LUISS

Degree Program in Strategic Management

Course of Industry Dynamics

Industry 4.0 and the digitalization level of enterprises in Italy and Europe

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Introduction

The Fourth Industrial Revolution, characterized by the advent of Industry 4.0, is revolutionizing the global manufacturing landscape. Technologies such as artificial intelligence, the Internet of Things (IoT), robotics, and 3D printing converge to create intelligent and interconnected manufacturing systems, opening new frontiers for efficiency, flexibility, and product customization.

Chapter 1: *The Impact of Industry 4.0 on Industrial Sectors* will explore the impact of Industry 4.0 and new technologies, and Artificial Intelligence in particular, on significant manufacturing sectors, analyzing the transformations taking place. It will examine how Industry 4.0 is changing traditional business models, creating new production chains, and redefining the role of human labor within industrial processes. This chapter will especially delve into the applications of AI in industrial sectors, examining how machine learning, computer vision, and predictive analytics are helping to improve the efficiency, quality, and safety of production processes.

Chapter 2: *The Digitalization Level of Enterprises in Italy* focuses on the Italian context, where challenges and opportunities exist in adopting Industry 4.0 technologies. This chapter will analyze the level of digitization of Italian companies, comparing it with the European average. The factors hindering or favoring the adoption of Industry 4.0 in our country will be examined, and strategies to accelerate the digital transformation process will be proposed.

Chapter 3, *Comparison with Europe: Digitization and Industry 4.0 in Germany, France, and Spain,* will compare Italy's position in the European Industry 4.0 landscape with three important European nations: Germany, France, and Spain. The levels of digitization, government policies supporting Industry 4.0, and success stories of companies that have successfully implemented new technologies will be analyzed.

The thesis shows that the main purpose is to analyze the level of digitization of businesses in Italy and Europe, specifically focusing on how Industry 4.0, through technologies such as Artificial Intelligence, IoT and cloud computing, is transforming manufacturing and industrial sectors. The study compares Italy, Germany, France and Spain, assessing the degree of adoption of digital technologies and their impact on companies' economic performance.

Chapter 1: The Impact of Industry 4.0 on Industrial Sectors

1.1 Industry 4.0: The Nine Technological Pillars

Industry 4.0 is based on nine technological pillars. These innovations connect the physical and digital worlds and make intelligent, autonomous systems possible. Companies and supply chains already use some of these advanced technologies, but the full potential of Industry 4.0 comes to life when they are used together.

1. Big Data and AI analysis: in an Industry 4.0 landscape, Big Data is collected from various sources. This includes acquiring data from IoT-enabled assets, equipment, and devices. Data sources extend outside the production area into other companies and world areas. They can consist of everything from customer reviews and market trends that inform R&D and design to weather and traffic apps that help ensure smoother logistics. AI-supported analytics and machine learning are applied to real-time data, and insights are harnessed to improve decision-making and automation in every area of manufacturing and supply chain management.
2. Horizontal and vertical System: an essential framework of Industry 4.0 is horizontal and vertical integration. With horizontal integration, processes are tightly integrated at the 'field' level, in the production area, multiple production facilities, and the entire supply chain. With vertical integration, all layers of an organization are linked together, and data flows freely from the production area to the top floor and back again. In other words, production is tightly integrated with business processes such as R&D, quality assurance, sales and marketing, and other departments, reducing data and knowledge silos and simplifying operations.
3. Cloud computing is the 'big engine' of Industry 4.0 and digital transformation. Today's cloud technology forms the basis for the most advanced technologies, from AI to machine learning to IoT integration, and provides companies with the means to innovate. The data that powers Industry 4.0 technologies reside in the cloud, and the cyber-physical systems at the heart of Industry 4.0 use the cloud to communicate and coordinate in real-time.
4. Augmented Reality **(AR):** Augmented reality typically overlays digital content in a natural environment. With an AR system, employees use smart glasses or mobile devices to view real-time IoT data, digitized parts, repair or assembly instructions, training content, and more while looking at a physical object, such as equipment or a product. AR is still emerging but has

important implications for maintenance, service and quality assurance, technician training, and safety.

5. Industrial Internet of Things (**IIoT**)**:** The Internet of Things (IoT), mainly the Industrial Internet of Things, is so central to Industry 4.0 that the two terms are often used interchangeably. Most physical things in Industry 4.0 - devices, robots, machinery, equipment, and products - use sensors and RFID tags to provide real-time data on their condition, performance, or location. This technology enables companies to manage smoother supply chains, quickly design and modify products, prevent equipment downtime, keep up with consumer preferences, track products and stock, and much more.
6. Additive manufacturing/ 3D printing: additive manufacturing or 3D printing was initially used as a rapid prototyping tool but now offers a broader range of applications, from mass customization to distributed manufacturing. With 3D printing, components and products can be stored as design files in virtual inventories and printed on demand, reducing costs and the need for off-site/off-shore production. Every year, the scope of 3D printing grows more diverse, increasingly including primary filaments such as metals, high-performance polymers, ceramics, and even biomaterials.
7. Autonomous robots: with Industry 4.0, a new generation of autonomous robots is emerging. Programmed to perform tasks with minimal human intervention, autonomous robots vary widely in size and function, from inventory scanning drones to autonomous mobile robots for pick-and-place operations. Equipped with state-of-the-art software, AI, sensors, and machine vision, these robots can perform complex and delicate tasks. They can recognize, analyze, and act on the information they receive from their surroundings.
8. Simulation/digital twins: A digital twin is a virtual simulation of a real machine, product, process, or system created by exploiting IoT sensor data. This Industry 4.0 staple enables companies to better understand, analyze, and improve the performance and maintenance of industrial systems and products. A plant operator, for example, can use a digital twin to identify a specific malfunctioning component, predict potential problems, and improve uptime.
9. Cybersecurity: with the increased connectivity and use of Big Data in Industry 4.0, effective cybersecurity is critical. By implementing Zero Trust architecture and technologies such as machine learning and blockchain, companies can automate threat detection, prevention, and response and minimize the risk of data breaches and production delays in their networks.

1. 1.2 Definition, Functioning, and Applications of AI

Introduction to Artificial Intelligence

Artificial Intelligence (AI) is one of the biggest modern technological revolutions. This technology covers various applications, from machine learning to robotics to neural networks. A strong impact on both the current digital and social environment and technological transformation characterizes AI.

Definition of Artificial Intelligence

AI is the field of computer science that deals with developing hardware and software systems capable of performing tasks requiring human intelligence, such as interacting with the environment, learning, reasoning, and planning. According to the Artificial Intelligence Observatory of the Politecnico di Milano, AI is based on creating 'machines' that can learn and adapt similarly to humans.

Origins and History of Artificial Intelligence

The roots of AI date back to the 1950s, a period of great scientific ferment. Alan Turing, one of the founding fathers of modern computing, was one of the first to suggest that machines could be considered 'intelligent' if their behavior was indistinguishable from that of a human, as proposed in his famous 'Turing Test,' according to which a machine could be considered **intelligent** if its behavior, observed by a human, was considered indistinguishable from that of a person.

Strong and Weak Artificial Intelligence

AI falls into two broad categories:

- **Strong AI**: Refers to the creation of self-aware machines capable of replicating human intelligence. This type of AI falls under the research field of General Artificial Intelligence (AGI).
- **Weak AI**: Focuses on machines designed to solve specific problems without real awareness of the tasks performed. This approach is common in AI applications like chatbots or recommendation systems.

Machine Learning and Deep Learning

The following terms, important in AI, are to be distinguished: Machine Learning (ML) and Deep Learning (DL):

- **Machine Learning**: A sub-area of AI that develops algorithms capable of learning from data and improving their performance over time without being explicitly programmed for each specific task.
- **Deep Learning**: A subset of ML that uses deep neural networks for learning from data. Foundational models, such as GPT and DALL-E, have awakened an interest in Generative Artificial

Intelligence (Generative AI), a type of AI that generates new content, such as text, images, and video.

Main Applications of Artificial Intelligence

AI has applications in many areas, including:

- **Chatbots and Virtual Assistants**: They provide continuous assistance to customers and employees, finding applications in marketing, sales support, human resources management, and home automation.
- Natural **Language Processing (NLP)**: Enables interaction and understanding between man and machine through natural language processing.
- Computer **Vision** allows computers to automatically understand images and videos, and it is used in numerous applications, from facial recognition to autonomous driving.
- **Intelligent Data Processing (IDP)**: Includes solutions that use AI algorithms to extract information from structured and unstructured data, which is crucial for prediction and classification.
- **Recommendation Systems**: Used extensively in social networks and eCommerce to suggest products and content to users.
- **Artificial Intelligence Physical Solutions**, such as autonomous vehicles and robots, are yet to be widespread in Italy.

Generative AI and New Developments

Generative AI, which includes tools such as OpenAI's ChatGPT and Google's Gemini, has become very popular due to its ability to generate creative content that was previously considered solely the domain of humans. ChatGPT, for instance, can create text and images, compile code, and interact naturally with users. Its advanced version, ChatGPT-4, is multimodal and can handle textual and visual input.

Ethical Implications and Regulations

Adopting AI brings several ethical challenges, such as the risk of bias in data and algorithms, privacy issues, and transparency in decision-making processes. The European Union introduced the AI Act, the world's first AI regulation, to ensure that AI systems are secure and respect users' rights.

Impact of AI on the Labour Market

AI has the potential to automate many work activities, bringing both opportunities and risks. The paper points out that, if managed correctly, AI could balance the projected jobs gap due to an aging population. However, it is crucial to address the new needs of workers through training and fair redistribution of benefits.

AI diffusion in Italy

According to ***Artificial Intelligence*** Observatory Research, the AI market in Italy is growing rapidly, with a 52% increase over the previous year, reaching EUR 760 million in 2023. Large companies account for most of this market, but small and medium-sized enterprises are also starting to explore the potential of AI, particularly in the adoption of Generative AI.

The 2023 ISTAT survey offers a snapshot of the degree of diffusion of artificial intelligence in the Italian business landscape, focusing on companies with 10 or more employees and analyzing strategic sectors such as industry and services; the study provides valuable insights into the evolution of AI adoption in our country. The ISTAT survey presents a series of indicators on the use of artificial intelligence (AI) technologies in different economic activities.

The percentages indicate the proportion of companies using or applying specific AI technologies in particular business areas.

For example, in the manufacturing sector,

- 15% of enterprises use AI to manage business administration processes,
- 13% for Research and Development (R&D) or innovation activities,
- 16% for accounting, control or financial management,
- 30% of enterprises use AI to extract knowledge and information from a text document,
- 20% use it to convert the spoken language into a format readable by the computing device,
- 18% of enterprises use AI to generate written or spoken language,
- 30% to identify objects or people on the basis of images,
- 26% of enterprises use AI for data analysis through machine learning (e.g. deep learning),
- 52% to automate workflows or support decision-making,
- 23% of companies use AI to enable the autonomous physical movement of machines.

In terms of application in specific business areas,

- 92% of manufacturing companies use AI in at least one listed business area,
- 19% use it in marketing or sales,
- 52% in the production process,
- 18% in logistics,
- 22% in ICT security.
- 34% of companies use AI in at least two of the listed business areas, and
- 16% in at least three areas.

These figures vary widely between different business sectors, reflecting the different needs and opportunities offered by AI in each one.

For example, in the telecommunications sector,

- 91% of companies use AI in at least one listed business area,
- 47% using it in marketing or sales,
- 23% in the production process,
- 2% in logistics, and
- 45% in ICT security.
- 41% of enterprises use AI in at least two listed business areas, and
- 24% in at least three areas.[1]

[1] See, ISTAT. (2023). *Artificial Intelligence*. Italy: ISTAT.

Figure 1. AI 2023 usage in different sectors

source : ISTAT. (2023). Artificial Intelligence. *Italy: ISTAT.*

It can be argued that AI is a powerful technology that offers enormous potential but also significant ethical and social risks. The balance between innovation and regulation will be crucial to maximizing AI's benefits while minimizing its potential harm. Furthermore, the future of AI will depend on our ability to integrate it into human activities responsibly and sustainably.

1.3 Manufacturing: Intelligent Automation and Robotics

Industry 4.0 represents an epoch-making transformation of the manufacturing sector, driven by the grafting of innovative technologies such as artificial intelligence, the Internet of Things, and collaborative robotics. This synergy gives rise to smart factories characterized by unprecedented levels of efficiency, flexibility, and productivity.

Implementing artificial intelligence in manufacturing offers many tangible benefits, including increased productivity and efficiency through the automation of repetitive tasks, process optimization, and the reduction of human error. This translates into higher product quality ensured by intelligent control systems, which simultaneously reduce costs by optimizing production, reducing waste, and preventing machine breakdowns. In addition, artificial intelligence gives companies greater flexibility and adaptability to changing market and customer needs, opening new opportunities for developing innovative products and services. In summary, artificial intelligence is a powerful tool for improving the overall performance of the manufacturing sector.[2]

As mentioned, one of the main benefits of intelligent automation and robotics in manufacturing is increased productivity. Robots and intelligent machines can operate 24/7 without the need for breaks and perform repetitive and tiring tasks much faster than humans - this can translate into a significant increase in production and a reduction in costs.[3]

In addition to increased productivity, intelligent automation and robotics significantly improve the quality of manufacturing products. Indeed, robots and intelligent machines can perform tasks with far greater precision and consistency than humans, minimizing variability and errors. This results in reduced defects and more excellent uniformity of the finished product. In addition, integrating real-time data analysis systems into automated production processes makes it possible to constantly monitor quality parameters and identify any anomalies or deviations from standards at an early stage. In this way, timely action can be taken to correct problems and prevent the production of nonconforming products.

A further decisive advantage offered by intelligent automation and robotics in manufacturing is the increased flexibility of production processes. Thanks to their inherent adaptability, intelligent automation systems can be quickly reconfigured to produce different product variants or implement process changes in response to changing market requirements.[4]

One aspect of fundamental importance in the adoption of intelligent automation and robotics in the manufacturing industry is that of safety in the workplace. Indeed, robots and intelligent machines can be used to perform dangerous, repetitive or strenuous tasks that, if performed by humans, could expose them to serious health and safety risks.

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2 See, He, C., Zhang, C., Bian, T., Jiao, K., Su, W., Wu, K.-J., & Su, A. (2023). A review on artificial intelligence enabled design, synthesis, and process optimization of chemical products for Industry 4.0. *Processes, 11*(2), 330.

3 Adebayo, R. A., Obiuto, N. C., Olajiga, O. K., & Festus-Ikhuoria, I. C. (2024). AI-enhanced manufacturing robotics: A review of applications and trends. *World Journal of Advanced Research and Reviews, 21*(3), 2060-2072. https://doi.org/10.30574/wjarr.2024.21.3.0924.

4 Adebayo, R. A., Obiuto, N. C., Olajiga, O. K., & Festus-Ikhuoria, I. C. (2024). *Ibid.*

Although intelligent automation and robotics may lead to the automation of some tasks currently performed by humans, it is important to emphasize that they also create new job opportunities in high-demand sectors with excellent growth prospects.

Intelligent automation and robotics are revolutionizing the manufacturing sector, also introducing new possibilities for human-machine collaboration, product inspection, predictive maintenance, and production optimization. Cobots, collaborative robots, support operators in complex tasks, while machine vision inspects products with precision, identifies materials, and guides robots. Sensors and data analysis tools predict machine maintenance, preventing breakdowns and optimizing downtime. Finally, optimization software plans and schedules production more efficiently, reducing waste and increasing productivity. In fact, this integration between man and machine leads to more efficient, flexible and safe manufacturing, positively impacting product quality and company competitiveness.

In addition to the advantages already listed, intelligent automation and robotics can significantly contribute to environmental sustainability: intelligent systems optimize the use of energy and materials and reduce production waste. Therefore, they open up new frontiers in the development of innovative products and services, paving the way for mass customization, with the possibility of tailoring products to the specific needs of each customer. Intelligent automation and robotics thus represent a powerful tool for improving the efficiency, quality, and sustainability of production processes, with positive spin-offs for both companies and society as a whole.[5]

[5] Adebayo, R. A., Obiuto, N. C., Olajiga, O. K., & Festus-Ikhuoria, I. C. (2024). *Ibid.*

1.4 Logistics and Supply Chain: Optimization and Traceability

In today's global economic landscape of increasingly intricate and interconnected supply chains, the competitiveness of companies is closely linked to the efficiency, resilience, and transparency of their supply chains. In this context, optimization and traceability play a key role. Supply chain optimization embraces the use of tools, technologies, and methodologies aimed at improving the efficiency and effectiveness of all processes within the supply chain, from raw materials to the distribution of finished products to the customer. This process allows for optimizing costs, reducing waste, improving visibility and control of the flow of goods and information, increasing the supply chain's resilience in the face of unforeseen events, and ensuring greater end-customer satisfaction. On the other hand, traceability refers to the ability to monitor and track the movement of goods and information throughout the supply chain. By collecting and analyzing real-time data, companies can gain complete visibility into the path of their products, identify potential bottlenecks, optimize delivery routes, and ensure compliance with regulatory standards.[6]

The objective is to pursue an all-round improvement, encompassing cost reduction through optimization of material flows, warehouse processes, and transport routes; improvement of customer service by ensuring timely and accurate deliveries, reducing waiting times and increasing visibility of order status; increasing productivity by automating manual tasks, reducing waste and optimizing resources; improving product quality by minimizing damage and errors during transport and storage; and reducing environmental impact by optimizing transport and using environmentally friendly packaging. In short, the aim is to create a more efficient, customer-focused, productive, quality-conscious and sustainable company.

Different technologies can be integrated to optimize the supply chain. Supply chain management (SCM) software offers a complete view of the supply chain, allowing all processes to be planned, optimized, and monitored. Artificial intelligence (AI) systems analyze data, identify trends, and predict problems, supporting faster and more informed decisions. Finally, the Internet of Things (IoT) collects real-time data on goods, resources, and their movement along the supply chain, thanks to sensors and IoT devices. Supply chain traceability is essential to monitor the route of goods and products from their origin to the end customer. This makes it possible to guarantee the safety and authenticity of products, combat

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[6] Biradar, V. S., Ali Khudhair Al-Jiboory, Sahu, G., Tilak, G., Kommabatla Mahender, & Natrayan, L. (2023). *Intelligent control systems for industrial automation and robotics.* https://doi.org/10.1109/upcon59197.2023.10434927

counterfeiting and protect consumers. It also facilitates quality control by quickly identifying and isolating defective or contaminated products. In case of problems, traceability streamlines recall processes, allowing affected products to be identified and withdrawn from the market efficiently. Finally, traceability is essential to meet the specific regulations of many sectors, such as food and pharmaceuticals.[7]

The integration of optimization and traceability into the supply chain revolutionizes businesses by providing complete visibility that allows problems to be identified and resolved quickly. This translates into better data-driven decision-making that optimizes production, inventory, transportation, and distribution. Traceability, therefore, reduces the risks of counterfeiting, contamination, and supply chain breaks, increasing customer satisfaction with better service and higher-quality products. Finally, optimization contributes to sustainability by reducing the environmental impact of the supply chain.

1.5 AI in Production: Predictive Maintenance, Quality Control and Decision Making

As mentioned above, artificial intelligence is transforming the manufacturing sector, opening up new frontiers for process optimization, increased efficiency, and improved product quality.

Another prime example is predictive maintenance: AI can anticipate failures and malfunctions thanks to real-time analysis of machine sensor data, enabling proactive maintenance that reduces unplanned downtime and repair costs. Therefore, AI identifies the causes of recurring failures, helping to improve the design of machines and production processes.

AI-based machine vision systems inspect products with unparalleled speed and accuracy, identifying defects and imperfections that would escape the human eye;- this ensures consistent quality of production, minimizing waste, and non-conforming products; what's more, AI automates the process of sorting and classifying products, optimizing efficiency and productivity.

Artificial intelligence is not only limited to improving operations and product quality but also supports strategic decision-making. By analyzing vast volumes of production data, AI identifies trends and patterns that would otherwise escape human attention. This enables managers to make informed decisions on decisive issues such as production planning, resource allocation and supply chain management. Optimizing inventories and reducing lead times are just a few examples of how AI is transforming manufacturing companies' decisions, improving efficiency and overall competitiveness.

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[7] Biradar, V. S., Ali Khudhair Al-Jiboory, Sahu, G., Tilak, G., Kommabatla Mahender, & Natrayan, L. (2023). *Ibid.*

In a context characterized by increasing digitalization, in which data is of such great importance, the ISTAT 2022 survey on cyber security is of strategic importance. The analysis, conducted on a representative sample of Italian companies, provides valuable insights into the measures adopted to protect corporate data and counter cyber threats, with a focus on sectoral differences. In general, practices such as complex password authentication (over 80% in almost all sectors), data backup (over 80% on average), and network access control (over 60% on average) are widely adopted, - however, there are significant differences between sectors in the adoption of other more specific measures.[8]

Biometric identification and authentication, for example, is more widespread in the ICT, telecommunications and professional sectors, while it is less common in retail and construction. Similarly, encryption techniques are more widely adopted in sectors with high processing of sensitive data, such as ICT and telecommunications.

Staff training on IT security is widespread, in both mandatory and voluntary forms, but there are significant differences between sectors. ICT companies, for example, have the highest levels of mandatory training.

[8] See, ISTAT. (2022). *Computer security*. Italy: ISTAT.

1.6 Services: Artificial Intelligence and Customer Experience

In Italy, the link between artificial intelligence and customer experience is steadily strengthening. Sectors such as banking, finance, insurance, and commerce are increasingly adopting AI solutions to improve the customer experience. The realization that customer satisfaction is crucial for a simple and personalized shopping experience drives Italian companies to invest in these technologies.[9]

When a customer is faced with a problem with a product, he first and foremost seeks empathy, speed, and competence in his interaction with the company. He wants to feel listened to, understood, and confident that his problem will be resolved effectively and promptly. A company's ability to meet these expectations depends on several factors, including its size, sector and, above all, a strongly customer-oriented corporate culture. Greater maturity and attention to consumer needs results in a more positive service experience and a strengthening of the trust relationship between the company and the customer.[10]

Customer Experience (CX) is an ongoing process that companies put in place to deliver a memorable customer experience at every touch point. This is done through the collection and analysis of customer data, which allows them to personalize interactions, automate processes and provide immediate assistance. At the heart of this evolution is artificial intelligence, which is a key resource for the future of CX, customer service and marketing, enabling the creation of increasingly engaging experiences tailored to individual needs.

Artificial intelligence, particularly generative intelligence, is revolutionizing the customer experience. Thanks to AI, it is possible to create highly realistic product visualizations from simple descriptions or data. This innovation makes it possible to offer customers a more engaging and personalized shopping experience, thus associating artificial intelligence with a decidedly positive factor.[11]

Increasingly sophisticated chatbots can handle customer interactions wholly and naturally, from the first to the last request, without requiring direct human intervention. This evolution allows ticket management systems to operate faster and more efficiently.

Business processes must be optimized to ensure efficient handling of customer requests, from the first interaction to the final resolution. It is crucial to map the customer journey to identify critical touch points and ensure that they are smooth and seamless.[12]

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9 Cf., R. Maglie. (13 November 2023). Artificial Intelligence applied to Customer Experience: what's new, Techbusiness, Retrieved on 07/08/2024 from: https://techbusiness.it/intelligenza-artificiale-customer-experience/

10 Ibid.

11 Ibid.

12 Ibid.

Artificial intelligence algorithms revolutionize the way companies interact with their customers - by deeply analyzing a wide range of data, such as purchases made, browsing history, and online interactions, these algorithms build personalized profiles for each user. With this detailed information, product suggestions, promotions, and content that are highly relevant to individual interests can be offered. This personalized approach significantly improves the shopping experience and stimulates greater customer engagement and loyalty, resulting in increased sales. Prime examples of this strategy are Amazon, which offers products in line with purchase history, and Netflix, which recommends films and TV series based on users' tastes.

In the past, customer service could have been improved by a lack of data and information about customers, making it difficult to understand their needs and provide personalized support. Today, thanks to artificial intelligence (AI), the analysis of customer interactions, online reviews, and social media makes it possible to identify trends, recurring problems, and areas for improvement. This has led to more proactive and personalized customer service, with the ability to identify and solve problems in a timely manner, thus improving brand reputation. Examples of companies using AI to improve the customer experience include Disney, which analyzes reviews on social media to optimize theme parks, and Starbucks, which customizes promotions and offers.

1.7 Impact of Artificial Intelligence on Italian Manufacturing Activities

Artificial intelligence (AI) is having a significant impact on Italian manufacturing activities, transforming the sector in several ways:

- **Process optimization**: AI optimizes manufacturing processes, improving operational efficiency and reducing waste. For example, using advanced algorithms and data analysis allows defects to be detected and corrected, reducing waste and cutting costs.
- **Digital twins**: one of the most exciting applications is digital twins, which are digital replicas of physical production systems. These models enable real-time simulation, monitoring, and optimization, improving overall efficiency and reducing downtime.
- **Supply and demand forecasting**: AI helps manufacturing companies predict supply and demand, adapting to changing market demands. This enables improved production planning and supply chain management.
- **Sustainability**: AI also contributes to sustainability by optimizing resources and reducing environmental impact. This is especially important in achieving companies' ESG (Environmental, Social, and Governance) goals.
- **Challenges and confusion**: Despite the benefits, AI adoption also presents challenges. Excessive media hype and unrealistic expectations can create confusion, making it difficult for companies to implement established technologies effectively.

The relationship between turnover and digitization levels in Italian manufacturing companies is of great interest. Several studies have shown that companies with a high level of digitization tend to have better economic performance than those less digitized.

Increased Profits: manufacturing organizations that have achieved an optimized level of digitization have seen profits increase by 40%. This is due to increased operational efficiency, reduced waste, and the ability to respond more quickly to market needs.

Competitiveness: Companies that invest in digital technologies such as IoT, collaborative robotics, and big data analytics can improve their competitiveness. This translates into greater capacity for innovation and better supply chain management.

Operational Efficiency: Digitization allows them to optimize production processes, reduce downtime, and improve product quality. This leads to reduced costs and increased turnover.

Challenges: however, not all companies are able to take full advantage of the opportunities offered by digitization. Lack of digital skills and resistance to change are among the main obstacles companies face.

There is a clear correlation between high levels of digitization and increased turnover in Italian manufacturing companies. Investing in digital technologies and training the necessary skills can lead to significant economic benefits.

Some recent data on turnover in Italian manufacturing companies:

- **Turnover Growth**: according to a report by Intesa Sanpaolo and Prometeia, the turnover of the Italian manufacturing industry is expected to stabilize at 1160 billion euros in 2024, an increase of 250 billion compared to 2019.
- **Distribution of** Turnover: data from ISTAT show a distribution of turnover among Italian manufacturing companies, with significant variations among different quartiles.
- **Investment in Digital**: an analysis by MilanoFinanza shows that 74% of Italian manufacturing companies are investing more in digital, contributing to revenue growth.

This data indicates a positive trend in the Italian manufacturing sector, with a strong drive toward digitization.

According to ISTAT data, adopting artificial intelligence (AI) in Italian manufacturing saw significant growth between 2019 and 2023. Here are some highlights:

- **Percentage of enterprises using AI**: In 2023, 5% of enterprises with at least 10 employees reported using artificial intelligence technologies.
- **Adoption of cloud computing services**: 61.4% of enterprises have adopted intermediate or sophisticated cloud computing services, compared with 38.9% of the EU27 average.
- **Use of Internet-connected devices (IoT)**: 55.7% of SMEs use Internet-connected devices, a significant increase from 2019.

These data show a positive trend in adopting advanced technologies, although there is still room for improvement, especially in the deployment of AI.

1.8 Ethical and Social Implications of Artificial Intelligence

The main ethical implications of artificial intelligence concern the possibility of discrimination, lack of transparency, invasion of privacy, loss of jobs and the development of autonomous weapons. AI systems could amplify existing biases, lead to inexplicable decisions with potential harm, be used for mass surveillance, cause unemployment and create autonomous weapons with devastating consequences. For these reasons, it is crucial to develop artificial intelligence responsibly, with clear ethical principles that ensure justice, transparency, accountability and safety for all.

Artificial intelligence (AI) not only raises ethical issues but also significantly impacts society. One of the main problems is digital inequality, as access and capabilities to utilize AI technologies could exacerbate existing divisions, creating a gap between those who have and those who need more skills and resources to harness the benefits of AI. Therefore, AI will transform the world of work, requiring new skills and a reskilling of the workforce. It is crucial to ensure that this transition takes place fairly and inclusively, supporting those workers most affected by automation. Although AI can increase productivity and economic growth, it is essential to distribute the benefits fairly and invest in retraining and social protection programs for those who may lose their jobs. Finally, effective governance mechanisms need to be developed to ensure that the development and use of AI is aligned with democratic values, human rights and the common good.

Addressing the challenges posed by artificial intelligence (AI) requires a global and coordinated effort by governments, companies, researchers and citizens. To ensure the responsible development and use of AI, clear and shared ethical guidelines that respect human rights, transparency and accountability must be defined. Promoting responsible AI research and innovation is crucial to ensure that technological advances are geared towards the good of society. At the same time, there is a need to educate and raise public awareness about AI to foster an informed and informed public debate. Collaboration between all stakeholders is crucial to define the future of AI in a responsible and inclusive manner. Only through collective engagement can we ensure that this powerful technology is used for the benefit of all.

Chapter 2: The Digitalization Level of Enterprises in Italy

2.1 The Digital Divide

Despite being the third largest economy in the European Union, Italy ranked 18th in the DESI 2022 index, with a score of 49.3 compared to the EU average of 52.3. However, the progress made over the past five years is remarkable. It bodes well for the future, especially considering Italy's strategic importance for the European Union in achieving the goals of the digital decade. The growing political attention to digital issues, manifested by the creation of a dedicated ministry and the adoption of several key strategies, has undoubtedly contributed to this acceleration, demonstrating the country's willingness to bridge the digital gap and become an increasingly leading player in Europe's digital transformation. [13]

Despite the progress highlighted, Italy still faces several challenges in achieving digital excellence.
The diffusion of basic digital skills among the population remains a crucial issue. Although there has been an improvement, half of Italian citizens still lack the necessary skills to interact with the digital world effectively.
Similarly, the shortage of digital specialists in the Italian production fabric is a significant obstacle to developing an increasingly digitized economy. Low enrolment and graduation rates in information and communication technology sectors jeopardize the country's competitiveness in the long term. To reverse this trend, it is essential to invest heavily in training and updating digital skills, at all levels of the education and training system. Only in this way will Italy be able to close the gap with the most advanced countries and contribute actively to realizing the European digital decade.
In essence, while Italy has embarked on a promising digital transformation path, it needs to step up its efforts to strengthen its digital skills, both individually and collectively. The National Recovery and Resilience Plan offers a unique opportunity to accelerate this process, but targeted industrial policies and a long-term strategy for the development of digital human capital must accompany investments.[14]
About connectivity, although there has been significant progress in the deployment of broadband services, significant territorial and digital disparities still persist. The coverage of very high-capacity networks, in particular fiber to the building, is a critical issue that limits the competitiveness of Italian companies and slows down innovation.

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13 See, European Commission. (2022). *Digitization index of the economy and society (DESI) 2022 Italy*.

14 See, European Commission. (2022). *Ibid.*

While most small and medium-sized enterprises have embarked on a digitization path, adopting cloud services and other basic digital solutions, the use of more advanced technologies such as big data and artificial intelligence still remains marginal. This lag is partly due to the complexity of these technologies, the lack of specific skills within companies, and the scarcity of incentives for digital innovation. Closing this gap requires a coordinated effort by institutions, businesses and academia to promote the diffusion of digital skills, to facilitate access to credit for companies willing to invest in digital technologies, and to create innovation ecosystems at the local level. [15]

The **ISTAT 2023 analysis of digital technologies in Italian companies with at least 10 employees** (the small and medium-sized enterprises that represent the backbone of the Italian production fabric) reveals a heterogeneous landscape of adoption. The study, conducted annually at the national level, explores the use of digital tools for internal organization, supply chain management, and IoT.

- The ISTAT survey therefore presents a series of indicators on the use of different types of software and technologies by enterprises in various economic sectors.
    - Manufacturing shows a usage of 19% for both CRM and BI software, with 58% using at least one management software and 54% using ERP systems.
    - The food, beverage and tobacco industries show a slightly higher use of BI software (20%) than CRM (12%), with 51% using at least one management software and 47% using ERP systems.
    - The textile, clothing, leather goods and similar industries show a lower use of these technologies, with only 8% using CRM software and 9% BI.
    - The sector with the highest use of these technologies is the manufacture of computers and electronic and optical products, electro-medical equipment, measuring equipment and watches, with 29% of companies using CRM software, 30% BI, 81% at least one management software and 80% ERP systems.

  In general, the use of these technologies varies considerably across economic sectors, with the ICT sector showing the highest use (50% CRM, 38% BI, 70% at least one management software, 62% ERP). Overall, 19% of enterprises in all economic activities use CRM software, 18% BI, 49% at least one management software and 42% ERP systems. These figures highlight the growing importance of digital technologies in today's enterprises.[16]

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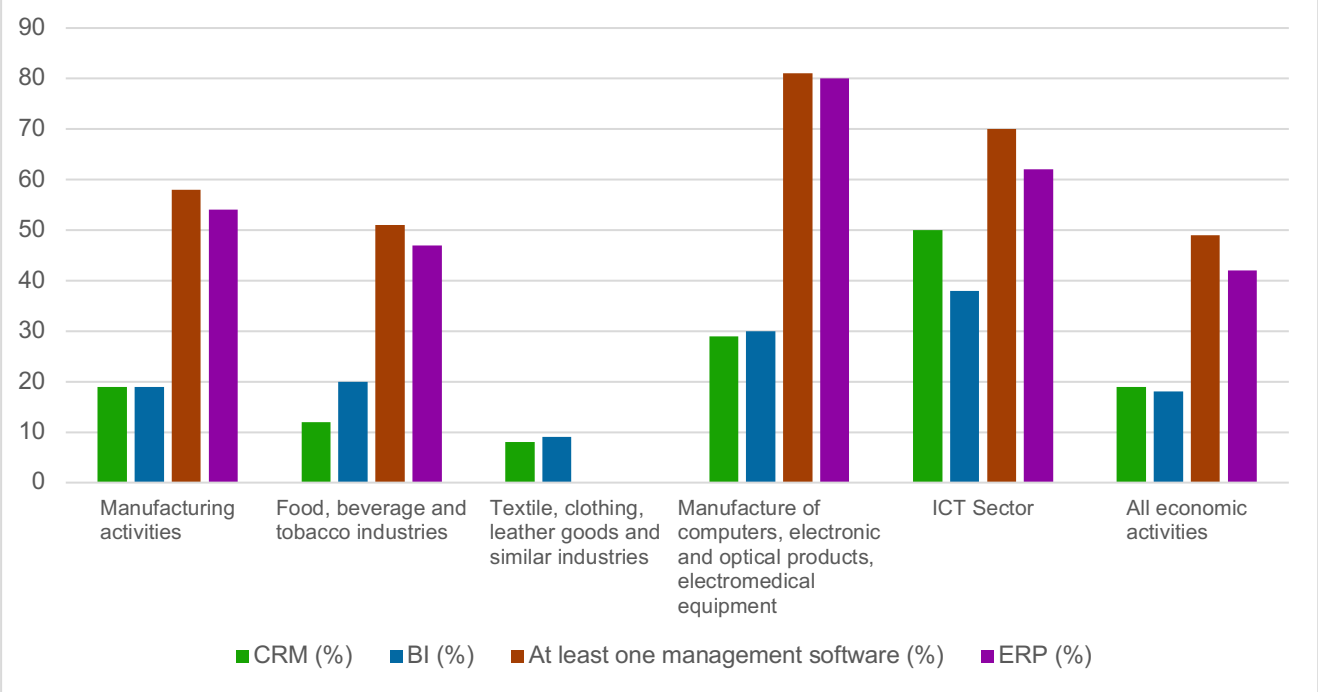
15 See, European Commission. (2022). *Ibid.*

16 See, ISTAT. (2023). *Technologies for internal organisation, supply chains and the internet of things*. Italy: ISTAT.

Figure 2. Technology for internal organization



Source : ISTAT. (2023). *Technologies for internal organisation, supply chains and the internet of things*. Italy

- According to the latest ISTAT report, Italian companies with at least 10 employees increasingly use big data; the 2023 annual survey provides a detailed analysis by sector, highlighting which types of data are most analyzed and with which objectives. The ISTAT survey thus presents several indicators relating to data analysis by companies in various economic sectors. The percentages indicate the proportion of enterprises analyzing data internally or with external providers' help. For example, in the manufacturing sector, 29% of the enterprises analyze data, of which 28% do so internally. Of these, 17% analyze data on transactions, 11% on customers, 8% on social media, 7% on the web, 3% on location (vehicles and PCs), 11% on smart tools or sensors, 2% on PA open data and 2% on satellite data. Only 4% of companies in this sector use external providers for data analysis. In the food, beverage, and tobacco industries, 34% of companies analyze data, of which 32% do so internally. Of these, 20% analyze data on transactions, 11% on customers, 11% on social media, 9% on the web, 3% on location, 11% on smart tools or sensors, 5% on PA open data and 4% on satellite data. 5% of companies in this sector use external providers for data analysis. The survey shows that data analysis is a common practice in many business sectors, with various methods and data sources used. However, the use of external providers for data analysis is less common than in-house analysis. Moreover, the

analysis of transaction and customer data seems to be more common than the analysis of data from social media, web, location, smart tools or sensors, PA open data and satellite data.[17]

- The 2023 ISTAT survey maps, among other things, the landscape of cloud computing adoption in the Italian business fabric. The data collected on an annual basis and focused on companies with at least 10 employees offer a precise picture of the ways and sectors in which these technologies are used. The ISTAT survey therefore presents a series of indicators on the use of cloud computing services in various economic activities. The percentages indicate the proportion of enterprises in each sector that use a given service. For example, in the manufacturing sector, 59% of enterprises use e-mail, 39% use office software, and so on. Similarly, in the food, beverage and tobacco industries, 56% of enterprises use e-mail, 34% use office software, and so on. This pattern is repeated for all sectors listed in the ISTAT survey. In terms of use of cloud computing services, enterprises purchasing at least one of the required cloud computing services range from 43% in the restaurant services sector to 92% in the publishing sector. Enterprises purchasing basic level cloud computing services range from 1% in the accommodation sector to 27% in the publishing business sector. Enterprises purchasing intermediate level cloud computing services range from 2% in the telecommunications sector to 9% in the transportation and warehousing sector. Finally, enterprises purchasing sophisticated level CC services range from 0% in the transport equipment manufacturing sector to 11% in the real estate sector. In general, the use of cloud computing services is widespread across all sectors, with some variations depending on the type of service and the level of sophistication of the cloud computing service. Publishing and telecommunications tend to have the highest percentages of cloud computing service usage, while food services and accommodation tend to have the lowest percentages.[18]

Italy is making significant progress in offering digital public services, gradually approaching the European average. The Digital Decade's goal of making all major public services available online for citizens and businesses is ambitious but achievable, especially considering, for example, the efforts already undertaken to digitize electronic health records. Despite this progress, the use of digital public services by Italian citizens is still below the European average. Although there has been a considerable increase over the last two years, with a 10% rise in usage, efforts need to be stepped up to spread a more widespread digital culture and to overcome resistance to the use of online services, especially among the older segments of the population. An appropriate awareness-raising and training campaign, combined

[17] See ISTAT. (2023). *Big Data analysis*. Italy: ISTAT.

[18] See, ISTAT. (2023). *Cloud Computing*. Italy: ISTAT.

with the provision of intuitive and easy-to-use digital services, is crucial to foster the widespread adoption of digital public services.[19]

To achieve this, it is necessary to invest in the simplification of administrative processes, interoperability between different administrations and the reduction of the 'digital divide'.

Furthermore, it is crucial to ensure personal data security and citizens' protection from computer fraud. Only through an integrated and coordinated approach will it be possible to achieve an increasingly efficient, transparent and citizen-friendly public administration.[20]

Looking at policy developments in recent years, Italy has focused more attention on digitalization, introducing numerous measures to foster the country's digital transformation. The National Recovery and Resilience Plan (PNRR) is giving further impetus to this process, allocating significant resources to the modernization of digital infrastructures, the digitalization of public administrations, and business support. Among the most significant initiatives are the tenders for the development of gigabit and 5G connectivity, vouchers for SMEs and measures for the dissemination of digital identity. However, despite these efforts, territorial inequalities and some critical issues still persist, such as the limited diffusion of electronic health records and the need to strengthen the digital skills of the population. To ensure a successful digital transition, effective coordination between the different institutions involved, constant monitoring of results and flexibility in adapting policies to the new challenges posed by the digital revolution are crucial.[21]

The National Recovery and Resilience Plan (NRP), with a total amount of EUR 191.5 billion, is a key instrument for accelerating the country's digital transition. Of the total resources, 25.1%, or EUR 48 billion, is earmarked for financing projects in the digital sector. Important milestones have already been achieved, including the 'Cloud first and interoperability' reform, which promotes the adoption of cloud computing in public administration, and the ICT procurement reform, which simplifies and accelerates tendering procedures. In addition, important projects of common European interest (IPCEI) were launched, such as the one on microelectronics, which will help strengthen Italy's industrial competitiveness in the digital sector.[22]

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19 See, European Commission. (2022). *Ibid.*

20 See, European Commission. (2022). *Ibid.*

21 See, European Commission. (2022). *Ibid.*

22 See, European Commission. (2022). *Ibid.*

2.1.1 What is DESI

Since 2014, the European Commission has annually monitored the progress of Member States in the digital area through the DESI (Digitization Economy and Society Index), publishing detailed reports including country profiles and thematic analysis at EU level. The DESI ranks Member States according to their level of digitization and assesses their relative progress over time, taking into account each one's starting point. Recently, DESI has been reformed to align with the objectives of the EU's 'Digital Decade,' an ambitious program aiming at a comprehensive and sustainable digital transformation by 2030. Eleven of the DESI 2022 indicators already measure these goals, and even closer alignment is expected in the future. Despite some signs of convergence, digitization in the EU still remains uneven, highlighting the need for further efforts to close the digital divide between Member States.[23]

While the digital leaders maintain their positions, a sizeable group of Member States is hovering around the EU average. Encouragingly, states that started from less favored positions are accelerating their digital transition, indicating a general convergence at the European level. In order to achieve the ambitious goals of the Digital Decade, a joint effort by all Member States is crucial. Each will contribute according to its specificities, resources and starting points, but all are called upon to play their part. The largest countries, in economic and demographic terms, will have a key role in driving the entire Union towards the 2030 goal, while digital leaders will have to continue to innovate and set new standards. At the same time, less advanced Member States will be pushed by their economic and social needs to intensify digitization efforts. To ensure comparability over time, DESI scores from previous years are recalculated periodically in the light of newly available information.

2.1.2 Human Capital

Italy, despite being in 25th place in the DESI 2022 ranking with an overall score of 36.6 out of 45.7, shows progress in basic and higher digital skills, with 46% and 23% of the population possessing them, respectively; however, it lags in digital content creation (58%) and in the presence of ICT specialists (3.8%), especially women (16%). Despite a slight improvement over time, our country remains below the EU average, highlighting the need for greater investment in digital training, especially in business (20%) and STEM degrees (3.9%), to close the gap with other Member States.[24]

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[23] See, European Commission. (2022). *Ibid.*

[24] See, European Commission. (2022). *Ibid.*

Italy has a significant gap in terms of digital human capital compared to the European average, ranking 25th out of 27 EU countries. The low level of basic digital skills of the population (46% against 54% of the EU average), combined with the low presence of graduates in ICT disciplines (only 1.4%, the lowest figure in the EU) and the limited diffusion of ICT specialists in the labor market (3.8% against 4.5% of the EU average), highlight structural criticalities in the Italian education and training system. Although the presence of women in the digital sector is closer to the EU average (16% vs. 19%), the insufficient supply of ICT training by Italian firms (15% vs. 20% of the EU average) further inhibits the development of advanced digital skills and the competitiveness of the national production system.[25]

Italy adopted a National e-Skills Strategy, translated into an Operational Plan in December 2020, which foresees 111 initiatives and ambitious targets to be achieved by 2025, including the diffusion of basic digital skills to 70% of the population, in line with European directives. A first evaluation of the Plan, conducted in 2021, showed significant progress, with more than a third of the monitored initiatives already underway or completed, covering a broad spectrum of interventions ranging from education and training to retraining of workers and enhancing the digital skills of the general population. Despite the positive results, there are still challenges to be met in order to achieve the objectives set and guarantee Italy a leading role in the digital society.[26]

Two reforms adopted in 2021, that of degree classes and that of doctoral programs, aim to make tertiary education more flexible and innovative, promoting interdisciplinary pathways, cutting-edge professional profiles, and greater collaboration between universities and businesses. At the same time, the ITS network has been consolidated, with increasing adoption of 4.0 technologies, thus offering young people highly specialized training courses in line with the demands of the labor market. The new Artificial Intelligence strategy, with its focus on skills and talent attraction, has given impetus to the National Doctorate in Artificial Intelligence, a major program for training high-level researchers in this strategic field. Finally, the European Programming Week helped to spread the culture of coding among young people, bringing them closer to the world of programming and stimulating their curiosity about STEM disciplines.[27]

However, sustained and coordinated efforts are needed at all levels to ensure an inclusive and lasting digital transformation. There is a need not only to strengthen existing initiatives but also to promote greater integration between e-skills and industrial and labour market policies. In this way, it will be possible to create an ecosystem favorable to innovation, entrepreneurship, and the creation of new

[25] See, European Commission. (2022). *Ibid.*

[26] See, European Commission. (2022). *Ibid.*

[27] See, European Commission. (2022). *Ibid.*

employment opportunities. It is also crucial to invest in the continuous training of workers to help them acquire the necessary skills to face the challenges of digitization. Only through a systemic and integrated approach will it be possible to fully exploit the potential of digital technologies and build a more equitable and prosperous society.[28]

2.1.3 Connectivity

In 2022, Italy ranked seventh in the DESI index with a score of 61.2 compared to the EU average of 59.9. Overall fixed broadband deployment increased from 61% in 2020 to 66% in 2022, while fixed broadband deployment at least 100 Mbps increased from 22% in 2019 to 38% in 2021. Fast broadband (NGA) coverage reached 97% of households in 2021, and very high-capacity fixed network (VHCN) coverage increased from 30% in 2019 to 44% in 2021. Fiber to the premises (FTTP) coverage increased from 30% in 2019 to 50% in 2021. As for 5G, the allocated spectrum remained stable at 60% from 2020 to 2022, while 5G coverage increased from 8% in 2020 to 99.7% in 2021 and then decreased to 66% in 2022. Mobile broadband deployment increased from 70% in 2018 to 80% in 2021, and the price index for broadband services saw a slight increase from 74 in 2019 to 76 in 2021.[29]

With an overall connectivity score of 61.2, Italy ranks 7th among EU Member States. In the last reporting period, the most significant progress was in 5G coverage, which increased from 8% to 99.7% of inhabited areas, including the percentage of 5G coverage provided through spectrum sharing technology. This increase can be attributed to the coverage and spectrum usage obligations related to the rights of use of the 5G pioneer bands granted in 2018, according to the regulations established by AGCOM (Resolution No. 231/18/CONS), the national regulatory authority in the electronic communications sector. In this context, all Italian provinces are starting to benefit from commercial 5G services. Further progress is expected towards achieving the goal of uninterrupted 5G wireless broadband coverage in all urban areas, main roads and railways by 2025, thanks to the coverage obligations related to the rights of use of the 700 MHz band, which will be available to operators (already holding rights of use) as of 1 July 2022.[30]

2.1.4 Integration of digital technologies

In 2022, Italy ranked 8th in the DESI ranking with a score of 40.7 compared to the EU average of 36.1. As far as SMEs are concerned, 60% have at least a basic level of digital intensity, while 55% of SMEs

[28] See, European Commission. (2022). *Ibid.*

[29] See, European Commission. (2022). *Ibid.*

[30] See, European Commission. (2022). *Ibid.*

in the EU have reached this level. Electronic information exchange is practiced by 32% of Italian companies compared to 38% of EU companies. The use of social media has increased to 27% in Italy and 29% in the EU. Big data analysis is used by 9% of Italian companies and 14% of EU companies. Cloud is adopted by 52% of Italian firms compared to 34% of EU firms. Artificial intelligence is used by 6% of Italian firms and 8% of EU firms. ICT for environmental sustainability is adopted by 60% of Italian enterprises and 66% of EU enterprises. Electronic invoicing is used by 95% of Italian enterprises compared to 32% of EU enterprises. Online sales activities involve 13% of Italian SMEs and 18% of EU SMEs, with e-commerce turnover at 9% in Italy and 12% in the EU. Cross-border online sales are practiced by 7% of Italian SMEs and 9% of EU SMEs.[31]

Italy ranks 8th in the EU for digital technology integration, with the majority of Italian SMEs having at least a basic level of digital intensity (60%, above the EU average of 55%); however, the overall performance is mixed when it comes to the diffusion of specific technologies: almost all Italian enterprises (95%) use e-invoicing thanks to legislative interventions, and the country performs well in the diffusion of cloud services (52% of enterprises, above the EU average of 34%). The National Plan "Transition 4.0' is the main instrument to support the diffusion of digital technologies among enterprises, with tax credits financed by the National Recovery and Resilience Plan (EUR 13.4 billion) and the complementary national fund (EUR 5.8 billion), and a scientific committee will monitor the economic impact of tax credits during their implementation.

Italy is home to one of the top 10 supercomputers in the world (9th place) and supercomputing centers such as CINECA, which support research and technology transfer in high-performance computing (HPC) and quantum computing. In 2021, EUR 17.7 million has been allocated from the Sustainable Growth Fund to support business participation in EuroHPC, contributing to the development of a European supercomputing and data processing ecosystem. Also in 2021, a group of public entities created the Italian Blockchain Service Infrastructure (IBSI) along the lines of the European initiative (EBSI), to test national use cases enabled by distributed ledger-based technologies, such as the use of digital certificates, anti-counterfeiting and climate change. It is crucial that Italy sustains integrated efforts to guide Italian firms towards digitization with policies supporting investment, capacity building and human capital enhancement, continuing to engage in advanced digital technologies and exploiting the resources of the national recovery and resilience plan to strengthen its position and play a central role in the EU.[32]

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[31] See, European Commission. (2022). *Ibid.*

[32] See, European Commission. (2022). *Ibid.*

2.1.5 Digital public services

In 2022, Italy ranked 19th in the Digitization of Economy and Society Index (DESI) with a score of 58.5 compared to the EU average of 67.3. Regarding digital public services, 40% of Italian internet users used e-government services, compared to 65% of the EU average. Pre-filled forms scored 48 out of 100, while digital public services for citizens and businesses scored 67 and 79, respectively. Finally, open data scored 92% compared to the maximum possible.[33]

Italy ranks 19th in the EU for digital public services, with only 40% of Italian internet users using them, well below the EU average of 65%. Despite this, Italy scores 92% in open data policies, but remains below the EU average for the availability of pre-filled forms. In terms of digital public service provision, Italy is close to the EU average for business services (79 vs. 82), but the gap is larger for citizen services (67 vs. 75). These results do not yet reflect the impetus provided by the national recovery and resilience plan, which with 'Digital Italy 2026' aims to modernize the public administration and its services.[34]

The 'Digital PA 2026' platform coordinates the implementation of the plan's measures, enabling public administrations to access funding and receive assistance; among the measures taken, in 2021, the government published the 'Cloud Italy Strategy' to improve the security and efficiency of the public administration's digital infrastructure, with the new Agency for National Cybersecurity (ACN) playing an important role in protecting national cyberspace; in addition, the government has introduced a new national interoperability framework with guidelines to create secure, mobile-first and API-based digital public services, simplifying procedures for information exchange between agencies and supporting the once-only principle; major e-government projects achieved significant results in 2021-2022.[35]

As a result of the 2020 'Simplification Decree' and the increasing use of digital identities, many public administrations allow access to their services via CIE ('Sign in with CIE'), while the 'IO' app, downloaded more than 26 million times, acts as a single access point to digital public services, allowing users to access the services of some 7.000 national and local authorities, receive notifications and store documents such as certificates and receipts; the app has automatically issued more than 268 million COVID-19 digital certificates and, by 2022, more than 57 million active electronic health records (EHRs) had been registered. However, the take-up among citizens, GPs and health facilities varies considerably from one region to another, remaining very low in some areas.

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33 See, European Commission. (2022). *Ibid.*

34 See, European Commission. (2022). *Ibid.*

35 See, European Commission. (2022). *Ibid.*

Through the National Recovery and Resilience Plan, the government is investing EUR 1.3 billion at central and local level to make the electronic health record a single access point for health data and services, ensuring full interoperability and portability between Italian regions; in addition, 8,000 civil servants have been involved in the 'Digital Skills for Public Administration' project and over 16.000 by the National Digital Skills Coalition, while a new strategic plan for the development of additional skills (upskilling) and new skills (reskilling) for civil servants was adopted in 2022, recognizing the central role of digital skills and promoting collaboration with large public and private operators to enrich the training offer.[36]

2.2 Factors Influencing the Level of Digitization: Size, Sector and Enterprise Culture

The digital divide in Italy is not limited to geographical differences but also manifests itself within the business fabric. In addition to regional disparities, their size strongly influences the level of digitization of businesses. Large companies, thanks to greater economic resources and internal competences, are generally more advanced in the adoption of digital technologies. In contrast, small and medium-sized enterprises (SMEs) face more complex challenges in the digitization process, mainly due to budget constraints, shortage of specialized personnel, and bureaucratic obstacles that hinder their technological innovation.

In addition to technology-intensive and dynamic sectors, the degree of internationalization of a company also influences its propensity to digitalization. Companies operating in global markets are often forced to adopt digital tools and processes to effectively manage relationships with customers and suppliers in different parts of the world.

The age of a company may be a factor related to the level of digitization, - in fact, younger companies, born in a digital environment, tend to be more familiar with technologies and are more likely to adopt them. Conversely, more mature firms may be more resistant to change and need help to integrate new technologies into existing processes.

Returning to company size, it is important to emphasize that even within SMEs, there are considerable differences. Micro enterprises (1-9 employees) are often the most disadvantaged in terms of digital resources and skills. Small enterprises (10-49 employees) can benefit from some economies of scale and are more likely to invest in digitization. Medium-sized enterprises (50-249 employees) usually have a more complex organizational structure and require more sophisticated digital solutions.

[36] See, European Commission. (2022). *Ibid.*

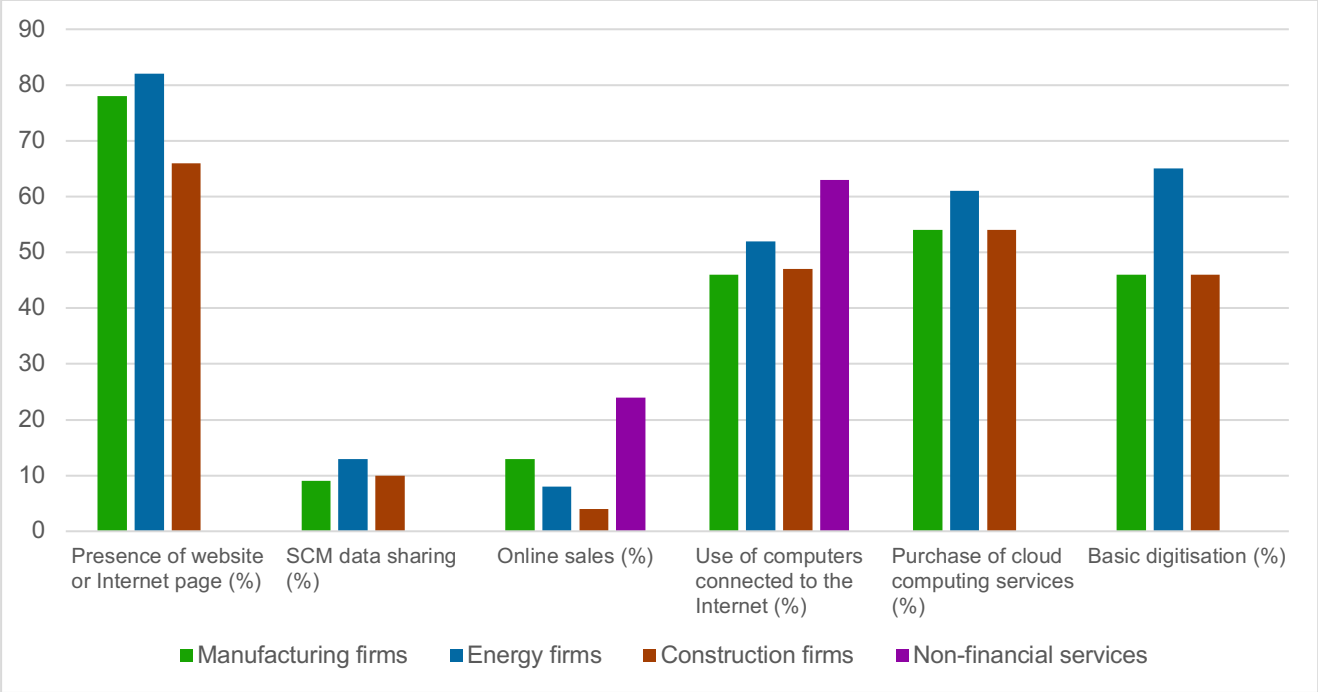
Therefore, companies with an open mindset to innovation and change are more likely to adopt new technologies and reap their benefits. A forward-looking management that recognizes the strategic value of digital and invests in training and technology tools is a key catalyst for this transformation. However, other factors such as the company's age, the availability of financial resources, collaborations with others and the adoption of cloud services significantly influence the level of digitization. In summary, a favorable corporate culture, coupled with a strategic vision and an enabling environment, is the ideal combination for a successful digital transformation.

Several factors, including company size, sector, and business culture influence the level of digitization of Italian companies. According to the latest ISTAT report (2023), focused on enterprises with 10-49 employees, it emerged that these elements play very decisive roles in determining the adoption and use of digital technologies.

The ISTAT analysis, conducted annually at the national level, provides a detailed picture of the Italian situation and identifies best practices and areas for improvement. The table presents a number of indicators related to the use of digital technology in enterprises in different economic sectors. Manufacturing enterprises show an incidence of 78% for the presence of a website or at least one page on the Internet, while for enterprises in the electricity, gas, steam and air conditioning, water, sewerage, waste management and sanitation sectors, the incidence is slightly higher, at 82%. For construction, the incidence drops to 66%. For supply chain management (SCM) data sharing, the incidence is much lower, at 9% for manufacturing, 13% for energy and similar, and 10% for construction. Online selling via web and/or EDI-type systems is more common in non-financial services, with an incidence of 24%, compared to 13% in manufacturing, 8% in energy and similar, and only 4% in construction. The use of computers connected to the Internet at least once a week by employees is highest in non-financial services, with an incidence of 63%, compared to 46% in manufacturing, 52% in energy and similar, and 47% in construction. Finally, the purchase of cloud computing (CC) services and the presence of a basic level of digitization are uniform across sectors, with the incidence ranging from 54% to 61% for CC and from 46% to 65% for basic digitization.[37]

[37] See, ISTAT. (2018). *Industry 4.0 indicators - digitization factors*. Italy: ISTAT.

Figure 3. Industry 4.0 indicators



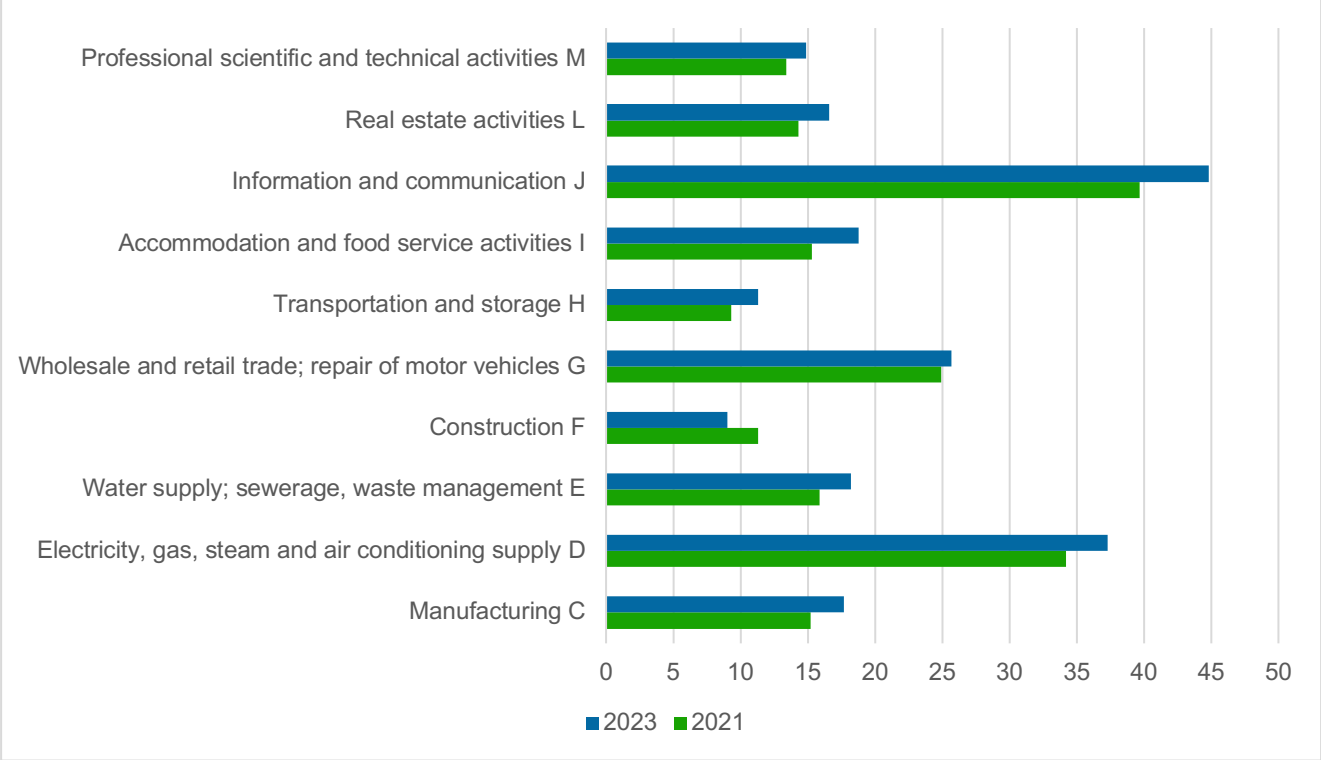
source: ISTAT. (2018). Industry 4.0 indicators - digitization factors. *Italy: ISTAT.*

2.3 Descriptive Analysis of Digital Intensity in Italy

In the context of analyzing Italian manufacturing sectors, with reference to the level of Digital Intensity, data reported by Eurostat for the years 2021 and 2023 provide a clear picture of the evolution of digital technologies within Italian companies.

The survey focuses on companies with a Very High Digital Intensity Index, that is, those that show a high adoption of advanced digital technologies. The sectors surveyed include a wide range of industries, each characterized by different dynamics regarding the integration of digital technologies.

Figure 4. Digital Intensity Italy



Source: Eurostat. Digital Intensity by sectors

- A first relevant figure is the Information and Communication (J) sector, which showed the highest level of Digital Intensity in both 2021 and 2023, rising from 39.7% to 44.8%. This significant increase highlights how the communication, media, and technology industry is leading the way in the adoption of digital tools, further consolidating its central role in the country's digital transformation.
- The Electricity, Gas, Steam, and Air Conditioning (D) sector follows, showing consistent growth from 34.2% in 2021 to 37.3% in 2023. This trend reflects the growing importance of digital technologies in optimizing energy resources, with increased digitization in production and distribution processes, especially in the context of energy transition.
- In contrast, traditional sectors such as Wholesale and Retail (G) and Real Estate (L) have relatively low but stable or moderately growing digitization rates. Wholesale and Retail Trade increased from 24.9% to 25.7%, while Real Estate saw an increase from 14.3% to 16.6%. This suggests that while lagging behind the technology sectors, these industries are also gradually adopting digital solutions, albeit slower.
- Another interesting observation concerns the Construction (F) sector, which, on the other hand, showed a decline from 11.3% in 2021 to 9% in 2023. This could reflect a stagnant

phase or difficulty in the adoption of advanced digital technologies, perhaps due to the practical and physical nature of activities in this sector.

- It is also important to note that sectors such as Transportation and Warehousing (H) and Professional, scientific, and Technical Activities (M) showed less marked progress than others but still showed significant increases, with increases from 9.3% to 11.3% and 13.4% to 14.9%, respectively.

The evolution of Digital Intensity levels in different Italian industries between 2021 and 2023 shows general growth, with some sectors more advanced in integrating digital technologies and others still facing challenges. This trend reflects the specific characteristics of each sector and the strategic priorities and investment capabilities of companies involved in the digital transition.

Chapter 3: Descriptive Analyses of Digitalization in Germany, Spain, France and Italy

3.1 Methodology

The initial stages of the empirical analysis involved collecting data sets from the European Institute of Statistics (Eurostat) on digitalization in different sectors of four European Countries: Germany, Spain, France, and Italy. The data were selected based on their completeness, relevance to the thematic scope of the study, and recent relevance to the period 2018-2022. In addition, the samples were selected strategically, considering the distribution across industry sectors and the size of the firms to understand the dynamics of innovation and digitalization.

The analysis is based on a main dataset aggregated for 4 nations over 3 years and includes the following variables:

Enterprises using software solutions, like CRM to analyse information about clients for marketing purposes	Enterprises that provided training to develop/upgrade ICT skills of their personnel
Enterprises where more than 50% of the persons employed have access to the internet for business purposes	3D Printing
Use industrial or service robots	Enterprises Analaysing Big Data from any data sources
Cloud computing services	Enterprises use IoT
Use at least 1 of the AI technologies	
Total turnover - mln euro	Total Value Added - mln euro

The last two variables examined (Total Turnover and Total Added Value) are sum values extrapolated from a dataset comprising the turnover and added value of the following sectors:

- Manufacturing (C)

- Electricity, gas, steam and air conditioning supply (D)
- Water supply; sewerage, waste management and remediation activities (E)
- Construction (F)
- Wholesale and retail trade; repair of motor vehicles and motorcycles (G)
- Transportation and storage (H)
- Accommodation and food service activities (I)
- Information and Communication (J)
- Real estate activities (L)
- Professional scientific and technical activities (M)

From this main dataset, four secondary datasets were extracted, each one corresponding to one of the countries involved in the analysis to delve deeper into the country's situation and finally to compare the different countries situations.

The variables underlying these measures were carefully chosen to highlight the critical points in this research. These were metrics on product innovations, process innovations, and the internal company level of digitalization.

Descriptive statistics constitute the most important part of this study's analytical part. Descriptive analysis is a basic tool that helps to understand the data's central distribution and spread in terms of central tendency. The analytical procedures were conducted using statistical software packages (SPSS), ensuring a rigorous examination of the data sets.

The methodology was developed to reflect scientific requirements and adhere to report accuracy and clarity. This detailed methodological documentation encourages a rich engagement with the empirical results presented in the following chapters, contributing to the discourse on digitalization in Italian industries.

3.2 Overview of Company Digitization in the Countries Considered

To better understand the level of digitization in the European countries examined, we wanted to proceed with a descriptive analysis. Descriptive analysis is a crucial step in understanding the distribution and variability of the data in the dataset under consideration. In this section, several statistical measures were considered for each variable, allowing us to get a clear picture of the diffusion of digital technologies and trends in the economic performance of firms in Germany, Spain, France, and Italy between 2018 and 2022.

The main statistical measures considered in the descriptive analysis include:

- **Mean**: The arithmetic mean represents the central value of each variable. It indicates the average level of digital technology adoption by firms. The average helps us understand which technologies are most frequently adopted during the period under consideration.
- **Standard deviation**: The standard deviation measures the dispersion of the data from the mean. A higher value indicates greater variability among the countries or years examined.
- **Minimum** and **Maximum**: These indicators allow us to identify the extremes of the distribution. The minimum value tells us the lowest level of adoption of a given technology or economic performance, while the maximum value represents the highest level.
- **Variance**: Variance is another measure of dispersion that, like standard deviation, gives us information about data distribution, although expressed in square units. High variance reflects high diversity in the economic size of firms in different countries.

These statistical measures provide a detailed overview of the variables' behavior and allow us to identify trends, cross-country differences, and temporal variations. By analyzing mean, standard deviation, and range of values, we can better understand the diffusion of digital technologies and their impact on firms' economic performance.

Below is the aggregate dataset that provides a detailed overview of the adoption of these technologies by country and year.

- Significant differences can be seen across countries, with Germany generally leading in adopting advanced technologies such as cloud computing, rising to 33.3% in 2020 and 47% in 2022. Industrial robots and AI use is also more prevalent in Germany than in other countries, with values growing steadily between 2018 and 2022.
- While following a similar growth trajectory, Spain and Italy show slightly lower adoption rates. For example, the use of CRM for marketing in Italy has remained relatively stable, fluctuating between 15% and 17% between 2018 and 2022, compared to Spain's 29.4% in 2022.
- Another engaging point concerns staff ICT training, which was more prevalent in Germany, with 31.6% of companies involved in 2020, compared to 12.9% in Italy in the same year. This indicates a greater focus of German companies on in-house digital skills development, reflecting a greater awareness of the long-term value of digital technologies.
- Impact on Economic Performance:
  - Aggregate economic performance variables, such as total turnover and total value added, also show significant variability across countries and years.
  - For example, total enterprise turnover ranges from 1.8 trillion euros to over 8.6 trillion euros, while total value-added ranges from 456,290 million euros to over 2.1 trillion euros.

- These values clearly show the different economic size of enterprises in the countries considered and how the adoption of digital technologies can be linked to the growth of economic value.
- In particular, the increase in turnover and value added is particularly evident in Germany, where enterprises tend to adopt advanced technologies such as AI and cloud computing at a faster rate than in other countries.
- This suggests that the adoption of advanced digital technologies can have a direct positive impact on firms' economic performance, contributing to their global competitiveness.

Table 1. First variables set

Variable		Enterprises using software to analyze information about clients for marketing purposes	Enterprises that provided training to develop/upgrade ICT skills of their personnel	Enterprises where more than 50% of the employees access to internet for business purposes	3D Printing	Use industrial or service robots	Enterprises analayzing Big Data from any data sources
Country	**Year**						
Germany	**2018**	25,8	27,8	41,9	4,9	5,	11,7
Spain		25,	22,2	41,4	3,	10,8	7,4
France		17,8	18,9	39,5	3,7	7,8	12,8
Italy		18,4	12,9	33,3	4,4	8,7	5,3
Germany	**2020**	20,3	31,6	48,7	7,3	5,7	14,6
Spain		23,9	21,7	45,1	5,3	8,8	10,7
France		14,7	21,3	45,4	4,2	8,1	18,8
Italy		15,	19,4	39,8	4,7	8,8	8,9
Germany	**2022**	20,	27,3	53,2	8,9	5,2	23,2
Spain		29,4	20,7	52,5	7,2	8,6	18,6
France		16,7	15,1	47,1	6,4	7,3	15,8
Italy		17,	19,3	43,4	5,5	8,7	11,6

Source: Eurostat

Table 2. Second variables set

Variable		Cloud computing services	Enterprises use IoT	Use at least 1 of the AI technologies	Total turnover - mln euro	Total Value Added - mln euro
Country	Year					
Germany	2018	22,4	22,8	8,5	6.554.661,4	1.714.316,9
Spain		22,	17,6	6,7	1.968.025,9	488.570,3
France		19,4	12,	5,8	3.664.215,1	920.412,1
Italy		22,5	23,5	5,5	2.923.884,9	703.648,5
Germany	2020	33,3	35,6	10,6	6.471.866,4	1.688.727,3
Spain		26,2	27,5	7,7	1.819.154,6	456.290,5
France		26,9	22,	6,7	3.482.910,2	890.519,6
Italy		56,1	32,3	6,2	2.621.618,4	646.916,6
Germany	2022	47,	45,5	11,6	8.673.930,1	2.152.026,02
Spain		30,	37,6	9,2	2.540.231,2	589.096,54
France		26,8	31,8	5,9	4.555.850,12	1.087.135,77
Italy		61,4	32,3	5,	3.935.895,12	876.988,86

Source: Eurostat

Descriptive statistics for each technology variable are represented below, providing details on mean, standard deviation, minimum and maximum for each variable.

- The statistics reveal a strong level of variability in business adoption of these technologies, with significant differences across countries and years considered.
- For example, the adoption of CRM solutions for marketing varies between a low of 14.7% and a high of 29.4%, with an average of 20.3%, indicating that in general, a moderate percentage of enterprises use CRM tools to analyze customer data.
- However, other technologies, such as the use of 3D printers and industrial or service robots, show lower levels of adoption (average of 5.4% and 7.7% respectively), suggesting less widespread penetration of these more advanced technologies.
- Cloud computing use, on the other hand, shows a high average of 32.8%, with wide variability ranging from a low of 19.4% to a high of 61.4%, underscoring how this technology is rapidly developing and increasingly central to businesses, especially in the context of accelerated digital transformation.
- Emerging technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) are also gaining ground. AI adoption shows an average of 7.45%, while IoT reaches an

average of 28.3%, highlighting how these technologies are essential to business competitiveness, although their use is still limited in many industries.

Table 3. Descriptive Statistics Overall Country

Statistcal measures	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Variables						
Total Value Added - mln euro	12,	456.290,5	2.152.026,02	1.017.887,41	546.682,31	298.861.549.815,8
Total turnover - mln euro	12,	1.819.154,6	8.673.930,1	4.101.020,28	2.113.305,93	4.466.061.983.157,65
Year	12,	2.018,	2.022,	2.020,	1,7	2,9
Enterprises using software solutions, like CRM to analyse information about clients for marketing purposes	12,	14,7	29,4	20,33	4,68	21,94
Enterprises that provided training to develop/upgrade ICT skills of their personnel	12,	12,9	31,6	21,51	5,28	27,95
Enterprises where more than 50% of the persons employed have access to the internet for business purposes	12,	33,3	53,2	44,27	5,67	32,25
3D Printing	12,	3,	8,9	5,45	1,7	2,9
Use industrial or service robots	12,	5,	10,8	7,79	1,72	2,96
Enterprises Analaysing Big Data from any data sources	12,	5,3	23,2	13,28	5,17	26,81
Cloud computing services	12,	19,4	61,4	32,83	14,12	199,58
Enterprises use IoT	12,	12,	45,5	28,37	9,31	86,69
Use at least 1 of the AI technologies	12,	5,	11,6	7,45	2,11	4,45

Source: SPSS

Overall, this analysis depicts steady growth in digital technology adoption between 2018 and 2022, with significant differences between countries. While Germany emerges as a leader in integrating advanced technologies, other countries such as Spain, France, and Italy are catching up, especially in adopting cloud computing and AI technologies. Adopting these technologies is often correlated with

improvements in economic performance, suggesting that investment in digital technologies is a winning strategy for companies seeking to grow and compete in global markets.

3.3 Case study Germany

Detailed analysis of the descriptive statistics for Germany reveals how German companies have progressively adopted advanced digital technologies between 2018 and 2022. The economic performance, represented by total value added and total turnover, reflects the robustness and steady growth of the German manufacturing fabric, with significant values and some stability, although there is clear variability between the years considered.

Economic variables:

- In particular, total value-added averages around 1,851 billion euros, with a standard deviation of about 260 billion euros, indicating a slight fluctuation year by year. Total turnover, with an average of 7,233 billion euros, shows greater variability, signaled by a standard deviation of more than 1,200 billion euros. This difference could reflect the impact of macroeconomic factors or the continued growth of key sectors such as manufacturing, which is increasingly focused on adopting digital technologies to improve operational efficiency and maintain global competitiveness.

Technological variables:

- From a technology adoption perspective, Germany shows steady growth in several areas. For example, artificial intelligence (AI) adoption has risen from a low of 8.5% in 2018 to a high of 11.6% in 2022, with an average of 10.2%. Although AI adoption is still relatively limited, the stable growth indicates that more and more companies are recognizing the value of this technology in improving decision-making and operational processes.
- Another significant area of growth is the use of the Internet of Things (IoT), which has seen a significant increase from 22.8% in 2018 to 45.5% in 2022. This strong increase reflects the increasing digitization of business operations in Germany, where IoT plays a key role in real-time data management and production process optimization.
- Cloud computing services also experienced significant growth, averaging 34.2% and varying significantly between a low of 22.4% and a high of 47%. This trend highlights the increasing importance of the cloud in managing data and scaling digital infrastructure, especially in a business environment that increasingly requires flexibility and access to large-scale computing resources.
- The adoption of Big Data analytics has followed a similar trajectory, averaging 16.5% and peaking at 23.2% in 2022. German companies are, therefore, investing in advanced data

analytics tools to gain more detailed insights into their operations and improve decision-making, making data-driven innovation a strategic priority.

- Despite growth in many technology areas, the adoption of industrial or service robots has remained relatively stable at an average of 5.3%. This suggests that while it is a promising technology, its use may be limited to specific areas such as advanced manufacturing or automated logistics, but has not reached mass adoption.
- 3D printing, on the other hand, showed slight growth, averaging 7% and varying between 4.9% and 8.9%. Again, this is still an emerging technology, finding application mainly in areas such as engineering and advanced manufacturing, but gaining ground as it becomes more accessible and versatile.
- Germany has shown steady growth in the adoption of CRM solutions for marketing and customer management, with an average of 22% and a maximum increase to 25.8% in 2022. This suggests that companies are investing in digital tools to improve their understanding of their customers and personalize their offers, leveraging the data collected through CRM to optimize marketing strategies.

Table 4. Descriptive Statistics Germany

Statistical measures	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Variables						
Total Value Added - mln euro	3,	1.688.727,3	2.152.026,02	1.851.690,0733	260.413,07101	67.814.967.552,16
Total turnover - mln euro	3,	6.471.866,4	8.673.930,1	7.233.485,967	1.248.147,9195	1.557.873.228.947,06
Use at least 1 of the AI technologies	3,	8,5	11,6	10,233	1,5822	2,503
Enterprises use IoT	3,	22,8	45,5	34,633	11,3808	129,523
Cloud computing services	3,	22,4	47,	34,233	12,3265	151,943
Enterprises Analaysing Big Data from any data sources	3,	11,7	23,2	16,5	5,9808	35,77
Use industrial or service robots	3,	5,	5,7	5,3	0,3606	0,13
3D Printing	3,	4,9	8,9	7,033	2,0133	4,053
Enterprises where more than 50% of the persons employed have access to the internet for business purposes	3,	41,9	53,2	47,933	5,6889	32,363
Enterprises that provided training to develop/upgrade ICT skills of their personnel	3,	27,3	31,6	28,9	2,3516	5,53
Enterprises using software solutions, like CRM to analyse information about clients for marketing purposes	3,	20,	25,8	22,033	3,2655	10,663
Year	3,	2.018,	2.022,	2.020,	2,	4,

Source: SPSS

One of the German companies' most important areas of focus is ICT skills development through staff training. The average of 28.9% of firms that provided ICT training indicates that investment in digital skills is seen as a strategic asset to remain competitive in a rapidly changing market. The slight variation between 27.3% and 31.6% shows that the focus on digital skills growth has remained constant throughout the period analyzed.

In conclusion, the descriptive analysis for Germany shows a country with a strong focus on digitization, with companies adopting technologies such as IoT, cloud computing, and Big Data analytics at an accelerated pace. AI and 3D printing are gaining ground, but still remain at lower levels of adoption. Businesses' commitment to ICT training and the use of CRM tools for marketing shows how Germany is preparing its industry sector for an increasingly technological and competitive future.

3.4 Case study Spain

The statistical analysis for Spain for the period 2018-2022 provides an in-depth picture of the adoption of digital technologies and the economic performance of Spanish companies. I will examine the different variables in detail, highlighting minimum, maximum, average values and observed variability. Economic variables:

- The total value added of Spanish firms shows moderate growth during the period under review. The minimum and maximum values indicate some economic stability, with little change from year to year. However, the standard deviation of about 69 billion euros suggests a significant difference in firms' economic performance, which could be influenced by external economic factors and the progressive adoption of digital technologies.
- Total turnover shows greater variability, with a wide difference between the minimum and maximum. The average of 2.109 billion euros suggests that the turnover of Spanish firms grew during the period under consideration, but the high standard deviation points to strong heterogeneity in the Spanish business sector, which may be due to the size and diversification of firms.

Technological variables:

- Adoption of CRM solutions in Spain increased gradually over the period examined, averaging 26.1%. The small change indicates that companies are implementing tools for data analysis and customer management, although the uptake of these technologies is not yet universal.
- Training in ICT skills showed a moderate increase, with an average of 21.5% of firms investing in digital upgrading for their employees. The low variance suggests that adoption of training programs is homogeneous among Spanish firms, although it remains relatively limited.
- Internet access for work purposes has increased significantly among Spanish firms. The average of 46.3% indicates that nearly half of employees have access to the internet for work purposes, with strong growth between 2018 and 2022, reflecting an increased commitment of firms to digitize their operations.
- 3D printing has shown moderate but steady growth, averaging 5.2%. This technology is still in the emerging adoption phase in Spain, with some companies using it to improve production processes, but its diffusion remains limited.

- The use of industrial or service robots averages 9.4%, with steady growth over time. This figure suggests that Spanish companies are progressively investing in automation, although the uptake of robots is still relatively low compared to other European countries.
- The adoption of Big Data analytics has increased significantly, with an average of 12.2% and a peak of 18.6% in 2022. The relatively high variation highlights that the use of advanced data analysis tools is spreading, but not all enterprises have adopted these methods yet.
- The use of cloud computing services has seen significant growth, averaging 26.07%. This increase reflects the growing importance of the cloud for Spanish enterprises, which are using it for data management and scalability of digital infrastructure.
- Internet of Things (IoT) adoption was notable, averaging 27.6%. The strong variability shown by the 10% standard deviation suggests that this technology is spreading rapidly, but at different rates across sectors and companies.
- Artificial intelligence grew slightly in Spain, with an average of 7.87%. Although adoption is still limited, companies are gradually integrating this technology, especially in innovative sectors.

Table 5. Descriptive Statistics Spain

Statistical measures	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Variables						
Total Value Added - mln euro	3,	456.290,5	589.096,54	511.319,1133	69.263,93323	4.797.492.446,177
Total turnover - mln euro	3,	1.819.154,6	2.540.231,2	2.109.137,233	380.686,4485	144.922.172.063,223
Year	3,	2.018,	2.022,	2.020,	2,	4,
Enterprises using software solutions, like CRM to analyze information about clients for marketing purposes	3,	23,9	29,4	26,1	2,9103	8,47
Enterprises that provided training to develop/upgrade ICT skills of their personnel	3,	20,7	22,2	21,533	0,7638	0,583
Enterprises where more than 50% of the persons employed have access to the internet for business purposes	3,	41,4	52,5	46,333	5,6518	31,943
3D Printing	3,	3,	7,2	5,167	2,1032	4,423
Use industrial or service robots	3,	8,6	10,8	9,4	1,2166	1,48
Enterprises Analyzing Big Data from any data sources	3,	7,4	18,6	12,233	5,7553	33,123
Cloud computing services	3,	22,	30,	26,067	4,0017	16,013
Enterprises use IoT	3,	17,6	37,6	27,567	10,0002	100,003
Use at least 1 of the AI technologies	3,	6,7	9,2	7,867	1,2583	1,583

Source: SPSS

Statistical analysis for Spain reveals that Spanish companies are gradually adopting advanced digital technologies, with moderate but steady growth in several areas. Adoption of CRM, IoT, and cloud computing is becoming more widespread, reflecting a growing commitment to digitization. At the same time, Big Data analytics andartificial intelligence are beginning to take hold, albeit at a slower pace than in other countries. Spanish companies, while showing some variability in the adoption of digital technologies, are gradually integrating innovations to remain competitive in the global market.

3.5 Case study France

In the context of France's digital evolution between 2018 and 2022, progress can be observed through a number of economic and technological variables that reflect businesses' increasing adoption of digital tools.

Economic variables:

- One of the key indicators of this process is Total Value Added, which measures the wealth produced by the economy, in this case by the ICT sector. The growth in Value Added, which ranges from about 890,519.60 million euros to 1,087,135.77 million euros, signals an increasingly significant contribution of the technology sector to the national economy. In parallel, Total Turnover also shows steady growth, rising from 3,482,910.20 to 4,555,850.12 million euros, confirming that the ICT sector is becoming increasingly relevant.

Technological variables:

- The adoption of digital tools is further confirmed by the increase in the number of companies using CRM (Customer Relationship Management) software to improve marketing strategies, from 14.7% to 17.8%. This shows how companies are increasingly relying on customer data to make more informed and personalized decisions. Investment in human capital is also a key driver in digitization. Between 2018 and 2022, the percentage of companies providing training to develop ICT skills increased from 15.1% to 21.3%, reflecting the growing importance of upgrading employees' technology skills to meet digital challenges.
- Another key aspect is connection to the Internet for business purposes. The percentage of companies in which more than 50% of employees have Internet access increased from 39.5% to 47.1%. This figure highlights how access to digital infrastructure is becoming an indispensable basis for the productivity and competitiveness of French companies. Without a stable and widespread connection, it would not be possible to implement other advanced technologies such as cloud computing and the Internet of Things (IoT), which are seeing increasing adoption over the period analyzed.
- The digitization of the manufacturing sector, one of the pillars of the French economy, is reflected in the increased adoption of innovative technologies such as 3D printing and industrial or service robots. Although growth is slower than in other sectors, these technologies are beginning to become increasingly integrated into manufacturing processes, improving operational efficiency and product quality. For example, the use of 3D printing has grown from 3.7% to 6.4%, while

robot adoption has increased from 7.3% to 8.1%. These numbers might seem modest, but they represent a gradual transformation of the industry toward greater automation and precision.

- The figure for companies analyzing Big Data, which rose from 12.8% to 18.8%, highlights how the ability to collect, manage and analyze large amounts of data is becoming increasingly central to companies. The ability to extract strategic information from data enables companies to improve their decision-making, develop new products and services, and enhance the customer experience.
- The use of cloud computing services is another key indicator of ongoing digitization. With the percentage of enterprises using the cloud growing from 19.4% to 26.9%, there is a clear shift toward managing and storing data via the Internet, enabling greater flexibility and scalability of business operations. Similarly, the adoption of the Internet of Things (IoT) increased significantly from 12.0% to 31.8%, signaling that more and more companies are integrating connected devices to improve efficiency and optimize production processes.

Table 6. Descriptive Statistics France

Statistical measures	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Variables						
Total Value Added - mln euro	3,	890.519,6	1.087.135,7	966.022,49	105.946,733	11.224.710.333,3
Total turnover - mln euro	3,	3.482.910,2	4.555.850,1	3.900.991,8	574.323,449	329.847.424.597,3
Year	3,	2.018,	2.022,	2.020,	2,	4,
Enterprises using software solutions, like CRM to analyze information about clients for marketing purposes	3,	14,7	17,8	16,4	1,5716	2,47
Enterprises that provided training to develop/upgrade ICT skills of their personnel	3,	15,1	21,3	18,433	3,1262	9,773
Enterprises where more than 50% of the persons employed have access to the internet for business purposes	3,	39,5	47,1	44,	3,9887	15,91
3D Printing	3,	3,7	6,4	4,767	1,4364	2,063
Use industrial or service robots	3,	7,3	8,1	7,733	0,4041	0,163
Enterprises Analyzing Big Data from any data sources	3,	12,8	18,8	15,8	3,	9,
Cloud computing services	3,	19,4	26,9	24,367	4,3016	18,503
Enterprises use IoT	3,	12,	31,8	21,933	9,9002	98,013
Use at least 1 of the AI technologies	3,	5,8	6,7	6,133	0,4933	0,243

Source: SPSS

The adoption of technologies related to Artificial Intelligence (AI), although in its early stages, increased from 5.8% to 6.7%. This figure represents the beginning of a deeper and more promising transformation for the future, as AI is a technology that can revolutionize the way businesses operate by automating complex processes and improving decision-making.

France has made significant progress on the path to digitization between 2018 and 2022. Businesses are increasingly integrating advanced technologies into their processes, improving both productivity and competitiveness on a global scale. Variables such as value added, turnover, adoption of emerging technologies, and investment in ICT training paint a positive and growing picture, suggesting that the country is embracing the digital revolution in an increasingly systematic way.

3.6 Case study Italy

The analysis of data on business digitization in Italy between 2018 and 2022 provides an important overview of the progress and critical areas related to technology adoption in the national business environment.

Economic variables:

- The Total Value Added of the ICT sector, which ranges from 646,916.60 million euros to 876,988.86 million euros, with an average of about 742,517.99 million, is a key indicator of the wealth produced by the technology sector. The increasing trend of this value shows how the ICT sector contributes significantly to the Italian economy, becoming more and more relevant.
- The Total Turnover of ICT enterprises varies between 2,621,618.40 and 3,935,895.12 million, with an average of 3,160,466.14 million. This figure confirms the continuous development of the technology sector in terms of revenues, indicating a growing market demand for technology services and products.

Technological variables:

- The use of CRM (Customer Relationship Management) solutions by Italian companies for marketing purposes showed an adoption rate ranging from 15% to 18.4%, with an average of 16.8%. This figure is significant as it reflects the increasing use of digital tools to collect and analyze customer data, with the aim of improving marketing strategies and offering more personalized services.
- The percentage of companies that have provided ICT training to their employees ranges from 12.9% to 19.4%, with an average of 17.2%. This figure highlights the importance placed by Italian companies on upgrading employees' digital skills. However, the relatively low percentage suggests that there is still room for improvement to ensure that ICT skills are properly distributed among the workforce, an essential step for complete digital transformation.
- Internet access for business purposes, or the percentage of companies where more than 50% of employees have Internet access, ranges from 33.3% to 43.4%, with an average of 38.8%. Although this figure shows some diffusion of digital infrastructure, a higher percentage would be desirable to ensure that all businesses can take full advantage of the potential of digital and connected technologies.
- The use of 3D printing ranges from 4.4% to 5.5%, with an average of 4.867%. This figure suggests that Italy is beginning to integrate this emerging technology into production processes,

with potential to improve additive manufacturing and reduce the time and cost of new product development.

- The percentage of companies using industrial or service robots is fairly stable, varying from 8.7% to 8.8%. The adoption of robotics represents a step toward automating production processes and increasing efficiency, a positive sign for Italian industry, although there is room for more widespread use of these technologies.
- The percentage of companies using Big Data analytics is between 5.3% and 11.6%, with an average of 8.6%. Although the adoption of advanced analytics technologies is growing, this value indicates that Italy is not yet fully exploiting the potential of Big Data, which could provide crucial strategic information to make more informed and competitive decisions.
- The adoption of cloud computing services has a remarkable variation, with percentages ranging from 22.5% to 61.4%, and an average of 46.667%. This figure is particularly positive and indicates that Italian enterprises are increasingly adopting the cloud to manage and store data, a sign of digital maturity that facilitates scalability and operational efficiency.
- Internet of Things (IoT) usage ranges from 23.5% to 32.3%, with an average of 29.367%. This figure shows that Italian enterprises are beginning to integrate connected devices to optimize business processes and improve operational efficiency, with good scope for adoption in the coming years.
- Adoption of AI-related technologies is relatively low, with percentages ranging from 5% to 6.2%, and an average of 5.567%. Although the level of AI adoption is still limited, there is significant potential for future growth, especially considering the crucial role AI could play in the digital transformation of enterprises, improving automation, productivity and innovation.

Table 7. Descriptive Statistics Italy

Statistics	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Variable						
Total Value Added - mln euro	3,	646.916,6	876.988,86	742.517,9867	119.860,08	14.366.438.950,6
Total turnover - mln euro	3,	2.621.618,4	3.935.895,1	3.160.466,14	688.337,734	473.808.836.523,4
Year	3,	2.018,	2.022,	2.020,	2,	4,
Enterprises using software solutions, like CRM to analyze information about clients for marketing purposes	3,	15,	18,4	16,8	1,7088	2,92
Enterprises that provided training to develop/upgrade ICT skills of their personnel	3,	12,9	19,4	17,2	3,7242	13,87
Enterprises where more than 50% of the persons employed have access to the internet for business purposes	3,	33,3	43,4	38,833	5,1189	26,203
3D Printing	3,	4,4	5,5	4,867	0,5686	0,323
Use industrial or service robots	3,	8,7	8,8	8,733	0,0577	0,003
Enterprises Analyzing Big Data from any data sources	3,	5,3	11,6	8,6	3,1607	9,99
Cloud computing services	3,	22,5	61,4	46,667	21,0961	445,043
Enterprises use IoT	3,	23,5	32,3	29,367	5,0807	25,813
Use at least 1 of the AI technologies	3,	5,	6,2	5,567	0,6028	0,363

Source: SPSS

Italy has made significant progress in the digitization of its enterprises between 2018 and 2022, especially in the adoption of cloud computing, IoT and robotics. However, there are still challenges ahead, particularly in the areas of ICT training, Internet access in enterprises, and the adoption of advanced technologies such as Artificial Intelligence and Big Data analytics. Accelerating the adoption of these technologies will be crucial to enable Italian businesses to compete on a global scale and to ensure that Italy can reap the full benefits of the digital revolution.

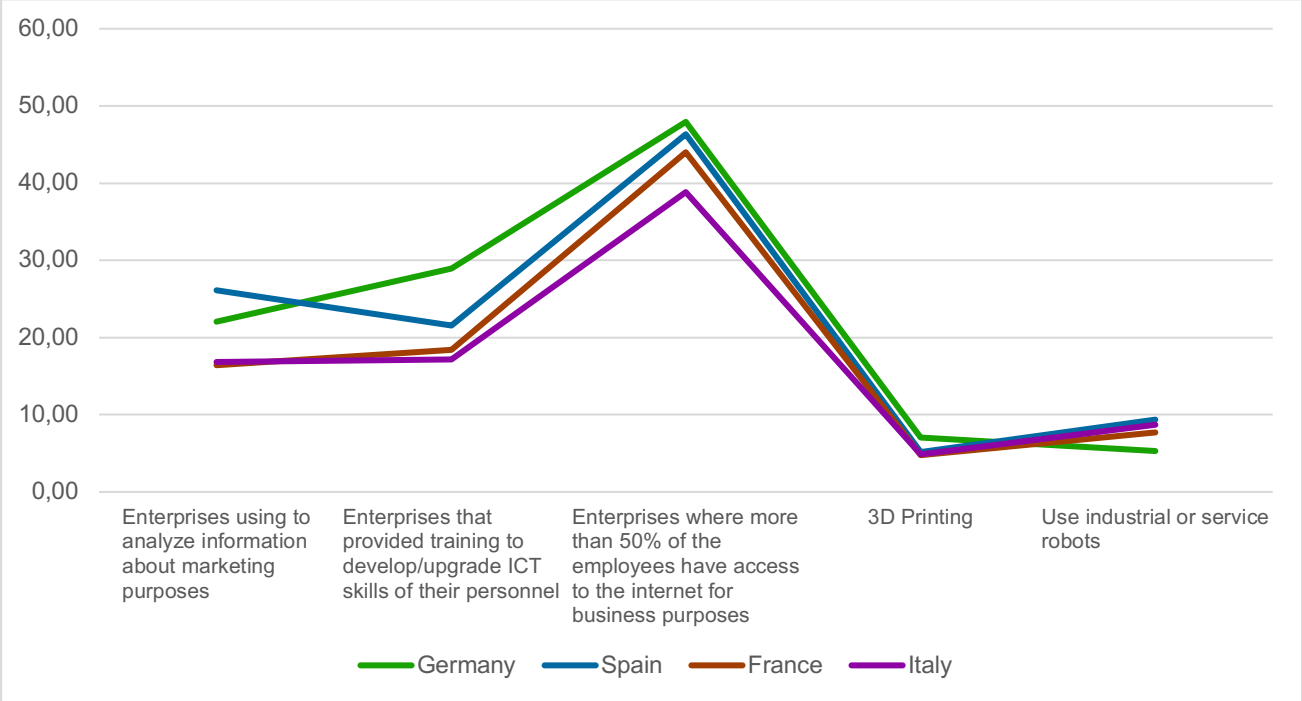
3.7 Comparison of the Digitalization and Industry 4.0 in the different countries

When comparing European countries in terms of digitization, significant differences emerge between Germany, France, Italy, and Spain. Each country excels in some areas while showing room for improvement in others. Let us take a discursive look at the main indicators, trying to outline which country is more advanced in the digitization process and which has made the most progress over time.

- Value Added and Total Turnover

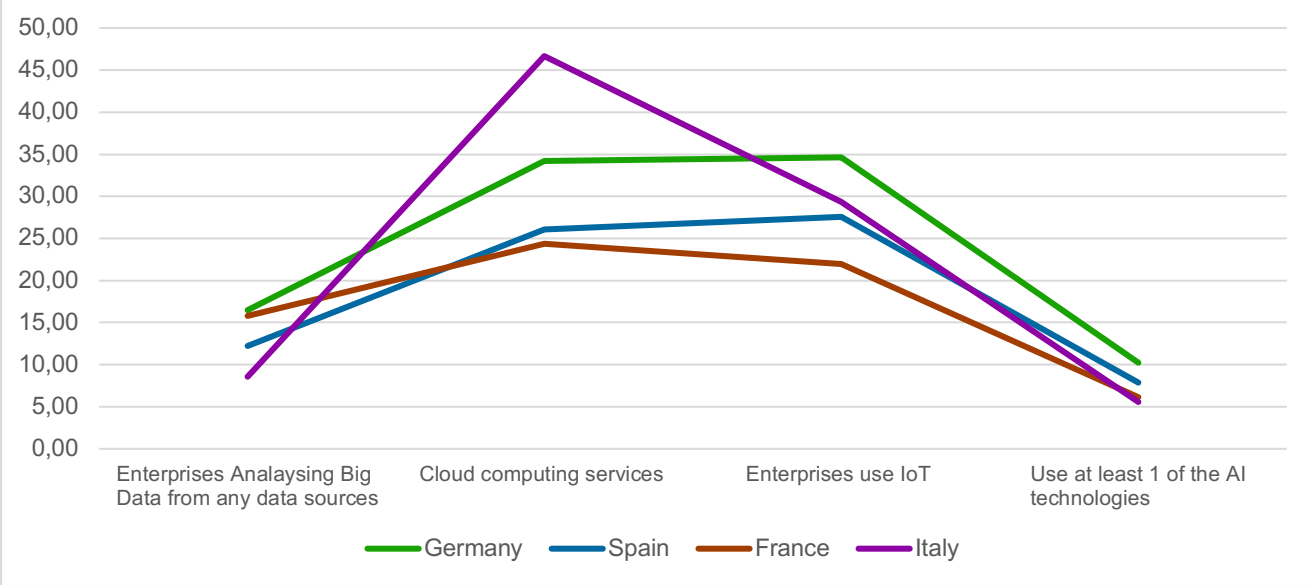
  Germany clearly emerges as the leading country in Total Value Added and Total Turnover in the digital technology sector. With value added ranging from about 1.6 to 2.1 trillion euros and turnover approaching 8 trillion, Germany is the driving force behind European digitization. This high economic value reflects a technologically advanced industrial base and strong demand for digital solutions from Germany's manufacturing sector and businesses. In contrast, Spain, with significantly lower values, shows a lower share of digitization in its GDP, signaling that Spain's technology sector still has large growth margins compared to other countries.

Figure 5. Mean Multiple Linear Graph Digital Technology pt.1



Source: Eurostat

Figure 6. Mean Multiple Linear Graph Digital Technology pt.2



Source: Eurostat

- Another relevant indicator is the adoption of Artificial Intelligence (AI).
  Germany also stands out here, with adoption rates ranging from 8.5% to 11.6%, showing how German companies are investing heavily in technologies that automate decision-making processes and improve operational efficiency. While not as advanced as Germany, Spain follows with slightly lower but still significant percentages, showing a growing interest in AI. Italy and France, on the other hand, lag on this front, with lower adoption rates, signaling that businesses in these countries could benefit from greater integration of AI into their processes.
- Regarding cloud computing, Italy is surprising as a leader, with an average adoption rate of over 46%, surpassing even Germany, which still shows high adoption rates, around 34%. This figure indicates that many Italian companies have recognized the benefits of the cloud, such as operational flexibility and reduced management costs. France, on the other hand, is slightly further behind with an average of around 24%, a sign that French companies may still be exploring the full potential of cloud technologies to improve their scalability.
- The adoption of the Internet of Things (IoT) is another area where Germany stands out, with adoption exceeding 45%, showing how German industries are investing in connected devices to improve efficiency and productivity. Italy also recorded a good level of IoT adoption, averaging around 29%, signaling that the country is working to integrate connected solutions into the production and manufacturing sectors. While having good adoption, Spain lags slightly behind

the levels of Germany and Italy, while France shows lower adoption, confirming that there is still ample room for improvement.

- Regarding Big Data analytics, Germany and France show similar adoption rates, around 16-17%, signaling that both countries recognize the value of data in business management and innovation. However, Spain and Italy lag further behind in this area, with Italy averaging less than 8%, suggesting that Italian companies could benefit from adopting data analytics technologies to improve their competitiveness.
- In the field of 3D printing, Germany once again leads the way, with adoption rates ranging from 4.9% to 8.9%. This reflects the importance of additive manufacturing in German industry, especially in high-tech sectors such as automotive and aerospace. Italy and Spain follow with similar but slightly lower percentages, while France has lower adoption, indicating that the 3D printing sector may still be developing in the country.
- Use of industrial robots

  An interesting finding concerns the use of industrial or service robots. Spain surprisingly emerges as a leader in this field, with an average adoption rate around 9.4%, surpassing both Germany and Italy. This suggests that Spain is making significant steps toward industrial automation, which could lead to higher productivity in the coming years. France shows similar values to Italy, both around 7-8%, while Germany, which has a traditionally strong industrial base, shows unexpectedly lower values, suggesting that the country may be focusing on other forms of technological innovation besides robotics.

  Looking at improvements over the years, Germany has shown continuous progress in almost all key areas, consolidating its technological leadership in Europe. However, it is Italy that has shown the most significant progress, particularly in the adoption of cloud computing, where it has surpassed more advanced countries such as Germany. Spain, while showing increasing adoption in some areas such as industrial robotics, still has a way to go to catch up with other countries in the adoption of technologies such as Artificial Intelligence and Big Data. Finally, France maintains a stable position but has failed to surpass Germany or Italy in any of the key variables, suggesting that the country could benefit from an acceleration in the adoption of advanced digital technologies.

In conclusion, Germany is positioned as the most advanced country in the European digital landscape, thanks to a strong industrial base and the adoption of emerging technologies such as AI and IoT. However, Italy has shown surprising resilience, particularly in the adoption of cloud computing, and could continue to improve in other areas with adequate investment. Spain and France, while showing progress

in some areas, have yet to close the gap with the leaders, focusing mainly on data analytics and artificial intelligence to accelerate their digital transformation.

3.8 Government Policies and Initiatives to Support Industry 4.0

Investments in digital infrastructure aim to transform the country's productive and social fabric, - on the one hand, the expansion of ultra-wide bandwidth and the improvement of connection speeds ensure widespread, high-performance connectivity, which is essential for the development of innovative digital services and for bridging the digital divide. On the other, the development and deployment of 5G networks open up new perspectives for advanced industrial applications, such as smart manufacturing and the Internet of Things, while the encouragement of the adoption of cloud services promotes the scalability and elasticity of IT infrastructures, enabling businesses to adapt more quickly to market changes and reduce operating costs.

On the other hand, training and research represent fundamental pillars for the growth and development of the industrial fabric; we find continuous training programs are aimed at bridging the gap between the skills required by the labor market and those possessed by workers, with a particular focus on the development of the digital skills needed to meet the challenges of technological transformation. Research support, through the funding of innovative projects, stimulates the emergence of new ideas and solutions that can be applied in the industrial world, thus helping to strengthen the competitiveness of businesses. Finally, collaboration between universities and businesses is a driving force for innovation, facilitating the transfer of scientific knowledge from the academic world to the productive environment and accelerating the development of new technologies.

The panorama of tax incentives for digitization and Industry 4.0 is enriched with measures to stimulate investments by companies in the field of digitization and Industry 4.0. These include tax deductions for companies adopting innovative technologies and Industry 4.0 projects aimed at modernizing production processes. At the same time, the provision of tax credits is a further tool to encourage the digitization of business processes. Lastly, to make these opportunities even more attractive, there is a simplification of the administrative burden on companies wishing to undertake innovation paths, thus facilitating access to these incentives.

Cybersecurity represents a very decisive challenge for modern businesses - in fact, the promotion of robust cybersecurity measures is crucial to protect industrial systems from increasingly sophisticated cyber-attacks, thereby protecting business continuity and the confidentiality of sensitive data. It is imperative to make businesses aware of the importance of investing in state-of-the-art security solutions

and to train staff on best practices to prevent and respond effectively to potential cyber threats. Only through a combination of advanced technologies and a cybersecurity-oriented corporate culture can the risks associated with cyber threats be significantly reduced and the resilience of critical infrastructures ensured.

Several European countries have shown a marked propensity to adopt Industry 4.0 technologies, distinguishing themselves through a strategic approach to innovation. Nations such as Germany and France have seized the opportunities offered by this new industrial revolution by investing heavily in research and development. These huge allocations have not only fostered the creation of cutting-edge technologies but have also helped stimulate the emergence of dynamic and collaborative innovation ecosystems, where companies, universities, and research centers work synergistically to develop innovative and sustainable solutions.

Public-private synergies, manifesting themselves in partnerships between governments, businesses and academic institutions, have greatly stimulated the flow of technological innovation. This combination has acted as a catalyst for the large-scale deployment of Industry 4.0 solutions, thus accelerating the digital transformation of production processes and business models, with positive impacts on competitiveness at national and international level.

Many governments have implemented targeted industrial policies to accelerate the digitization process of national enterprises, deploying a range of instruments to incentivize and support this change. The most common measures include tax breaks, low-interest financing, and specific training programs designed to equip companies with the necessary skills to face digital transformation and seize its opportunities.

Digital infrastructures are the indispensable foundation for deploying Industry 4.0 technologies, as the availability of high-speed connections and reliable cloud services is a prerequisite for developing and implementing innovative and automated solutions in production processes. Indeed, the digitization of industrial systems requires a solid infrastructure network capable of supporting the enormous amount of data generated by sensors and intelligent devices while guaranteeing the security and confidentiality of the information exchanged. In this context, cloud computing acts as a key enabler, offering companies the flexibility and scalability they need to manage their data and applications efficiently and cost-effectively.

The implementation of Industry 4.0, characterized by a deep integration between the physical and digital worlds, requires a cultural evolution within companies. A corporate culture that promotes innovation, experimentation, and the adoption of new technologies becomes, in fact, a determining factor for the success of this transformation process. It is only through an open approach to change and constant

investment in training and developing staff skills that companies can fully grasp the opportunities offered by the fourth industrial revolution and consolidate their competitiveness on the global market.

The implementation of Industry 4.0 in Europe, while advancing, still needs to be improved by several critical issues. The digital divide between regions and between large and small companies persists, with the latter often limited by a need for digital skills. Therefore, investments in digital technologies still need to be increased in some countries, slowing down the transition to Industry 4.0. Finally, increasing digitization exposes businesses to new cyber threats, while the automation and digitization of production processes pose significant challenges in terms of employment, requiring policies to retrain and support workers.

Conclusions

This thesis examined the level of enterprise digitization in four European countries (Italy, Germany, France and Spain) over the period 2018-2022, highlighting the key factors influencing the adoption of digital technologies and their impact on business economic performance. The results show how **digitization** represents a crucial opportunity for economic growth and business competitiveness in an increasingly globalized and digitized environment.

One of the central aspects that emerged from the analysis is the **diversity of digital technology adoption** among the countries considered. **Germany** is confirmed as the country with the most advanced level of digitization, thanks to the fastest adoption of technologies such as Artificial Intelligence (AI), cloud computing and the Internet of Things (IoT). This positions Germany as a leader in Europe in the technology sector, directly impacting the growth of business value added and turnover. German companies tend to invest more in staff digital skills, a crucial factor in ensuring effective digital transformation.

While showing significant progress in some areas, such as the adoption of cloud computing (where it ranks among the top countries in Europe), **Italy** has nevertheless shown challenges in closing the digital divide compared to more advanced countries. In particular, the diffusion of advanced technologies such as AI and Big Data analytics has been slower than in other countries, limiting the full growth potential of Italian companies. Lack of adequate digital skills and low adoption of innovative technologies remain among the main obstacles for the digitization of Italian SMEs.

France is in an intermediate position, with a good level of digitization in key areas such as cloud computing and IoT, but shows a lag in the adoption of AI and other advanced technologies. **Spain**, on the other hand, has made progress especially in the adoption of industrial robotics, but lags behind in the adoption of AI-related technologies and data analytics.

It is clear from the analysis that **digitization** has a positive impact on business economic performance, as evidenced by the increase in turnover and value added of companies adopting advanced digital technologies. However, to maximize this impact, it is necessary for businesses, especially in Italy, to invest more in digital skills and innovation processes.

In addition, the role of **government policies** is crucial in supporting business digitization. In Italy, the National Recovery and Resilience Plan (PNRR) and other government initiatives have provided a policy framework to incentivize the adoption of digital technologies, but further effort is needed to ensure that these incentives are accessible and well used by SMEs.

To help accelerate the digitization of Italian businesses, it should be recommended:

1. **Targeted investment in digital skills**, with a focus on training ICT specialists and upgrading workers' skills.
2. **Greater diffusion of advanced technologies** such as AI and Big Data, through policies that facilitate SMEs' access to these technologies.
3. **Continued government support**, with financial incentives and measures that facilitate the adoption of digital technologies even in less developed regions.
4. **Collaboration between businesses and academic institutions** to develop digital innovation projects and strengthen the national technology ecosystem.

In conclusion, digitalization is a crucial element for the future of Italian businesses, and a joint effort between companies, institutions and government will be essential to bridge the digital divide and improve the country's competitiveness in the European context.

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