different levels of innovation and digital maturity among EU countries. The dendrogram visualization provides a clear hierarchical representation of these relationships, allowing an intuitive understanding of how closely different EU member states are related regarding their innovation and digital technology landscapes.

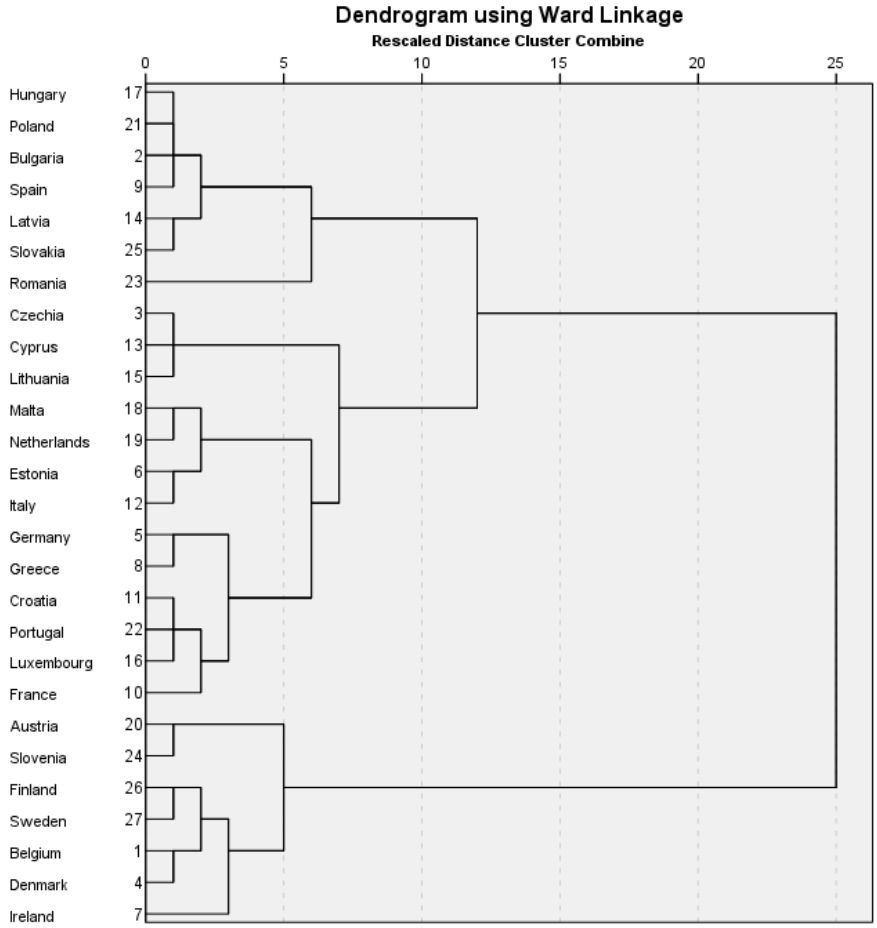

Figure 4. Dendrogram. Source: authors' design using SPSS v.27.

Table 5 presents data for the level of digital technology adoption and innovation, with indicators grouped into the three clusters.

Cluster 1 includes countries, such as Hungary, Poland, Bulgaria, Spain, Latvia, Slovakia, and Romania. These countries have variable innovation expenditures and revenues and different degrees of digital technology adoption. Hungary and Poland exhibit moderate values of EXPIA and similar percentages of ENTIA but differ in AI and IoT adoption. Spain stands out with high TIA values, while Latvia and Slovakia have higher innovation expenditures but different percentages of digital technology adoption.

Cluster 2 comprises countries like the Czech Republic, Cyprus, Lithuania, Malta, the Netherlands, Estonia, Italy, Germany, Greece, Croatia, Portugal, Luxembourg, and France. These countries generally exhibit higher percentages of EXPIA and ENTIA. Cyprus and Estonia have significant expenditures on innovation activities, and Italy and Germany show high percentages of enterprises that innovate. Adopting digital technologies, such as AI, BD, and CC, is more widespread in these countries, reflecting a greater innovation capacity.

Cluster 3 includes countries like Austria, Slovenia, Finland, Sweden, Belgium, Denmark, and Ireland, with the highest innovation revenues and high percentages of enterprises that innovate. Finland and Sweden have the highest percentages of using digital technologies, such as CC and ISR. Denmark and Ireland stand out with a high percentage (over 60%) of enterprises engaged in innovation activities and significant IoT, CC, and AI adoption.

The data from Table 5 confirm the validity of hypothesis H3, indicating that EU countries can be grouped into homogeneous clusters based on digital technologies, innovation expenditures and revenues, and the percentage of enterprises that innovate. Each cluster reflects a different level of digital technology adoption and innovation capacity, highlighting each country's diversity and economic specialization within the European Union.

Table 5. Clusters.

	EXPIA	ENTIA	TIA	AI	BD	CC	ISR	IoT
Hungary	40.4	32.7	7.8	0.7	6.4	25.2	4.3	22.3
Poland	47.4	34.9	7.5	0.7	7.9	24.4	7.1	18.6
Bulgaria	47.9	36.2	7.4	0.9	5.7	10.9	5.5	15.0
Spain	39.6	33.4	21.7	2.3	6.5	26.2	8.8	27.5
Latvia	60.4	32.0	6.3	1.1	7.4	21.3	3.4	28.4
Slovakia	60.8	36.6	14.9	0.9	4.6	25.6	7.4	27.4
Romania	9.1	10.7	5.2	0.5	4.3	15.7	3.6	10.5
Cluster 1 mean	43.66	30.93	10.11	1.01	6.11	21.33	5.73	21.39
Czechia	63.8	56.9	14.4	1.4	9.1	28.9	6.9	31.4
Cyprus	65.0	65.8	13.8	1.4	2.7	34.6	2.7	33.3
Lithuania	80.6	53.0	11.5	1.2	8.7	30.8	4.6	28.4
Malta	39.3	41.1	6.5	4.5	28.7	52.2	6.4	28.0
Netherlands	52.4	55.8	8.9	6.1	25.9	52.6	6.9	20.7
Estonia	58.4	64.2	10.4	1.1	8.0	56.3	3.3	17.4
Italy	39.1	55.7	13.5	1.4	7.4	59.1	8.8	32.3
Germany	39.1	68.8	14.0	2.9	16.6	33.3	5.7	35.6
Greece	51.9	72.6	20.3	1.2	12.2	16.7	2.3	22.8
Croatia	39.3	54.9	13.1	2.5	13.0	39.0	7.4	23.2
Portugal	28.6	51.1	14.5	2.0	10.2	29.0	9.1	23.1
Luxembourg	43.3	45.9	3.8	3.5	16.8	29.1	5.5	22.2
France	10.1	54.8	6.2	2.4	19.5	26.9	8.1	22.0
Cluster 2 mean	46.99	56.97	11.61	2.43	13.75	37.58	5.98	26.18
Austria	16.3	60.0	13.0	3.7	7.0	38.1	5.5	50.8
Slovenia	6.5	55.2	12.3	3.2	5.1	38.6	8.3	49.5
Finland	18.4	68.6	19.3	6.1	19.2	75.5	10.3	40.5
Sweden	13.2	65.2	12.7	4.4	13.0	69.5	5.7	40.3
Belgium	22.4	71.3	15.1	4.4	21.9	53.2	9.3	28.2
Denmark	32.5	57.7	15.0	8.8	23.7	66.9	12.8	20.0
Ireland	7.5	57.6	42.4	3.5	22.4	50.9	1.7	34.0
Cluster 3 mean	16.69	62.23	18.54	4.87	16.04	56.10	7.66	37.61
EU means	38.27	51.58	13.02	2.70	12.37	38.17	6.35	27.90

Source: authors' design using SPSS v.27.

5. Discussion

Companies that successfully leverage the potential of digital transformation will outperform competitors in terms of revenue growth and operational efficiency [1]. These companies will reduce costs through process optimization and explore new revenue streams by developing innovative offerings [89]. Furthermore, they will build closer customer relationships by providing personalized solutions and high-quality services. In an increasingly globalized and interconnected market, the ability to rapidly adapt business strategies to technological changes and innovate will become a crucial factor for long-term success [17].

The social crisis generated by COVID-19 in 2020 profoundly affected innovation in firms and other organizations across all EU countries. The pandemic created unprecedented challenges, disrupting traditional ways of working, accelerating the need for adaptability, and pushing businesses and public institutions to innovate rapidly in response to the crisis. This environment catalyzed social innovation, driving organizations to develop new solutions to address emergent social needs, particularly in healthcare, education, remote work, and social services. Social innovation during this period was characterized by the rapid development and implementation of new practices, processes, and collaborations to mitigate the pandemic's social and economic impacts. Digital technologies were pivotal in enabling and driving these social innovations [67].

This paper aims to investigate the influence of digital technologies on social innovation by examining three main hypotheses. These hypotheses addressed the relationship between

digital technologies and revenues from innovation activities, their impact on various types of innovation, and the possibility of grouping EU countries into homogeneous clusters. The goal was to gain a deeper understanding of the dynamics of innovation in the EU and to identify common patterns and regional specificities to guide future development strategies.

The first Hypothesis (H1) indicates that digital technologies significantly and positively impact the additional performance of companies derived from social innovation activities. This result is supported by recent research highlighting various digitalization practices and their effects on business performance [20,31,44,90]. Thus, our findings support that a holistic digitalization aligned with company strategy and values and involving deep employee engagement in the digital transformation can significantly improve business performance. This behavior enhances operational efficiency and facilitates the development of innovative products and services that better meet market demands and provide long-term competitive advantages.

Digitalization creates value for companies and significantly impacts their overall performance. Recent studies emphasize that adopting digital technologies can improve operational efficiency, reduce costs, and enhance the customer experience, contributing to revenue growth and market position strengthening [31,91]. Our findings highlight the importance of investments in digitalization to increase competitiveness through continuous innovation. Companies that successfully adopt and integrate digital technologies into their strategies and business models can stay ahead of the market and quickly anticipate and respond to changes in the global business environment.

The second Hypothesis (H2) results confirm that digitalization positively impacts companies' innovation capacities, enhancing market competitiveness. Previous studies [21,31,45,92] have demonstrated that adopting digital technologies can stimulate creativity and efficiency in an organization's innovation processes. Digitalization promotes the development of more integrated innovative solutions to the complex demands of the modern market. Our research results underscore the strategic importance of integrating digital technologies across all business aspects, from internal operations to customer interactions and product development.

Digital technologies significantly accelerated the product development cycle, enabling companies to bring innovations to market faster. Digital technologies, such as AI, BD, CC, the IoT, and ISR, catalyzed innovation across multiple organizational domains. These technologies are not merely tools but transformative forces that reshape how businesses conceive, develop, and implement innovations. Implementing digital technologies not only speeds up the launch of new products but also improves their quality and relevance, providing a significant competitive advantage for companies that adopt these technologies [22].

AI profoundly impacted business process innovation by enabling companies to automate complex tasks, make data-driven decisions, and personalize customer experiences at scale. This technology influenced the development of new methods for producing goods and providing services by optimizing production lines, predicting maintenance needs, and enhancing quality control processes. In logistics, AI and the IoT worked to create smart supply chains, improving tracking, reducing waste, and enhancing overall efficiency [60].

BD was crucial in shaping new business practices for organizing procedures and external relations. BD allowed companies to make informed strategic decisions and tailor their offerings to meet evolving market demands. This technology also influenced new methods of organizing work responsibilities and decision-making by providing managers with real-time data and predictive analytics to guide their choices [32].

CC revolutionized how businesses approach information processing and communication. It has enabled new or improved methods for collaborative work, data storage, and information sharing, breaking down silos within organizations and facilitating seamless communication with external partners. This technology also paved the way for new methods in accounting and administrative operations, allowing for real-time financial reporting, improved compliance, and more efficient resource allocation [56].

The IoT has been instrumental in driving innovations across various domains. In marketing, IoT devices provide valuable data for creating new promotion methods, product placement, and after-sales services [54]. They enable businesses to track product usage, gather real-time customer feedback, and offer personalized marketing experiences [53,55].

ISR has significantly impacted the development of new or improved methods for producing goods and providing services [66]. They have enabled businesses to achieve higher precision, consistency, and productivity levels in manufacturing. In the service sector, robots are transforming customer interactions, from automated checkout systems to AI-powered customer service bots.

These digital technologies do not operate in isolation but often work synergistically to drive innovation. Combining IoT sensors, BD, and AI can lead to predictive maintenance systems in manufacturing, representing a new approach to production methods and logistics management. Similarly, integrating CC with AI and BD enables new forms of collaborative innovation, allowing businesses to tap into collective intelligence and co-create solutions with customers and partners [48–51].

The research of Hypothesis H3 confirms that EU countries can be grouped into homogeneous clusters based on digital technologies, innovation expenditures and revenues, and the percentage of innovative enterprises. Each cluster reflects a different level of digital technology adoption and innovation capacity, highlighting economic diversity within the EU. Cluster 1 includes countries like Hungary, Poland, Bulgaria, Spain, Latvia, Slovakia, and Romania, with variable innovation expenditures, revenues, and lower-than-average EU digital technology adoption. Cluster 2 comprises countries like the Czech Republic, Cyprus, Lithuania, Malta, the Netherlands, Estonia, Italy, Germany, Greece, Croatia, Portugal, Luxembourg, and France, where the adoption of digital technologies, such as AI, BD, and CC, is more widespread, reflecting a higher innovation capacity. Cluster 3 includes countries like Austria, Slovenia, Finland, Sweden, Belgium, Denmark, and Ireland, with the highest innovation revenues and high percentages of innovative enterprises.

Digital technologies enhance existing business strategies and redefine the fundamentals of competition in the digital era. Companies that efficiently integrate AI, BD, the IoT, CC, and ISR into their strategies will be better positioned to create sustainable competitive advantages through operational excellence and reduced costs or unique and personalized product and service offerings [57]. The distinction between cost and differentiation strategies may become less evident in the future as companies use these technologies to excel in both areas simultaneously.

Success in the digital era depends on more than merely adopting technologies; it requires fundamentally transforming how organizations operate, innovate, and create value. Companies that develop adequate levels of digital readiness and organizational capacity view challenges as opportunities and deeply integrate digital technologies into their business processes, defining the future competitive landscape [93]. This transformation is not just about technology but also about a mindset shift and a culture of continuous innovation that allows organizations to remain agile and relevant in a rapidly changing business environment [94]. The importance of these digital technology-based innovations extends beyond the immediate benefits for companies and consumers. They play a decisive role in addressing global challenges. Moreover, these digital technology-based innovations create a network effect, where progress in one area catalyzes innovations in others [28].

Innovations in goods and services, processes, and organizational practices facilitated by digital technologies are the driving force of the digital economy and the catalyst for profound social and economic transformation [28]. They continuously redefine the possible limits, creating new industries, reshaping existing ones, and providing innovative solutions to global challenges. In this context, adaptability and the ability to embrace and implement these innovations become critical factors for success and sustainability in the digital era [95–97]. Optimizing resources through digitalization allows companies to use materials and energy more efficiently, reducing waste and operational costs [31]. Digitalization transforms how companies operate and profoundly influences our lives [98,99].

5.1. Theoretical Implications

Our investigation substantially advances the comprehension of digital transformation's impact on innovative practices and competitive positioning within the European Union's economic landscape. The findings demonstrate that adopting digital technologies, when aligned with organizational strategy and values, can improve operational efficiency and increase revenue, thus supporting the development of innovative products and services. Furthermore, digital transformation stimulates creativity and efficiency in social innovation processes, strengthening companies' competitiveness. The research provides a detailed perspective on regional economic diversity and specialization by grouping EU countries into homogeneous clusters. This approach helps to understand the dynamics of regional innovation better and can guide the development of policies and strategies tailored to the specificities of each cluster. Our study emphasizes the importance of integrating digital technologies into business strategies to maximize the social innovation process.

5.2. Practical and Managerial Implications

Integrating digital technologies into business strategies is critical for companies that seek to remain competitive and drive revenue growth. The strategic adoption of these technologies allows businesses to optimize processes, reduce costs, and create new revenue streams through innovative products and services. Managers play a crucial role in this digital transformation and should approach it holistically, ensuring that the digitalization efforts align with the company's core values and overarching strategy. It is equally important to actively involve employees in the transformation process, as their engagement and adaptability are essential to successfully implementing new technologies.

To strengthen customer relationships, companies must focus on delivering personalized solutions and maintaining high service quality standards. In today's globalized and interconnected marketplace, the ability to swiftly adapt business strategies in response to technological advancements and evolving market demands is essential for long-term success. Investments in digital technologies enhance operational efficiency and foster a culture of creativity and innovation, which is vital for the ongoing development of competitive products and services.

At an industrial level, digital technologies facilitate greater integration among various actors within the value chain. This integration supports the emergence of hybrid and innovative business models, which can redefine traditional industry structures. Managers must be prepared for this fundamental shift in how organizations operate and innovate, cultivating a culture of continuous innovation to ensure their companies remain relevant and competitive in a rapidly evolving business landscape. Furthermore, by strategically leveraging digital technologies, managers can create sustainable competitive advantages, shaping the future competitive environment. Managers should focus on developing actionable strategies that prioritize the continuous upskilling of employees to handle new technologies, foster partnerships with tech providers to stay at the forefront of innovation, and actively monitor emerging digital trends to swiftly incorporate relevant advancements, such as quantum computing or AI-driven analytics, into their operations.

5.3. Limitations and Future Research

While this study offers valuable insights into the relationship between digital technologies and innovation within the EU, it is essential to acknowledge certain limitations that present future research opportunities. The cross-sectional nature of the data employed in this study restricts our ability to draw definitive causal conclusions about the impact of digital technology adoption on innovation outcomes. Future research could address this by utilizing longitudinal data, which would allow for an examination of the long-term effects of digitalization on innovation and overall company performance.

Moreover, the study's focus on EU countries may limit the applicability of the findings to other economic and geographical contexts. Expanding future analyses to include a more diverse range of countries, particularly those with varying financial and digital develop-

ment levels, could offer broader perspectives. Moreover, this study did not consider specific contextual factors, such as government policies, organizational culture, or industry-specific characteristics, which could potentially influence the relationship between digitalization and innovation. Investigating how these factors interact with digital technology adoption in future research could yield a more comprehensive understanding of the dynamics at play.

Another area for further exploration is the influence of specific digital technologies, such as artificial intelligence, blockchain, quantum computing, or augmented reality, on different types of innovation. While this study considered various forms of innovation, it did not delve deeply into how particular technologies drive each type. This line of research could provide more nuanced guidance for practitioners and policymakers, especially in understanding emerging technologies' distinct roles in fostering innovation.

Finally, this study predominantly relied on quantitative data. Future research could adopt a mixed-methods approach, incorporating qualitative methods to explore how digitalization influences organizational innovation processes. Furthermore, as new technologies like quantum computing emerge, it would be valuable to investigate their potential impact on innovation and the ethical implications of AI in innovation processes. Such explorations could significantly enhance the relevance and depth of future research in this field.

6. Conclusions

In an era where digitalization is becoming increasingly integral to business operations, the ability to seamlessly integrate digital technologies into innovation management is emerging as a critical competitive advantage. These technologies do more than provide access to vast sources of information and knowledge; they enable real-time collaboration across global teams, fundamentally reshaping how innovation is perceived and managed within contemporary organizations. Digitalization is a supportive tool and a transformative force that redefines the innovation landscape.

This paper has underscored the pivotal role that digital technologies play in driving innovation within the European Union. The findings confirmed that adopting digital technologies enhances companies' performance, particularly in revenue generation from innovation activities. This fact highlighted the necessity for a holistic approach to digitalization that is closely aligned with the company's overarching strategy and actively engages employees throughout the transformation process. The research further demonstrated that digitalization enhances companies' innovative capabilities, enabling them to develop more competitive products and services while optimizing internal processes.

The study's analysis revealed that EU countries can be categorized into distinct clusters based on their levels of digital technology adoption, innovation expenditures, revenues, and the proportion of innovative enterprises. This cluster analysis provided valuable insights for policymakers, allowing for the development of tailored strategies that address the specific needs of each group of countries. The study's findings emphasized that success in the digital era requires more than just adopting advanced technologies; it demanded a fundamental transformation in organizational operations, innovation processes, and value-creation strategies.

The implications for the European Union's innovation landscape are profound. Companies that effectively integrate digital technologies, such as AI, Big Data, the IoT, cloud computing, and information systems resources, into their strategies are better positioned to secure sustainable competitive advantages. As the lines between different economic sectors continue to blur, the capacity to adopt and implement digital technology-driven innovations will increasingly determine long-term competitiveness and sustainability. This digital transformation signifies a technological shift and a revolution in how the modern economy approaches innovation and value creation, with far-reaching consequences for the EU's future in the global market.

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References

1. Parida, V.; Sjödin, D.; Reim, W. Reviewing Literature on Digitalization, Business Model Innovation, and Sustainable Industry: Past Achievements and Future Promises. *Sustainability* **2019**, *11*, 391. [CrossRef]
2. Cenamor, J.; Sjodin, D.R.; Parida, V. Adopting a platform approach in servitization: Leveraging the value of digitalization. *Int. J. Prod. Econ.* **2017**, *192*, 54–65. [CrossRef]
3. Sjodin, D.R.; Parida, V.; Leksell, M.; Petrovic, A. Smart Factory Implementation and Process Innovation: A Preliminary Maturity Model for Leveraging Digitalization in Manufacturing. Moving to smart factories presents specific challenges that can be addressed through a structured approach focused on people, processes, and technologies. *Res. Technol. Manag.* **2018**, *61*, 22–31. [CrossRef]
4. Urbinati, A.; Chiaroni, D.; Chiesa, V.; Frattini, F. The role of digital technologies in open innovation processes: An exploratory multiple case study analysis. *RD Manag.* **2020**, *50*, 136–160. [CrossRef]
5. Mulgan, G. The Process of Social Innovation. *Innov. Technol. Gov. Glob.* **2006**, *1*, 145–162. [CrossRef]
6. Bianchi, M.; Croce, A.; Dell'era, C.; Di Benedetto, C.A.; Frattini, F. Organizing for inbound open innovation: How external consultants and a dedicated R&D unit influence product innovation performance. *J. Prod. Innov. Manag.* **2016**, *33*, 492–510. [CrossRef]
7. Sikimic, U.; Chiesa, V.; Frattini, F.; Scalera, V.G. Investigating the influence of technology inflows on technology outflows in open innovation processes: A longitudinal analysis. *J. Prod. Innov. Manag.* **2016**, *33*, 652–669. [CrossRef]
8. Fan, X.; Wang, Y.; Lu, X. Digital Transformation Drives Sustainable Innovation Capability Improvement in Manufacturing Enterprises: Based on FsQCA and NCA Approaches. *Sustainability* **2023**, *15*, 542. [CrossRef]
9. Westerman, G.; Bonnet, D.; McAfee, A. *Leading Digital: Turning Technology into Business Transformation*; Harvard Business Review Press: Boston, MA, USA, 2014.
10. Porter, M.E. *Competitive Advantage: Creating and Sustaining Superior Performance*; Free Press: New York, NY, USA, 1985.
11. Ponsignon, F.; Kleinhans, S.; Bressolles, G. The contribution of quality management to an organisation's digital transformation: A qualitative study. *Total Qual. Manag. Bus. Excel* **2019**, *30*, S17–S34. [CrossRef]
12. Zaki, M. Digital transformation: Harnessing digital technologies for the next generation of services. *J. Serv. Mark.* **2019**, *33*, 429–435. [CrossRef]
13. Porter, M.E.; Heppelmann, J.E. How smart, connected products are transforming companies. *Harv. Bus. Rev.* **2015**, *93*, 96–114.
14. Iansiti, M.; Lakhani, K. Digital ubiquity: How connections, sensors, and data are revolutionizing business. *Harv. Bus. Rev.* **2014**, *92*, 90–99.
15. Lenka, S.; Parida, V.; Wincent, J. Digitalization capabilities as enablers of value co-creation in servitizing firms. *Psychol. Mark.* **2017**, *34*, 92–100. [CrossRef]
16. Grubic, T.; Jennions, I. Remote monitoring technology and servitised strategies-factors characterising the organisational application. *Int. J. Prod. Res.* **2017**, *56*, 2133–2149. [CrossRef]
17. Visnjic, I.; Neely, A.; Jovanovic, M. The path to outcome delivery: Interplay of service market strategy and open business models. *Technovation* **2018**, *72–73*, 46–59. [CrossRef]

18. Luz Martín-Peña, M.; Díaz-Garrido, E.; Sánchez-López, J.M. The digitalization and servitization of manufacturing: A review on digital business models. *Strateg. Chang.* **2018**, *27*, 91–99. [CrossRef]
19. Laudien, S.M.; Daxböck, B. The influence of the industrial Internet of things on business model design: A qualitative-empirical analysis. *Int. J. Innov. Manag.* **2016**, *20*, 1640014. [CrossRef]
20. Bouwman, H.; Nikou, S.; Molina-Castillo, F.J.; de Reuver, M. The impact of digitalization on business models. *Dig. Policy Regul. Gov.* **2018**, *20*, 105–124. [CrossRef]
21. Rachinger, M.; Rauter, R.; Müller, C.; Vorraber, W.; Schirgi, E. Digitalization and its influence on business model innovation. *J. Manuf. Technol. Manag.* **2018**, *30*, 1143–1160. [CrossRef]
22. Kroll, H.; Horvat, D.; Jäger, A. *Effects of Automatisation and Digitalisation on Manufacturing Companies' Production Efficiency and Innovation Performance*; Fraunhofer ISI: Karlsruhe, Germany, 2018. Available online: https://publica-rest.fraunhofer.de/server/api/core/bitstreams/30e793ad-693a-4fba-891b-491fa1337131/content (accessed on 18 June 2024).
23. Schumpeter, J.A. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*; Harvard University Press: Cambridge, MA, USA, 1934.
24. Drucker, P.F. *Innovation and Entrepreneurship: Practice and Principles*; Harper & Row: New York, NY, USA, 1985.
25. Bessant, J.R.; Tidd, J. *Managing Innovation: Integrating Technological, Market and Organizational Change*; Wiley: Hoboken, NJ, USA, 2020.
26. Ferreira, J.J.; Fernandes, C.I.; Ferreira, F.A. To be or not to be digital that is the question: Firm innovation and performance. *J. Bus. Res.* **2018**, *101*, 583–590. [CrossRef]
27. Zhang, Z.; Jin, J.; Li, S.; Zhang, Y. Digital transformation of incumbent firms from the perspective of portfolios of innovation. *Technol. Soc.* **2023**, *72*, 102149. [CrossRef]
28. Yaqub, M.Z.; Alsabban, A. Industry-4.0-Enabled Digital Transformation: Prospects, Instruments, Challenges, and Implications for Business Strategies. *Sustainability* **2023**, *15*, 8553. [CrossRef]
29. Hughes, L.; Dwivedi, Y.K.; Rana, N.P.; Williams, M.D.; Raghavan, V. Perspectives on the future of manufacturing within the Industry 4.0 era. *Prod. Plan. Control* **2022**, *33*, 138–158. [CrossRef]
30. Schumpeter, J.A. Entrepreneurship as Innovation. Champaign: University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship. 2000. Available online: https://ssrn.com/abstract=1512266 (accessed on 18 June 2024).
31. Sánchez Ramírez, S.; Guadamillas Gómez, F.; González Ramos, M.I.; Grieva, O. The Effect of Digitalization on Innovation Capabilities through the Lenses of the Knowledge Management Strategy. *Adm. Sci.* **2022**, *12*, 144. [CrossRef]
32. Di Vaio, A.; Palladino, R.; Pezzi, A.; Kalisz, D.E. The role of digital innovation in knowledge management systems: A systematic literature review. *J. Bus. Res.* **2021**, *123*, 220–231. [CrossRef]
33. Eisenhardt, K.M.; Martin, J.A. Dynamic capabilities: What are they? *Strateg. Manag. J.* **2000**, *21*, 1105–1121. [CrossRef]
34. Lynn, T.; Rosati, P.; Conway, E.; Curran, D.; Fox, G.; O'Gorman, C. (Eds.) The digital economy and digital business. In *Digital Towns*; Palgrave Macmillan: Cham, Switzerland, 2022; pp. 69–89. [CrossRef]
35. Soni, G.; Kumar, S.; Mahto, R.V.; Mangla, S.K.; Mittal, M.L.; Lim, W.M. A decision-making framework for Industry 4.0 technology implementation: The case of FinTech and sustainable supply chain finance for SMEs. *Technol. Forecast. Soc. Chang.* **2022**, *180*, 121686. [CrossRef]
36. Shi, Y.; Zheng, X.; Venkatesh, V.G.; Humdan, E.A.; Paul, S.K. The impact of digitalization on supply chain resilience: An empirical study of the Chinese manufacturing industry. *J. Bus. Ind. Mark.* **2023**, *38*, 1–11. [CrossRef]
37. Ben Arfi, W.; Hikkerova, L. Corporate entrepreneurship, product innovation, and knowledge conversion: The role of digital platforms. *Small Bus Econ.* **2021**, *56*, 1191–1204. [CrossRef]
38. Saunila, M. Innovation capability in SMEs: A systematic review of the literature. *J. Innov. Knowl.* **2020**, *5*, 260–265. [CrossRef]
39. Burmeister, C.; Luttgens, D.; Piller, F.T. Business model innovation for industry 4.0: Why the 'industrial internet' mandates a new perspective on innovation. *Die Unternehm.* **2016**, *72*, 124–152. [CrossRef]
40. Gajdzik, B.; Wolniak, R. Influence of industry 4.0 projects on business operations: Literature and empirical pilot studies based on case studies in Poland. *J. Open Innov. Technol. Mark. Complex.* **2022**, *8*, 44. [CrossRef]
41. Kelly, G. *Management Theory and Practice*, 9th ed.; CENGAGE: Singapore, 2020.
42. Bresciani, S.; Ciampi, F.; Meli, F.; Ferraris, A. Using big data for co-innovation processes: Mapping the field of data-driven innovation, proposing theoretical developments and providing a research agenda. *Int. J. Inf. Manag.* **2021**, *60*, 102347. [CrossRef]
43. Hinings, B.; Gegenhuber, T.; Greenwood, R. Digital innovation and transformation: An institutional perspective. *Inf. Organ.* **2018**, *28*, 52–61. [CrossRef]
44. Isaksson, A.J.; Harjunkoski, I.; Sand, G. The impact of digitalization on the future of control and operations. *Comput. Chem. Eng.* **2018**, *114*, 122–129. [CrossRef]
45. Akter, S.; Fosso Wamba, S.; Gunasekaran, A.; Dubey, R.; Childe, S.J. How to improve firm performance using big data analytics capability and business strategy alignment? *Int. J. Prod. Econ.* **2016**, *182*, 113–131. [CrossRef]
46. Annarelli, A.; Battistella, C.; Nonino, F.; Parida, V.; Pessot, E. Literature review on digitalization capabilities: Co-citation analysis of antecedents, conceptualization and consequences. *Technol. Forecast. Soc. Chang.* **2021**, *166*, 120635. [CrossRef]
47. Gunasilan, U. Entrepreneurship as a Driver of the Digital Transformation. *Int. Rev. Manag. Mark.* **2019**, *9*, 23–29. [CrossRef]

48. Santos-Pereira, C.; Durão, N.; Moreira, F.; Veloso, B. The importance of digital transformation in international business. *Sustainability* **2022**, *14*, 834. [CrossRef]
49. Feliciano-Cestero, M.M.; Ameen, N.; Kotabe, M.; Paul, J.; Signoret, M. Is digital transformation threatened? A systematic literature review of the factors influencing firms' digital transformation and internationalization. *J. Bus. Res.* **2023**, *157*, 113546. [CrossRef]
50. Gazová, A.; Papulová, Z.; Smolka, D. Effect of Business Process Management on Level of Automation and Technologies Connected to Industry 4.G. *Procedia Comput. Sci.* **2022**, *200*, 1498–1507. [CrossRef]
51. Gil-Gomez, H.; Guerola-Navarro, V.; Oltra-Badenes, R.; Lozano-Quilis, J.A. Customer relationship management: Digital transformation and sustainable business model innovation. *Econ. Res.-Ekon. Istraživanja* **2020**, *33*, 2733–2750. [CrossRef]
52. Gaviria-Marin, M.; Merigó, J.M.; Baier-Fuentes, H. Knowledge management: A global examination based on bibliometric analysis. *Technol. Forecast. Soc. Chang.* **2019**, *140*, 194–220. [CrossRef]
53. Leiting, A.K.; De Cuyper, L.; Kauffmann, C. The Internet of Things and the case of Bosch: Changing business models while staying true to yourself. *Technovation* **2022**, *118*, 102497. [CrossRef]
54. Ardito, L.; D'Adda, D.; Messeni Petruzzelli, A. Mapping innovation dynamics in the Internet of Things domain: A patent analysis. *Technol. Forecast. Soc. Chang.* **2017**, *136*, 317–330. [CrossRef]
55. Caputo, A.; Marzi, G.; Pellegrini, M.M. The internet of things in manufacturing innovation processes: Development and application of a conceptual framework. *Bus. Process Manag. J.* **2016**, *22*, 383–402. [CrossRef]
56. Fisher, O.; Watson, N.; Porcu, L.; Bacon, D.; Rigley, M.; Gomes, R.L. Cloud manufacturing as a sustainable process manufacturing route. *J. Manuf. Syst.* **2018**, *47*, 53–68. [CrossRef]
57. Obermayer, N.; Csizmadia, T.; Hargitai, D.M. Influence of Industry 4.0 technologies on corporate operation and performance management from human aspects. *Meditari Account. Res.* **2022**, *30*, 1027–1049. [CrossRef]
58. Lian, J.W.; Yen, D.C.; Wang, Y.T. An exploratory study to understand the critical factors affecting the decision to adopt cloud computing in Taiwan hospital. *Int. J. Inf. Manag.* **2014**, *34*, 28–36. [CrossRef]
59. Chowdhury, S.; Budhwar, P.; Dey, P.K.; Joel-Edgar, S.; Abadie, A. AI-employee collaboration and business performance: Integrating knowledge-based view, socio-technical systems and organisational socialisation framework. *J. Bus. Res.* **2022**, *144*, 31–49. [CrossRef]
60. Zhou, X.; Yang, Z.; Hyman, M.R.; Li, G.; Munim, Z.H. Guest editorial: Impact of artificial intelligence on business strategy in emerging markets: A conceptual framework and future research directions. *Int. J. Emerg. Mark.* **2022**, *17*, 917–929. [CrossRef]
61. Ritter, T.; Lettl, C. The wider implications of business-model research. *Long Range Plan.* **2018**, *51*, 1–8. [CrossRef]
62. Dai, B.; Liang, W. The Impact of Big Data Technical Skills on Novel Business Model Innovation Based on the Role of Resource Integration and Environmental Uncertainty. *Sustainability* **2022**, *14*, 2670. [CrossRef]
63. O'Donovan, P.; Leahy, K.; Bruton, K.; O'Sullivan, D.T. Big data in manufacturing: A systematic mapping study. *J. Big Data* **2015**, *2*, 20. [CrossRef]
64. Hilbert, M. Big Data for development: A review of promises and challenges. *Dev. Policy Rev.* **2016**, *34*, 135–174. [CrossRef]
65. Mourtzis, D.; Angelopoulos, J.; Panopoulos, N.A. Literature Review of the Challenges and Opportunities of the Transition from Industry 4.0 to Society 5.0. *Energies* **2022**, *15*, 6276. [CrossRef]
66. Duong Linh, N.K.; Al-Fadhli, M.; Jagtap, S.; Bader, F.; Martindale, W.; Swainson, M.; Paoli, A.; Andrea, P. A review of robotics and autonomous systems in the food industry: From the supply chains perspective. *Trends Food Sci. Technol.* **2020**, *106*, 355–364. [CrossRef]
67. Santos-Pereira, C.; Veloso, B.; Durào, N.; Moreira, F. The influence of technological innovations on international business strategy before and during COVID-19 pandemic. *Procedia Comput. Sci.* **2022**, *196*, 44–51. [CrossRef]
68. Capello, R.; Lenzi, C. Territorial patterns of innovation and economic growth in European regions. *Growth Chang.* **2013**, *44*, 195–227. [CrossRef]
69. Szopik-Depczyńska, K.; Kędzierska-Szczepaniak, A.; Szczepaniak, K.; Cheba, K.; Gajda, W.; Ioppolo, G. Innovation in sustainable development: An investigation of the EU context using 2030 agenda indicators. *Land Use Policy* **2018**, *79*, 251–262. [CrossRef]
70. Żelazny, R.; Pietrucha, J. Measuring innovation and institution: The creative economy index. *Equilibrium* **2017**, *12*, 43–62. [CrossRef]
71. Hollanders, H.; Es-Sadki, N. *European Innovation Scoreboard 2017*; Publications Office of the European Union: Luxembourg, 2017; Available online: https://op.europa.eu/en/publication-detail/-/publication/5b916ff4-523d-11e7-a5ca-01aa75ed71a1 (accessed on 18 June 2024).
72. Eurostat. Turnover of Enterprises from New or Significantly Improved Products, by NACE Rev. 2 Activity and Size Class (2020). Available online: https://ec.europa.eu/eurostat/databrowser/view/inn_cis12_prodt__custom_10195915/default/table?lang=en (accessed on 25 June 2024).
73. Eurostat. Artificial Intelligence by Size Class of Enterprise. Available online: https://ec.europa.eu/eurostat/databrowser/view/isoc_eb_ai__custom_11964281/default/table?lang=en (accessed on 25 June 2024).
74. Eurostat. Big Data Analysis by Size Class of Enterprise. Available online: https://ec.europa.eu/eurostat/databrowser/view/isoc_eb_bd__custom_11349669/default/table?lang=en (accessed on 25 June 2024).
75. Eurostat. Cloud Computing Services by Size Class of Enterprise. Available online: https://ec.europa.eu/eurostat/databrowser/view/isoc_cicce_use__custom_11349708/default/table?lang=en (accessed on 25 June 2024).

76. Eurostat. 3D Printing and Robotics by Size Class of Enterprise. Available online: https://ec.europa.eu/eurostat/databrowser/view/isoc_eb_p3d__custom_11350117/default/table?lang=en (accessed on 25 June 2024).
77. Eurostat. Internet of Things by Size Class of Enterprise. Available online: https://ec.europa.eu/eurostat/databrowser/view/isoc_eb_iot__custom_11349731/default/table?lang=en (accessed on 25 June 2024).
78. Eurostat. Enterprises That Introduced New or Improved Processes by Type of Innovation, NACE Rev. 2 Activity and Size Class (2020). Available online: https://ec.europa.eu/eurostat/databrowser/view/inn_cis12_spec__custom_10195863/default/table?lang=en (accessed on 25 June 2024).
79. Eurostat. Enterprises and Expenditure of Enterprises on Innovation Activities by Area of Expenditure, NACE Rev. 2 Activity and Size Class (2020). Available online: https://ec.europa.eu/eurostat/databrowser/view/inn_cis12_exp__custom_10195969/default/table?lang=en (accessed on 25 June 2024).
80. Eurostat. Enterprises with Innovation Activities during 2018 and 2020 by NACE Rev. 2 Activity and Size Class (2020). Available online: https://ec.europa.eu/eurostat/databrowser/view/inn_cis12_inact__custom_11963520/default/table?lang=en (accessed on 25 June 2024).
81. I.B.M. SPSS—Neural Networks. 2012. Available online: https://www.ibm.com/downloads/cas/N7LLA2LB (accessed on 30 June 2024).
82. Aggarwal, C. *Neural Networks and Deep Learning: A Textbook*; Springer: Cham, Switzerland, 2018.
83. Russell, S.; Norvig, P. *Artificial Intelligence: A Modern Approach*, 3rd ed.; Pearson Educational: Upper Saddle River, NJ, USA, 2010.
84. Hu, Y.; Li, K.; Meng, A. Agglomerative Hierarchical Clustering Using Ward Linkage. Available online: https://jbhender.github.io/Stats506/F18/GP/Group10.html (accessed on 1 July 2024).
85. Attalah, M.; Blanton, M. (Eds.) *Algorithms and Theory of Computation Handbook*, 2nd ed.; Taylor and Francis, CRC Press: Boca Raton, FL, USA, 2010.
86. Penn State, Eberly College of Science. Agglomerative Hierarchical Clustering. Available online: https://online.stat.psu.edu/stat505/lesson/14/14.4 (accessed on 30 June 2024).
87. Ketchen, D.J.; Shook, C.L. The application of cluster analysis in strategic management research: An analysis and critique. *Strateg. Manag. J.* **1996**, *17*, 441–458. [CrossRef]
88. Bishop, C.M. *Pattern Recognition and Machine Learning*; Springer Science+Business Media, LLC: Singapore, 2006.
89. Foss, N.J.; Saebi, T. Fifteen years of research on business model innovation: How far have we come, and where should we go? *J. Manag.* **2017**, *43*, 200–227. [CrossRef]
90. Horvath, K.; Szerb, L. Managerial practices and the productivity of knowledge-intensive service businesses: An analysis of digital/IT and cash management practices. *Strateg. Chang.* **2018**, *27*, 161–172. [CrossRef]
91. Ribeiro-Navarrete, S.; Botella-Carrubi, D.; Palacios-Marqués, D.; Orero-Blat, M. The effect of digitalization on business performance: An applied study of KIBS. *J. Bus. Res.* **2021**, *126*, 319–326. [CrossRef]
92. Wamba, S.F.; Akter, S.; Edwards, A.; Chopin, G.; Gnanzou, D. How 'big data' can make big impact: Findings from a systematic review and a longitudinal case study. *Int. J. Prod. Econ.* **2015**, *165*, 234–246. [CrossRef]
93. Marcon, É.; Le Dain, M.A.; Frank, A.G. Designing business models for Industry 4.0 technologies provision: Changes in business dimensions through digital transformation. *Technol. Forecast. Soc. Chang.* **2022**, *185*, 122078. [CrossRef]
94. Martinez, F. Process excellence the key for digitalisation. *Bus. Process Manag. J.* **2019**, *25*, 1716–1733. [CrossRef]
95. Verhoef, P.; Broekhuizen, T.; Bart, Y.; Bhattacharya, A.; Qi, D.J.; Fabian, N.; Haenlein, M. Digital transformation: A multidisciplinary reflection and research agenda. *J. Bus. Res.* **2021**, *122*, 889–901. [CrossRef]
96. Binsaeed, R.H.; Grigorescu, A.; Yousaf, Z.; Radu, F.; Nassani, A.A.; Tabirca, A.I. Harnessing Big Data Analytics to Accelerate Innovation: An Empirical Study on Sport-Based Entrepreneurs. *Sustainability* **2023**, *15*, 10090. [CrossRef]
97. Tiron-Tudor, A.; Kolisnyk, M.; Savrina, B. Digital sustainable development as an emerging concept. *Manag. Chall. Contemp. Soc. Proc.* **2024**, *14*, 1–6.
98. Gbadegeshin, S.A. The effect of digitalization on the commercialization process of high-technology companies in the life sciences industry. *Technol. Innov. Manag. Rev.* **2019**, *9*, 49–63. [CrossRef]
99. Criveanu, M.M. Investigating Digital Intensity and E-Commerce as Drivers for Sustainability and Economic Growth in the EU Countries. *Electronics* **2023**, *12*, 2318. [CrossRef]