

# Examining the role of Technology Transfer on Digitalization: Consequences and challenges

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## Abstract

Digitalization has become critical in today's economies as it allows individuals access to resources and capabilities that could not have been accessed without it. However, the development of digital infrastructures is not easy. The digital transition has been recognized as a global challenge in today's societies that need collaboration to get valuable technological assets. This idea has been defined as "technology transfer" (TT) and has been identified as one of the most critical determinants for digitalization achievement. Although there is consensus on the positive side of TT and digitalization, there is anecdotal evidence of the negative part and the challenges that this new paradigm brings. To offer a holistic understanding of the consequences and impact of TT in a digitalized economy, this chapter provides a conceptualization of TT and digitalization, investigates its advantages and disadvantages; shows some applied evidence through the lenses of real cases; and identifies the main challenges and implications that TT and digitalization have on today's society and organizations.

## Keywords

Technology transfer; digitalization; conceptualization; knowledge; advantages; disadvantages; project; collaboration; skills; consequences; challenges; implications; innovation; Industry 4.0; transition; digital transformation; training; digital skills.

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## **1. Introduction**

Digitalization has become critical in today's economies. Globalization has driven to more competitive environments where digital performance and infrastructures are needed to resist ecosystem changes (Lopez-Manuel et al. 2022). In this sense, digitalization allows individuals access to resources and capabilities that could not have been accessed without it (Adebanjo et al. 2021; Del Giudice et al. 2021). Proof of this can be seen in the Covid-19 pandemic, where the necessity of individuals to be connected was completely noticeable under the lockdown (Ferrer-Serrano et al. 2020; World Economic Forum, 2021). But digitalization is not only a must for individuals under extreme events but also for companies (both local and internationalized) who need to compete in global and complex contexts where being well-connected is often a driver to survival (Denicolai et al. 2021).

However, the development of digital infrastructures is not an easy task (Block et al. 2022; Tortorella et al. 2020). The digital transition has been recognized as a global challenge in today's societies that need collaboration to get valuable technological assets (Fini et al. 2023). This idea has been defined as "technology transfer" (TT), and it has been identified as one of the most critical determinants for digitalization achievement (Johnson et al. 2023; Sengupta and Rossi, 2023). Therefore, academics, managers and policymakers have focused on the elaboration of strategies that enable the promotion of digitalization through TT.

Some examples can be found at the European Commission, which has established a roadmap of strategies that foster collaboration between institutions to achieve the digital transformation by 2030 in the form of a Path to the Digital Decade. The latest initiative, Horizon Europe, has increased the funding of its predecessor Horizon 2020, by almost 19

percent. In particular, a total of 413 projects concerning digitalization<sup>1</sup> have been funded to date, amounting to 2.5 billion euros. Countries are also becoming aware of the need to have an adequate TT agency. Germany is making headway in setting up a national TT agency to stimulate the collaboration between universities, research centers and industry, especially for digitalization projects<sup>2</sup>.

Also, managers have shown interest in TT as an enabler strategy that fosters the digital transition. For instance, in March 2023, Amazon and Iberdrola announced a new global collaboration to support the development of large-scale renewable energy projects and leverage cloud computing technology to enhance digitalization in the energy transition<sup>3</sup>. Another example can be found in the Netherlands, where TNO<sup>4</sup> works as an independent research organization that provides infrastructures for potential collaborations for innovation projects. The thematic areas in which they focus include digitalization, as they consider it to be one of the main pillars and challenges for today's society.

Although there is consensus on the positive side of TT and digitalization, there is anecdotal evidence of the negative part, as well as the challenges that this new paradigm brings. To offer a holistic understanding of the consequences and impact of TT in a digitalized economy, this chapter aims to (1) conceptualize TT and digitalization terms, (2) investigate its advantages and disadvantages; (3) show some applied evidence through

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<sup>1</sup> The Digital Europe Programme with a planned overall budget of €7.5 billion (in current prices) will provide strategic funding to answer these challenges, supporting projects in five key capacity areas: in supercomputing, artificial intelligence, cybersecurity, advanced digital skills, and ensuring a wide use of digital technologies across the economy and society, including through Digital Innovation Hubs. In press: <https://digital-strategy.ec.europa.eu/en/activities/digital-programme>

<sup>2</sup> In press:

<https://sciencebusiness.net/news/germany-making-headway-setting-national-technology-transfer-agency>

<sup>3</sup> In press:

<https://nawindpower.com/iberdrola-amazon-partner-to-accelerate-a-cleaner-and-smarter-energy-system>

<sup>4</sup> Corporative website:

<https://www.tno.nl/en/about-tno/mission-strategy/>

the lenses of real cases; and (4) to identify the main challenges and implications that TT and digitalization have on today's society and organizations.

To accomplish these objectives, we have first reviewed TT and digitalization literature to outline the most up-to-date frame. Second, we have explored a collaborative European-funded project developed from 2018-2022 (MATES<sup>5</sup>). Various of the pilot experiences of this project offers key empirical evidence of TT dynamics that allows the exchange of technological resources in order to foster digitalization in the maritime industry. Finally, we have elaborated a list of the main challenges identified in the previous sections, offering both academic and practical evidence and implications for policy makers and managers.

Therefore, this study contributes to the previous literature offering a better understanding of the TT strategy to foster the digital transition in nowadays complex ecosystems. It also contributes by offering evidence of the consequences and current implications of the real impact of TT on digitalization through the exploration of a European collaborative project based on collaboration dynamics. This double perspective, the theoretical and practical understanding of the phenomenon, has allowed us to finally offer a critical reflection of real challenges and implications to be considered in future research.

This chapter is structured as follows. First, sections 2, 3 and 4 present a review of the main advantages and disadvantages of TT and digitalization. Second, section 5 takes off this academic knowledge into reality through the presentation of applied evidence.

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<sup>5</sup> Project website:  
<https://www.projectmates.eu/>

Finally, section 4 finds some challenges and implications that TT and digitalization drive for today's society and organizations.

## **2. Conceptual foundations: Technology transfer**

According to Bengoa et al. (2020), TT refers to the process of transferring knowledge, discoveries, inventions, and other intellectual property from one agent to another agent for the purpose of further development, commercialization, and/or public use. This can involve the transfer of patents, copyrights, trademarks, expertise, skills, and know-how, as well as the establishment of new ventures. TT is a great driver for innovation and economic growth by making scientific and technological advancements available to a wider audience. It is often facilitated through partnerships between academic institutions, government agencies, and private industry and can take many different forms, including licensing agreements, joint ventures, and spinoff companies. The origins of TT can be traced back to the industrial revolution when knowledge and technology were first codified and systematized. In scientific literature, TT finds its beginnings in the 1970s (Bengoa et al., 2020).

TT encompasses a range of activities and mechanisms through which knowledge, skills, and technological innovations are shared and disseminated across various entities, including universities, research institutions, industries, and nations. This process is pivotal in promoting technological advancements, enhancing industrial competitiveness, and fostering economic growth (Bengoa et al. 2020). In the following paragraphs, the individual concepts of TT, including university TT, international TT, intra-firm TT, inter-firm TT, absorptive capacity, and public innovation policies, will be explained while highlighting their interconnectedness. An overview including brief summaries of all concepts can be found in Table 1.

University TT, the most exhaustive and oldest research field, is a critical component of the innovation ecosystem, as it facilitates the commercialization of research outputs generated by academic institutions (Bengoa et al. 2020). This process encompasses various mechanisms such as academic entrepreneurship (Schmitz et al. 2017), licensing (Balconi et al. 2004), spinoffs (Pirnay et al. 2003), research collaborations, consulting, and training services (Siegel and Wright, 2015) or use of TT offices (Siegel et al. 2004). University TT not only propels the adoption of cutting-edge technologies in the market but also fosters relationships between academia and industry, promoting knowledge exchange and enhancing the overall innovation landscape (Bengoa et al. 2020; Ferrer-Serrano et al. 2021).

International TT refers to the cross-border exchange of technological know-how, expertise, and intellectual property. This process can occur through trade, foreign direct investment, licensing, joint ventures, and collaborative research endeavors, with the need for adaptation to local conditions (Aitken and Harrison, 1999). International TT enables countries and organizations to access novel technologies and practices, fostering technological advancements and promoting global economic growth. As sub-categories, transfer at the international level can take place in both intra- and inter-firm contexts (Kotabe et al. 2003). However, these two concepts are not limited to the international context.

Intra-firm and inter-firm TTs refer to the sharing of knowledge, skills, and technology within and between organizations, respectively. Intra-firm TT encompasses the diffusion of best practices, knowledge sharing among departments or teams, and internal training initiatives, which collectively enhance organizational efficiency and innovation capacity (Ferrer-Serrano et al. 2021; Lin et al. 2002). The dissemination of knowledge promoted by organizational culture, formal and informal communication, or

infrastructure (Lin et al. 2002). On the other hand, inter-firm TT involves collaborative efforts between companies, such as joint ventures, research partnerships, and licensing agreements, which facilitate knowledge exchange and foster the development of novel technologies and products (Kotabe et al. 2003).

A vital role in the effectiveness of all types of TT processes has the concept of absorptive capacity. It refers to the ability of an organization or a country to identify, assimilate, and utilize new knowledge and technology from external sources (Zahra and George, 2002). A strong absorptive capacity is contingent upon several factors, including organizational structure, human capital, and prior knowledge. Enhancing absorptive capacity can bolster an entity's capability to adopt and capitalize on novel technologies and innovations, thereby strengthening its competitive advantage (Zahra and George, 2002).

Public innovation policies also span across a wide range of TT approaches, as they encompass government-driven initiatives aimed at encouraging and supporting innovation, research, and TT (Grimaldi et al. 2011). These policies may include research and development funding, tax incentives, intellectual property protection, and support for industry-academia collaboration. Effective public innovation policies can create a conducive environment for TT and innovation, driving economic growth and fostering technological advancements.

These multifaceted concepts of TT and their interactions contribute to the overall innovation ecosystem, while specific contexts and circumstances of TT vary depending on a number of factors, including the type of technology being transferred, the industry or sector involved, the stage of development of the technology, and the nature of the collaboration between agents (Kirchberger and Pohl, 2016). Hence, the effective and appropriate implementation of TT mechanisms, coupled with strong absorptive capacity

and supportive public innovation policies, can significantly enhance technological progress, stimulate economic growth, and promote global sustainability. However, TT can also encompass disadvantages which must be weighed against its advantages. By understanding the different concepts, approaches, and challenges, it is possible to develop a more nuanced and comprehensive understanding of the role of TT in digitalization.

**Table 1.** TT conceptualization

<b>Concepts of TT</b>	<b>Description</b>
University Technology Transfer (University TT)	The process of transferring academic research outputs to the commercial sector fosters innovation and industry-academia collaboration (Bengoa et al. 2020).
International Technology Transfer (International TT)	The cross-border exchange of technology, knowledge, and skills promotes global technological advancements and economic growth (Aitken and Harrison, 1999).
Intra-firm Technology Transfer (Intra-firm TT)	The sharing of knowledge, technology, and skills within an organization enhances internal efficiency and innovation capacity (Lin et al. 2002).
Inter-firm Technology Transfer (Inter-firm TT)	Collaborative efforts between companies facilitate knowledge exchange and foster the development of novel technologies and products (Kotabe et al. 2003).
Absorptive Capacity	The ability of an organization or country to recognize, assimilate, and utilize external knowledge and technology effectively (Zahra and George, 2002).
Public Innovation Policies	Government-driven initiatives that encourage and support innovation, research, and TT to foster economic growth and technological advancements (Grimaldi et al. 2011).

## **2.1. Advantages of TT**

Technology transfer offers numerous advantages that contribute to the growth and development of various sectors while propelling digitalization forward (see Table 2). As companies leverage new technologies and expertise gained through TT, they enhance their competitiveness within their respective industries (João et al. 2020). In this context, TT plays a critical role in bridging the gap between academia and industry by facilitating information transfer (Schmitz et al. 2017). By accelerating commercialization, TT speeds up the process of bringing new products and services to the market. This acceleration, in

turn, stimulates economic growth by fostering innovation and entrepreneurship, ultimately driving economic expansion and job creation (João et al. 2020).

One of the key aspects of TT is the encouragement of collaboration. By fostering knowledge-sharing and cooperation among researchers, institutions, and industries, TT creates a synergistic environment where ideas can be exchanged, and innovative solutions can be developed. This collaborative atmosphere also enhances educational opportunities, as students and researchers gain access to cutting-edge technologies and knowledge from various fields, thereby broadening their horizons and improving the overall quality of research and education (Audretsch et al. 2014).

Fostering entrepreneurship is another significant advantage of TT. The adoption of new technologies often leads to the creation of start-ups and the development of innovative products and services, which, in turn, further drives economic growth and diversification (Schmitz et al. 2017). This entrepreneurial spirit is closely connected to the reduction of global inequalities, as TT provides developing countries with access to advanced technologies, narrowing the gap between developed and developing nations (Audretsch et al. 2014).

TT also enables technology localization, which involves the adaptation of imported technologies to suit the unique needs and conditions of the recipient country. This process not only improves the overall effectiveness of TT efforts but also contributes to the development of more context-appropriate solutions that can address local challenges (Audretsch et al. 2014).

Lastly, TT plays a crucial role in contributing to global problem-solving. By enabling the pooling of resources and expertise from various sources, TT allows for collaborative efforts to address pressing global issues, such as climate change. Through

the combination of these interconnected advantages, TT emerges as a driving force for innovation, global collaboration, and sustainable development, ultimately shaping a more equitable and prosperous world (Kedia and Bhagat, 1988).

**Table 2.** TT advantages

<b>Advantages of TT</b>	<b>Description</b>
Accelerates commercialization	TT speeds up the process of bringing new products and services to the market (João et al. 2020).
Stimulates economic growth	By fostering innovation and entrepreneurship, TT drives economic expansion and job creation (João et al. 2020).
Enhances competitiveness	Companies can leverage new technologies and expertise to gain a competitive edge in their industries (João et al. 2020).
Bridges academia-industry gap	TT facilitates the transfer of knowledge and technology from research institutions to the private sector (Schmitz et al. 2017).
Encourages collaboration	TT fosters knowledge sharing and cooperation among researchers, institutions, and industries (Audretsch et al. 2014).
Enhances educational opportunities	Students and researchers gain access to cutting-edge technologies and knowledge from various fields (Audretsch et al. 2014).
Fosters entrepreneurship	The adoption of new technologies often leads to the creation of start-ups and innovative products/services (Schmitz et al. 2017).
Reduces global inequalities	TT provides developing countries with access to advanced technologies, fostering economic growth (Audretsch et al. 2014).
Enables technology localization	TT facilitates the adaptation of imported technologies to suit the unique needs of the recipient country (Audretsch et al. 2014).
Contributes to global problem-solving	TT enables the pooling of resources and expertise to address pressing global issues like climate change (Kedia and Bhagat, 1988).

## 2.2 Disadvantages of TT

Despite its numerous benefits, technology transfer also presents certain drawbacks that warrant consideration (see Table 3). One significant disadvantage of TT is the risk of becoming dependent on foreign entities for access to key technologies and expertise (Grimes et al. 2014). This dependence can be problematic if the foreign entity decides to withdraw its support or increase its fees. Moreover, the reliance on TT may stifle local innovation and hinder the development of homegrown solutions, leading to reduced incentives for local research and development (Millar and Choi, 2009).

Cultural differences and barriers between the transferring and receiving entities can limit absorptive capacity and make the TT process costly and time-consuming (Choi, 2009). Differences in language, work practices, and management styles can create misunderstandings and delays (Millar and Choi, 2009). Furthermore, the misalignment of goals and objectives between the entities may lead to potential conflicts and inefficiencies, impeding the success of TT initiatives (Choi, 2009).

Intellectual property (IP) leakage is another concern, as TT can lead to unintended sharing of IP, allowing competitors to benefit from the innovation (Ockwell et al. 2010). This issue is closely related to the potential loss of control over key technologies and knowledge, which can occur if the transferring entity does not retain sufficient intellectual property rights or if the receiving entity develops the technology further and becomes a competitor (Ockwell et al. 2010). Reverse TT, wherein the recipient develops superior technology and transfers it back to the original entity, may also diminish the transferring entity's competitive advantage (Millar and Choi, 2009).

Legal and regulatory issues involving complex compliance challenges can further increase costs and delays, exacerbating the overall effectiveness of TT (Ockwell et al. 2010; Kaushik et al. 2014). Additionally, the benefits from TT may not be equitably distributed among stakeholders, leading to disparities and tensions (Millar and Choi, 2009).

Environmental and societal impacts must be considered in the context of TT. Transferred technology may contribute to environmental degradation if not properly managed and regulated, while negative societal consequences may arise from the adoption of certain technologies in the recipient's society and culture (Siegel et al. 2003; Das and Jedlicka, 1993). Ethical concerns, such as the use of technology for potentially

harmful or controversial purposes like nuclear or chemical technologies, must also be taken into account (Phan et al. 2006).

In the academic field, TT can lead to the exploitation of academic research for commercial gain without proper compensation to the academic institution or researchers (Karnani, 2013). This can result in an overemphasis on the commercial viability of research, potentially overshadowing scientific merit or societal impact and narrowing the research focus to commercially viable areas at the expense of more exploratory or basic research (Karnani, 2013).

In conclusion, it is essential to address these potential disadvantages when planning and implementing TT initiatives. By doing so, it may be possible to ensure responsible and ethical TT, maximizing its benefits while minimizing risks and adverse effects.

**Table 3.** TT disadvantages

<b>Disadvantages of TT</b>	<b>Description</b>
Dependence on Foreign Entities	TT can lead to reliance on foreign entities for key technologies and expertise, stifling local innovation (Grimes et al. 2014).
Cultural Differences and Barriers	Differences in language, work practices, and management styles can limit absorptive capacity and create misunderstandings (Choi, 2009; Millar and Choi, 2009).
Misalignment of Goals and Objectives	Different goals and objectives between transferring and receiving entities may lead to conflicts and inefficiencies (Choi, 2009).
Intellectual Property Leakage	TT can result in the unintended sharing of intellectual property, allowing competitors to benefit from the innovation (Ockwell et al. 2010).
Loss of Control over Key Technologies	Transferring entities may lose control over key technologies and knowledge if they do not retain sufficient intellectual property rights (Ockwell et al. 2010).
Reverse TT	Recipients may develop superior technology and transfer it back to the original entity, diminishing its competitive advantage (Millar and Choi, 2009).
Legal and Regulatory Issues	Complex legal and regulatory compliance challenges can increase costs and delays in TT (Ockwell et al. 2010; Kaushik et al. 2014).

Unequal Distribution of Benefits	Benefits from TT may not be equitably distributed among stakeholders, leading to disparities and tensions (Millar and Choi, 2009).
Environmental, Societal, and Ethical Implications	TT can lead to environmental degradation, negative societal impacts, and ethical concerns if not properly managed, regulated, or used for controversial purposes (Siegel et al. 2003; Das and Jedlicka, 1993; Phan et al. 2006).
The exploitation of Academic Research	TT in academia can lead to the exploitation of research for commercial gain without proper compensation (Karnani, 2013).
Overemphasis on Commercial Viability	TT may result in an overemphasis on commercial viability, overshadowing scientific merit or societal impact (Karnani, 2013).

### 3. Conceptual foundations: Digitalization

Digitalization has emerged as a pervasive force that has fundamentally transformed society, economy, and business over recent decades. As a defining trend of the 21st century, it has facilitated the development of new business models, such as e-commerce and the sharing economy, while also enabling previously unimaginable products and services. The influence of this megatrend extends to diverse areas, including entertainment, security features of smart homes, e-healthcare, smart mobility, and smart cities (Gay and Rumpe, 2015). This paradigm shift began in the 1990s and 2000s with the rise of the Internet and mobile computing, driving businesses and organizations to adopt digital technologies, transform their operations, and deliver new value to customers (Ritter and Pedersen, 2020).

However, the term "digitalization" is often used inconsistently, resulting in unclear and unfocused definitions (Hellsten and Paunu, 2020). While some descriptions simply refer to the shift from analog to digital (Hagberg et al. 2016), this fails to capture the full scope of digitalization, particularly from a managerial perspective.

In the business world, digitalization involves using digital technologies and data to create new revenue opportunities, enhance competitiveness, transform business processes, and enable new digital business models centered around digital information

(Gobble, 2018). This comprehensive integration leads to fundamental changes in business operations, customer interactions, and employee engagement (Ritter and Pedersen, 2020).

A wide range of concepts falls under the umbrella of digitalization, with digital transformation and digital disruption being the two significant overarching terms (Vial, 2019; Matt et al. 2015). Digital transformation encompasses the use of digital technologies to improve existing processes and create new ones, while digital disruption involves fundamentally changing industry practices through the creation of new digital business models (Vial, 2019; Matt et al. 2015). All other concepts in the realm of digitalization can be seen as contributing to transformation and/or disruption.

For instance, Industry 4.0, or the fourth industrial revolution, has shaped the business landscape by incorporating digital technologies into manufacturing value chains and processes, thereby enhancing productivity and efficiency (Lasi et al. 2014). This shift aligns with the broader trend of digital transformation. Similarly, digital ecosystems, which represent interconnected networks of digital platforms, products, and services (Barykin et al. 2020), enable companies and individuals to create, share, and consume information and resources. The Internet of Things (IoT) fuels these ecosystems by allowing everyday objects and devices to connect and exchange data through the Internet (Barykin et al. 2020), further driving digital transformation and disruption.

The interconnected nature of digital ecosystems and IoT devices generates vast amounts of structured and unstructured data, known as Big Data (Roy and Roy, 2019). The analysis and management of Big Data, which leads to insights and informed decision-making, is a crucial aspect of digital transformation. Artificial Intelligence (AI) and Machine Learning, as a subset of AI, play vital roles in processing this data and automating decision-making processes across industries (Cubric, 2020).

Augmented Reality (AR) and Virtual Reality (VR) are immersive technologies that enhance user experiences and interactions, enabling businesses to create new products and services that merge digital and physical worlds (Ribaupierre and Eagleson, 2017). These technologies can contribute to both digital transformation and digital disruption. Blockchain technology, a decentralized and distributed ledger system, has the potential to revolutionize industries by securely recording and verifying transactions across multiple computers (Reyna et al. 2018). This innovation disrupts traditional transaction models and promotes more transparent and secure processes. Lastly, cybersecurity is essential for protecting computer systems, networks, and data from theft, damage, or unauthorized access in the increasingly digital world (Ten et al. 2010).

Each of these digitalization concepts offers unique insights into how digital technologies are transforming the economy, society, and individual lives (see Table 4). It is crucial to assess their potential for promoting innovation, productivity, and competitiveness, as well as their relationship to TT. Simultaneously, we must consider the challenges and benefits associated with their implementation to develop a more nuanced understanding of digitalization's potential (see Tables 5 and 6).

**Table 4.** Digitalization conceptualization

Concepts of digitalization	Description
Digital Transformation	The process of using digital technologies to improve existing business processes and create new ones (Vial, 2019; Matt et al. 2015).
Digital Disruption	The fundamental change in how business is conducted within an industry through the creation of new digital models (Vial, 2019; Matt et al. 2015)
Industry 4.0	The incorporation of digital technologies into manufacturing value chains and processes to enhance productivity (Lasi et al. 2014).
Digital Ecosystems	Interconnected networks of digital platforms, products, and services enable information and resource sharing (Barykin et al. 2020).
Internet of Things (IoT)	The interconnection of everyday objects and devices through the Internet enables them to send and receive data (Barykin et al. 2020).

Big Data	The analysis and management of vast amounts of structured and unstructured data to derive insights and make informed decisions (Roy and Roy, 2019).
Artificial Intelligence (AI) and Machine Learning	The development of computer systems capable of performing tasks that would typically require human intelligence and the teaching of computers to learn, adapt, and make decisions based on data inputs (Cubric, 2020).
Augmented Reality (AR) and Virtual Reality (VR)	The overlay of digital content onto the physical world and immersive, simulated environments created by computer-generated graphics allow users to experience and interact with virtual and enhanced worlds (Ribaupierre and Eagleson, 2017).
Blockchain	A decentralized, distributed ledger technology that securely records and verifies transactions across multiple computers (Reyna et al. 2018).
Cybersecurity	The practice of protecting computer systems, networks, and data from theft, damage, or unauthorized access (Ten et al. 2010).

### **3.1 Advantages of Digitalization**

First and foremost, digitalization has significantly increased efficiency and productivity for businesses by enabling the automation of numerous processes (Parviainen et al. 2017). Through automation, tasks that previously required substantial time and effort can be completed more quickly, leading to cost savings and improved productivity. This increased efficiency often translates into reduced costs for both businesses and consumers, as physical infrastructure and paper-based processes are rendered obsolete (Parviainen et al. 2017).

The enhanced efficiency brought about by digitalization also impacts collaboration and communication within organizations, allowing employees to work together effectively across geographical distances and time zones (Parviainen et al. 2017). This interconnectedness fosters increased productivity and the sharing of ideas, which in turn drives innovation. As a result, businesses can develop new products, services, and business models that set them apart from competitors while simultaneously improving customer experiences (Parviainen et al. 2017).

Improved access to information and services is another notable advantage of digitalization in a business context (Parviainen et al. 2017). By making resources more readily available, digitalization promotes greater participation in the economy and society, leading to increased employment opportunities in fields such as software development, data analysis, and digital marketing (Bresciani et al. 2021).

The interconnected nature of digitalization is further exemplified by its impact on data management. With the ability to collect, store, and analyze large volumes of data, businesses can make more informed decisions and identify new opportunities for growth (Raptis et al. 2019). This advantage feeds into the broader theme of increased economic growth, as digitalization drives productivity, efficiency, and innovation within organizations (Parviainen et al. 2017).

Greater agility and flexibility are other benefits derived from digitalization, allowing businesses to adapt quickly to changing market conditions and customer needs (Parviainen et al. 2017). This responsiveness is crucial for maintaining relevance in an ever-evolving business landscape. Furthermore, digitalization contributes to a reduced environmental impact by minimizing paper-based processes, enabling sustainable business models and remote work, which helps businesses lower their carbon footprint (Gensch et al. 2017).

**Table 5.** Digitalization advantages

Advantages of digitalization	Description
Increased efficiency and productivity	Automation of processes enables faster task completion, leading to cost savings and improved productivity for businesses (Parviainen et al. 2017).
Enhanced collaboration and communication	Digitalization allows employees to work together effectively across distances and time zones, fostering innovation and productivity (Parviainen et al. 2017).
Improved access to information and services	Digitalization promotes greater participation in the economy and society, creating new employment opportunities in various fields (Parviainen et al. 2017).

Increased employment opportunities	Digitalization creates new job opportunities in fields like software development, data analysis, and digital marketing (Bresciani et al. 2021).
Impact on data management and growth opportunities	The ability to collect, store, and analyze large volumes of data helps businesses make informed decisions and identify new growth opportunities (Raptis et al. 2019; Parviainen et al. 2017).
Greater agility and flexibility	Digitalization enables businesses to adapt quickly to changing market conditions and customer needs, maintaining their relevance in an ever-evolving landscape (Parviainen et al. 2017).
Reduced environmental impact	Digitalization minimizes paper-based processes and enables remote work, helping businesses lower their carbon footprint (Gensch et al. 2017).

### 3.2 Disadvantages of Digitalization

One significant disadvantage is the increased reliance on technology, which can create vulnerabilities and expose businesses to the risk of cyber-attacks and other security threats. As organizations become more dependent on digital systems, the potential consequences of technological failures and security breaches can have severe financial and reputational implications (Dalcher, 2007).

Technological obsolescence presents another challenge for businesses in the rapidly evolving digital landscape. Companies that have invested heavily in now-obsolete technologies may face financial difficulties and struggle to keep up with competitors who have adopted more advanced systems (Mellal, 2020). This issue is compounded by the disruption of traditional industries and the displacement of jobs resulting from automation and artificial intelligence (Skog et al. 2018). While digitalization can lead to increased efficiency and productivity, it may also cause job losses within a company, leading to workforce-related challenges and potential negative public perception (Braxton and Taska, 2023).

Digitalization can also introduce complexity and confusion, particularly for employees who are not familiar with the technology or lack the necessary digital skills. This can hinder the adoption of new technologies within an organization, resulting in

inefficiencies and an inability to fully capitalize on the potential benefits of digitalization. Consequently, companies may face challenges in addressing the digital divide among their workforce, which can exacerbate existing inequalities and hamper overall productivity (Cullen, 2001).

Privacy concerns represent another significant drawback of digitalization for businesses. As companies collect and use personal data, they face risks if sensitive information is compromised (Elmaghraby and Losavio, 2014). While improved data management can lead to better decision-making, it can also raise concerns about data privacy and security, which can result in legal and reputational consequences (Elmaghraby and Losavio, 2014).

While digitalization can contribute to reduced environmental impact in some respects, such as by minimizing paper-based processes and enabling remote work, it also has negative consequences for the environment (Romero et al. 2018). Digitalization can lead to increased energy consumption and electronic waste production, which can negatively impact a company's corporate social responsibility efforts and affect its public image (Romero et al. 2018).

Lastly, digitalization can contribute to the dissemination of disinformation and misinformation, particularly through social media platforms (Ciampaglia, 2018). For businesses, this can have negative effects on brand reputation and trust, ultimately undermining the potential benefits of improved customer experiences and communication.

By examining the conflicting aspects of digitalization and acknowledging the interconnectivity of its advantages and disadvantages, businesses can develop strategies and policies that maximize the benefits of digitalization while minimizing its drawbacks.

**Table 6.** Digitalization disadvantages

<b>Disadvantaged of digitalization</b>	<b>Description</b>
Increased reliance on technology	Greater reliance on technology exposes businesses to vulnerabilities, such as cyber-attacks and security threats, which can have financial and reputational implications (Dalcher, 2007).
Technological obsolescence	Rapid advancements can render existing technologies obsolete, challenging businesses that have invested in them and affecting competitiveness (Mellal, 2020).
Disruption of industries and job displacement	Digitalization can lead to job losses within companies, resulting in workforce challenges and potential negative public perception (Skog et al. 2018; Braxton and Taska, 2023).
Complexity and confusion	The proliferation of digital technologies can create complexity and confusion for employees, hindering technology adoption and hampering overall productivity (Cullen, 2001).
Privacy concerns	Digitalization raises privacy concerns as businesses collect and use personal data, potentially resulting in legal and reputational consequences (Elmaghraby and Losavio, 2014).
Environmental impact	Digitalization can contribute to increased energy consumption and electronic waste, negatively impacting corporate social responsibility and public image (Romero et al. 2018).
Disinformation and misinformation	Digitalization can contribute to the spread of disinformation and misinformation, negatively affecting brand reputation and trust (Ciampaglia, 2018).

#### **4. The role of technology transfer in digitalization**

TT plays a crucial role in the digitalization process by facilitating access to innovative technologies and expertise. Therefore, TT accelerates the pace of digitalization, not only for companies but for education and research centers, as well as administration and governments – basically – the whole society.

One primary domain where TT significantly contributes to digitalization is the expansion of digital infrastructure and connectivity. For example, the dissemination of mobile technologies from developed to developing countries has increased access to digital services, such as e-commerce, e-government, and e-health (Audretsch et al. 2014).

In addition to infrastructure, TT fosters the growth of digital skills and knowledge. The exchange of training programs and best practices in fields such as data analytics,

cybersecurity, and digital marketing enables companies to develop the expertise required to excel in the digital economy. Therefore, TT can also counterbalance disadvantages like complexity and confusion inherent in digitalization (Audretsch et al. 2014).

Moreover, TT can catalyze the development and adoption of cutting-edge digital technologies, such as artificial intelligence (AI) and blockchain. Through TT, companies gain access to the latest research, breakthroughs, and best practices from leading institutions and experts in these rapidly evolving fields. This access enables them to incorporate advanced technological solutions into their operations and product offerings, thereby maintaining a competitive edge in the market (João et al. 2020).

However, as mentioned in Sections 2.2 and 3.2, both TT and digitalization entail difficulties. TT in the context of digitalization presents potential challenges, such as substantial cultural and language barriers (Choi, 2009; Millar and Choi, 2009), discrepancies in regulatory frameworks (Ockwell et al. 2010; Kaushik et al. 2014), and intellectual property rights (Ockwell et al. 2010). Additionally, concerns regarding data privacy and security may arise when transferring digital technologies across borders (Elmaghraby and Losavio, 2014).

Despite these challenges, TT remains an essential driving force for digitalization. By encouraging the development and adoption of new digital technologies, enabling the exchange of digital infrastructure and skills, and bolstering the expansion of digital ecosystems, TT can help unlock the full potential of the digital economy while attending to the advantages and disadvantages associated with digitalization.

## **5. Real evidence of TT on digitalization: the MATES project**

Previous sections have shown how collaborative projects are a pathway to foster TT in key industry sectors. The formulation of strategies that address the main drivers of

change and which includes practical experiences enables the development of the technical and transversal skills required by the labor market. The identification of needs and challenges from which specific action lines can be drawn up paves the way for testing the resulting innovative actions. Processing and analysis of this test, their results and their impacts give a solid basis for robust recommendations which can be widely disseminated, thus contributing to the enhancement of industrial processes and technologies. The labor market in the maritime sector, in common with many other relevant European sectors, faces several current and future challenges, such as the digitalization of industrial processes, geopolitical and socioeconomic changes and a fair and inclusive transition for climate neutrality, among others.

In this context, the European-funded project MATES ("Maritime Alliance for fostering the European Blue Economy through a Marine Technology Skilling Strategy"), implemented from January 2018 to April 2022, provides genuine practical evidence as to how the technology knowledge transfer can boost digitalization and green practices. The project was developed within the framework of the European Commission's Blueprint<sup>6</sup> for sectoral cooperation on skills, an instrument to tackle skills shortages and deliver specific skills solutions through sectoral partnerships. Since the beginning of this program in 2018, twenty-eight projects have been funded from different strategic sectors, including automotive, additive manufacturing, tourism, health and cybersecurity, among others. In this particular scenario, the MATES project brought together a wide network of multidisciplinary experts encompassing the quadruple helix, coming from industry, public administration, education and training institutions and trade unions. The ensuing sharing of knowledge and expertise between these different actors enabled the MATES

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<sup>6</sup> Blueprint for sectoral cooperation on skills:  
<https://ec.europa.eu/social/main.jsp?catId=1415&langId=en>

project to create flourishing collaborations, which facilitated the introduction of innovative practices, aiming for a more interconnected and dynamic Blue Economy. Whereas the MATES project tackled a wide variety of aspects, reskilling and upskilling of the workforce in the use of digital technologies was understood to be one of the main pillars driving progress toward a more efficient, safe, and sustainable maritime industry. Leveraging technology and promoting its transference was a critical part of this effort.

The effective introduction of technologies throughout the value-chain requires trained human resources, but there is nevertheless often a mismatch between the industry needs and the available training. With the aim of bridging this gap, the project designed a marine technologies skills strategy dealing with challenges such as the lack of qualified staff or generational replacement.

### **5.1. Methodological approach**

The methodological approach of the project applied the Deming cycle<sup>7</sup>, which is based on four steps for continuous improvement, Plan-Do-Check-Act, and was articulated through agile management methodologies as defined by Rasnacis and Berzisa (2017). Overall, this approach was applied to enhance knowledge, visibility, scalability and transference, aiming for the development of the technical skills required by the European maritime industry that ultimately promote employability and economic growth.

After analyzing the skills supply and demand in Europe for the two sectors addressed, i.e., shipbuilding and offshore renewable energy, the main lines of action were selected. This served as the basis upon which eleven Pilot Experiences were planned and implemented to help the acquisition and/or improvement of the skills most in demand in these industries. Each Pilot Experience worked as a project itself, with a specific design

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<sup>7</sup> Deming cycle: <https://deming.org/explore/pdsa/>

to match training to the needs of technical disciplines. Following this course of action, the transfer of technological knowledge was achieved by:

- Delivering training courses and materials where technological knowledge was transferred through case studies and lessons learned on artificial intelligence, mechatronics, 3D printing, IoT, cloud computing and big data.
- Promoting cooperation between education, research centers and companies to simulate industrial spaces and create materials and equipment for quality and practical learning. Virtual reality, robotics, and other immersive technologies were developed to provide realistic training experiences to both students and maritime professionals (work-based learning, life-long learning).

**Table 7.** Pilot Experiences developed in the MATES project. Detailed information can be found on the project website *Compilation of Layman Reports*<sup>8</sup>

Type of experience	Pilot Experience	Participants
Online Training Materials	Education and Training for Data-Driven Maritime Industry.	Industry and Higher Education (HE) students
	Two Massive Online Open Courses on Industry 4.0 and the naval sector.	Industry, HE and Vocational Education Training (VET) students
Simulation of industrial spaces	Building an offshore wind jacket in order to promote industry-led techniques.	VET students
	Fitting out a shipyard replica for workshop training: design, construction, painting and equipment.	VET students
Training programs enhancing collaboration between academia and industry	Specialization course on innovation management for Shipbuilding.	Recently graduated university students.
	Additive Manufacturing and Risk Management in Shipbuilding and Ship Repair: upskilling and reskilling on green technologies.	Industry, HE and VET students.
	Training on marine renewable energy (wave and tide) and Training of Trainers in offshore wind energy.	Industry, HE students and VET teachers

<sup>8</sup> MATES Project website. Compilation of the Pilot Experience Layman Reports. <https://www.projectmates.eu/wp-content/uploads/2022/06/D4.2-COMPILATION-OF-LAYMANS-REPORTS.pdf>

Blended Transversal Learning	Training and audio-visual material in the framework of a competition environment. Engagement with educational centers.	Secondary Education (SE) and VET students and teachers.
	Short-term course on knowledge exchange between workers from traditional sectors and early-career youngsters. Educational challenges both "on board" and "on the pier."	SE and VET students, industry, scientists
	Mobility to exchange green technologies in order to develop a methodology adapted to the strategic needs of the organizations.	VET and HE students and teachers.
Recognition of skills and emergent professions	Definition of new Occupational Profiles: update of skills and occupations in the Offshore Renewable Energy and the Shipbuilding sectors, following ESCO <sup>9</sup> taxonomy.	Industry, VET and HE teachers.

## 5.2. Practical examples of digitalization

Although technological development and its transfer to different areas of the maritime industry played an important role in all Pilot Experiences, three of these were more focused on digitalization. Greater detail is provided below to explain the objectives and impact of these Experiences.

### 5.2.1. Education and Training for Data-Driven Maritime Industry -ED2MIT-

Innovative technologies, machinery and services require digital applications and data management at various stages of the processes. This experience identified a set of digital and data competences to develop training materials based on European recommendations DigiComp<sup>10</sup> and EntreComp<sup>11</sup>. Next, four training modules were prepared in line with the Data Management Body of Knowledge<sup>12</sup> and delivered online. 117 participants from nine different countries learned about:

- Data-related competencies and technologies

<sup>9</sup> European Skills/Competencies, qualifications and Occupations (ESCO). European Commission website: <https://ec.europa.eu/social/main.jsp?catId=1326&langId=en>

<sup>10</sup> DigiComp - Digital Competence Framework for Citizens. European Commission website: [https://joint-research-centre.ec.europa.eu/digcomp\\_en](https://joint-research-centre.ec.europa.eu/digcomp_en)

<sup>11</sup> EntreComp - Entrepreneurship Competence Framework. European Commission website: [https://joint-research-centre.ec.europa.eu/entrecomp-entrepreneurship-competence-framework\\_en](https://joint-research-centre.ec.europa.eu/entrecomp-entrepreneurship-competence-framework_en)

<sup>12</sup> Data Management Body of Knowledge – DMBOK, provides a basis for training on industrial Data Management and Governance and corresponding certification program <https://www.dataversity.net/what-is-the-data-management-body-of-knowledge-dmbok/>

- Cloud services and cloud economics
- Digital content creation, access and management
- Data Science and Big Data Analytics

The 43 hours of training demonstrated how these concepts could be applied in the Blue Sector throughout the technology's lifecycle from data collection, input/ingest, preparation, processing/analysis to visualization, and finally, data-driven decision-making. The course provides attractive content that, at that time, was not easily accessible to the maritime sector (because either they were not free or had not been adapted to the audience).

#### ***5.2.2. Two Massive Online Open Courses on Industry 4.0 and the naval sector.***

Bridging the existing gap between what is taught in centers of education and the real needs of the companies themselves motivated the development of this Pilot Experience. It focused on the analysis of new learning tools for reskilling and upskilling the engineering employees of the shipbuilding industry. Two Massive Open Courses (MOOCs) were prepared from the academic and industry perspective and delivered to engineering staff and VET students from five different countries.

1. Integration of Industry 4.0 with Shipbuilding: 20 hours of training where 392 participants learned about the application to Shipbuilding of 4.0 technologies (Internet of Things, Big Data, Data Analytics and Data Mining, Augmented Reality or Mixed Reality systems, Additive Manufacturing or 3D Printing, Cybersecurity, Collaborative Robots and Simulation).
2. Integrated Logistic Support (ILS): 10 hours of training when 40 participants analyzed how ILS is being updated through existing and emerging technologies. In terms of technology development, an Augmented Reality application that enables remote maintenance training was developed.

Stakeholders were invited to collaborate in the design of the training; all involved indicated that they found it relevant to get up-to-date information regarding the latest developments or to refresh engineers' and experts' skills.

This Pilot Experience made a significant contribution to the better alignment of industry needs and occupational profiles, showing by means of the validation of training and education, new pathways for effectively increasing employability and career opportunities.

### ***5.2.3. Building an offshore wind jacket in order to promote industry-led techniques***

The objective of this Pilot Experience was the simulation of industry spaces in VET centers and the construction of innovative devices for training purposes. 60 students involved in the training constructed a small-scale offshore wind jacket, similar to those installed in actual wind farms, using industry standards, cutting-edge automated robot welding and innovative non-destructive testing. The project-based learning method used impacted on the increase of the attractiveness of teaching and learning activities.

The collaboration between the education center and six local adjacent companies generated positive mutual effects: the industrial partners were kept informed of up-to-date procedures and technological standards and the education center trained competent potential future employees. This was identified as a good practice and is useful for other centers seeking to replicate the experience. In this case, digitalization was key to the creation of a virtual reality tool capable of use in painting processes for real-scale jackets. This is a cost-effective solution for providing real industrial situations to train skills in painting, welding and boiler-making, among others.

Outputs of all the Pilot Experiences were made publicly available on the MATES website<sup>13</sup> and the Marine Training Platform<sup>14</sup> and were disseminated at conferences, fairs, visits and by means of direct communications to marine professional companies and associations, the research community, and education centers.

### **5.3. Difficulties and recommendations**

All things considered, some difficulties were detected that, as noted in section 2.2, should be carefully addressed when transferring technology:

- Low knowledge concerning general computer technologies or experience in working with data applied to management or technological processes (e.g., 50% of the participants in the ED2MIT courses). A minimum entry level should be set for trainings, which would enable participants to successfully follow the courses and acquire the sectoral demanded skills.
- A lack of teachers and professionals with a mastery of both digital and sectoral knowledge can lead to knowledge-transfer constraints.
- The COVID-19 pandemic exposed with more intensity the existing gap between those who have easy, fast, affordable and quality access to knowledge and technology and those who do not.
- Failure to reach the expected participation rates and motivation for upskilling-reskilling to use digital and data technologies with a reasonable degree of competence.
- The current lack of official recognition for the effort of updating contents and skills in curricula can discourage teachers and educational professionals.

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<sup>13</sup> MATES Project website. Compilation of Pilot Experience Results and Impact. <https://www.projectmates.eu/wp-content/uploads/2022/06/D6.5-Compilation-of-PE-results-and-impact.pdf>

<sup>14</sup> Marine Training website: <https://www.marinetraining.eu/home>

- Drawbacks related to IP rights (i.e., confidential engineering drawings, training material, etc.) can complicate the collaboration between education centers and companies.

The MATES project delivered 32 core recommendations (see the adaptation for this chapter in Table 8) addressed to the principal groups of sectoral stakeholders: Policy makers (P), Standardization bodies (S), Social Partners (SP) and Professional Bodies, Education and Training providers (T), and Employers (E). Recommendations were organized in eight strategic areas to reinforce the maritime technologies with the necessary capacities and skill-sets that can enable adaptation to an increasingly digital, green and knowledge-driven economic context:

- Boost Cooperation
- Attract Talent
- Promote Skills Intelligence
- Improve Training Offer
- Offshore Renewable Energy
- Multipurpose Skills
- Active Learning and Mobility
- Digitalization

**Table 8.** Recommendations of the MATES project strategy for digitalization.

Adapted for this chapter.

Recommendations	Stakeholders
Providing training in digitalization for companies: <ul style="list-style-type: none"> <li>○ Using up-to-date digitalization technologies.</li> <li>○ Adapting content and training formats to SMEs' needs.</li> <li>○ Considering online training provisions, MOOCs and blended learning.</li> </ul>	SP T E SP T E E

<p>Promoting ICT (Information and Communication Technologies) adapted for the maritime sector:</p> <ul style="list-style-type: none"> <li>○ Enhancing knowledge and skills transferability.</li> <li>○ Boosting education, training and reskilling inclusive programs which assemble ICT and maritime sectoral experts.</li> <li>○ Organizing awareness campaigns on the benefits of common ICT methods and tools for different sectors.</li> </ul>	<p>P SP P SP P SP</p>
<p>Developing Digital and Data competence frameworks for the maritime industry:</p> <ul style="list-style-type: none"> <li>○ Based on European instruments e.g., EntreComp or DigComp, to provide a common language for describing competences, skills, knowledge and occupations.</li> <li>○ Recommending that company HR departments use EU VET and capacity standards in working with job vacancies, candidate assessments and career management.</li> <li>○ Furthering the revision of existing curricula and courses to ensure the inclusion of Digital and Data skills for specialized courses, professional qualifications, or workplace courses.</li> </ul>	<p>P S SP T P SP SP</p>

The use and exploitation of the project outputs and strategic recommendations were outlined in the MATES Sustainability and Long-term Action Plan. As part of this blueprint of actionable steps, partners formally engaged their involvement for the rollout and the practical application of the results. The expert network which had been created also contributed to the maximum uptake and impact of the strategy. Direct outreach and well-targeted transference of the project results were carried out at national, regional and European levels.

One of the most important mechanisms articulated for achieving this ambitious goal was the building of a large and sound partnership to join the European initiative, the Pact for Skills<sup>15</sup>. In summary, these kinds of projects and instruments are powerful tools to promote a fair and resilient green and digital transition by knowledge and TT.

## 6. Challenges and implications

As mentioned in previous sections, the transference of new digital technologies from academia to society and organizations has transformed the way people live, work,

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<sup>15</sup> Pact for Skills. European Commission website: [https://pact-for-skills.ec.europa.eu/about\\_en](https://pact-for-skills.ec.europa.eu/about_en)

learn, and interact with each other (Vial, 2019). The adoption of digital technologies creates new economic perspectives, increases innovation and opportunities, and influences individuals, industries, and society. Their implementation has increased efficiency and productivity in processes and business operations (Brynjolfsson and McAfee, 2014). Digital transformation has been studied extensively, showing that it has also enabled new business models, enhanced communication and collaboration, the collection and analysis of large amounts of data in real-time, expanded access to education and healthcare, and provided new forms of entertainment and leisure (Verhoerf, 2021).

However, the increasing use of digital technologies has also raised concerns about their impact on productivity, privacy, security, society, and the environment. The impact of digital transformation on business has been examined by practitioners and academics due to the challenge of succeeding in a constantly evolving and competitive environment (Sartal et al. 2022). As such, it is essential to balance the benefits and challenges of digital technologies and ensure they are used responsibly and sustainably.

The significant concerns related to the adoption of digital technologies and their implications have been categorized into two main challenges, namely Technological and Organizational challenges.

**Table 9.** Challenges of adopting new digital technologies

<b>Technological challenges</b>	<b>Organizational challenges</b>
Technical compatibility	Resistance to change
Cybersecurity and Data privacy	Human capital
Digital Divide	Environment

## **6.1. Technological challenges**

### **Technical compatibility**

The continuous evolution of digital technologies makes organizations keep up with the latest advancements to remain competitive. Integrating multiple technologies with existing systems may lead to compatibility issues that jeopardize interoperability. Furthermore, insufficient connectivity may create barriers to effective communication and collaboration and lead to data silos that can undermine operational efficiency, organizational performance, and innovation (Chen et al. 2021). Hence, significant planning and investment are necessary to manage this transition.

In this context, sharing digital resources can provide numerous benefits. It can contribute to overcoming the mentioned barriers by improving interoperability, and allowing different systems to communicate and work together seamlessly (Laudon and Laudon, 2018). By sharing resources such as hardware, software, and databases, organizations can reduce overall costs and optimize resource utilization instead of investing in their own separate systems and infrastructure. This approach can be particularly beneficial for small and medium-sized organizations with limited resources to invest in proprietary systems. Furthermore, sharing resources can enhance the flexibility and scalability of digital infrastructure, enabling organizations to adapt to changing needs and demands (Zhang and Fan, 2021). This kind of collaboration among organizations can enable the pooling of resources, the transference of knowledge, and the sharing of expertise to foster the development of innovative products and services (Bocken et al. 2014). Furthermore, collaboration can present new opportunities for growth and expansion to new markets, customers, and business models, which may not be possible through individual efforts in a fast-evolving digital landscape (Fobbe and Hilletofth, 2021).

## **Cybersecurity and data privacy**

The increasing adoption of technologies such as cloud computing and artificial intelligence (AI) is transforming how organizations use, share, and store information. While these technologies offer many benefits, such as increased efficiency, improved decision-making, and reduced costs, their implementation can raise ethical concerns regarding the integrity and confidentiality of data (Rodrigues et al. 2022). For example, cloud computing allows organizations to access their data and applications from anywhere with an internet connection. However, sensitive information is often stored outside the organization's physical location (Chen and Chen, 2021). On the other hand, AI is increasingly being used to analyze vast amounts of data and identify patterns, providing valuable insights for business decision-making. However, the lack of transparency of algorithms in data processing raises concerns about the presence of biases and errors that could lead to unfair or discriminatory applications (Davenport et al. 2019; Vinuesa et al. 2020).

Security and privacy concerns represent some of the organization's most significant challenges when adopting digital technologies. According to the State of Chief Information Managers (CIOs) Survey by Foundry (2023), Security management was rated as the top activity in which CIOs focus their time and expertise by 47% of the respondents. Moreover, the need for security improvements was cited as the first reason for tech budgets to increase in 2023.

The integration of multiple technologies and systems can heighten the risk of cyber-attacks and data breaches, making it imperative to invest in robust cybersecurity measures to safeguard their data (Kshetri, 2018; Siponen and Vance, 2010). As mentioned before, organizations must ensure that the integration of digital technologies with their existing systems does not compromise the confidentiality, integrity, and availability of

their data (Kshetri, 2018). It is paramount to ensure privacy and security, including implementing robust cybersecurity measures and complying with applicable laws and regulations. Moreover, organizations should also consider partnering with cybersecurity experts to help identify and address potential threats and vulnerabilities (Trim and Lee, 2021).

### **Digital divide**

In a globalized world, digital networks are crucial to providing an infrastructure that enables the development of strategies for enterprises and organizations for collaboration, exchange of information and knowledge, and foster development.

The COVID-19 pandemic is considered a significant driver of the acceleration in the adoption of modern technologies and the transformation in lifestyle, work patterns, and business strategies (Amankwah-Amoah et al. 2021). However, according to the International Telecommunication Union (ITU) (2021), there are still almost three billion people around the world (37%) that have never used the Internet. The data from ITU confirm that the capacity to connect is severely unequal. Over 2.9 billion people worldwide still do not have internet access, 98% of whom live in developing countries. The ITU estimates that \$28 billion is needed to connect the remaining unconnected to the Internet by 2030.

The inequalities of certain groups without access to Information and Communication Technologies (ICTs) have been particularly evident during the pandemic, where those without stable internet connections and appropriate devices have been disadvantaged (Lai and Widmar, 2021). The unequal distribution of access to and use of digital technologies, known as the digital divide, can result in significant economic and social disadvantages hindering the ability of certain groups to fully participate in

digital activities such as online education and remote work (Lythreatis et al. 2022). In this sense, four main gaps have been identified: 1) the usage gap occurs when individuals lack sufficient digital skills to use ICTs, hindering their ability to perform everyday tasks; 2) the access gap is due to specific population groups being unable to access ICTs, primarily due to socioeconomic inequalities; 3) the generation gap is characterized by older populations having low digital skills; 4) the digital gender gap leads to women having reduced access to ICTs and choosing fewer STEM careers (UNCTAD, 2021).

The consequences of the digital divide include social isolation, difficulties accessing education and work, heightened social and geographical differences, and increased vulnerability to digital crime (WEF, 2021). International organizations, such as the OECD, UN, and UNESCO, are working to ensure equal access to digital opportunities and reduce inequalities among different groups.

As it was experienced during the MATES project, bridging the digital divide requires addressing four key areas: infrastructure, affordability, institution framework, and digital literacy. Governments can reduce licensing costs and taxes and improve investment regulations to pave the way for the private sector. Research and development in the tech industry can help reduce costs and increase the efficiency of ICT services (WEF, 2021).

## **6.2. Organizational challenges**

### **Resistance to change**

Adopting new and disruptive technologies involves significant changes in essential company areas, such as processes or organizational culture, which can be unsettling. In addition, when considering the future of digitalization, there is a notable controversy surrounding its impact on productivity and jobs. Psychological and social

factors such as fear of job loss due to automation and digitization of tasks, comfort with the old system, resistance to learning, or lack of involvement in decision-making are triggers for reluctance to change during a digital transition (Zoppelletto et al. 2023).

Davenport et al. (2019) have identified five perspectives on the impact of automation. Dystopians believe this will lead to massive unemployment and economic dislocation, while utopians envision unprecedented wealth and productivity. Technology optimists predict a leap in productivity and economic growth but acknowledge that many jobs will be displaced. Productivity skeptics are pessimistic about the potential gains in national productivity levels and optimistic realists believe that productivity gains will match those of previous technology waves, but demand for middle-skill jobs may decrease.

As mentioned, the COVID-19 pandemic has accelerated digital transformation and social acceptance of the transition by increasing remote work and people's willingness to work exclusively in a digital environment. In addition, more people are willing to switch from traditional to digital jobs due to the perceived importance of digital work and its potential for secure income. However, the long-term impact of the pandemic on digital transformation remains a question (Nagel, 2020).

To avoid delays in the implementation of new technologies processes and missed opportunities, it might be recommendable to develop strategies to communicate the benefits of digital transformation and the positive impact that the new technologies adopted will have on work performance. It is also crucial to provide training and support to help workers develop the necessary skills and confidence and involve them in decision-making, creating a sense of ownership and control that allows addressing any fears, concerns, or challenges that arise (Neves et al. 2018).

## **Human capital**

The digitalization of the industry involves the incorporation of innovations such as advanced robotics, AI, hyperconnectivity, or Big Data. These technologies involve significant changes in production processes, transforming not only the nature of employment but also how we work, performed in more interactive and cooperative environments. This fact, together with the growing demand for increasingly specialized and personalized products, directly impacts the necessary skill and competence set required of professionals (Acemoglu, 2019).

UNESCO, in its report "Recommendation on the Ethics of Artificial Intelligence" (2021), emphasizes the necessity of assessing and addressing the impact of digitalization on labor markets, promoting collaboration agreements among governments, academic institutions, vocational education and training institutions, industry, workers' organizations and civil society to bridge the skill-set requirements gap and to ensure a fair transition for at-risk employees.

The literature suggests that while classical professional skills, such as critical thinking, problem-solving, and decision-making, are still necessary, the robotics era has placed more emphasis on technical skills and the ability to work collaboratively with machines (Frey and Osborne, 2017; Brynjolfsson and McAfee, 2014). In fact, according to the results of the survey in "The Future of Jobs Report" of the World Economic Forum (2020), skill shortages are particularly pronounced in emerging professions, i.e., Data Analysts and Scientists, AI and Machine Learning Specialists, or Software and Application Developers.

Furthermore, soft skills like emotional intelligence, adaptability, interpersonal communication, and cross-functional competencies have become more critical than ever

(WEF, 2018). These skills are essential in working collaboratively with machines and handling the evolving work environments that come with the use of robotics. In this context, a "T" model is sought, where a good base of traditional professional skills and a wide range of horizontal skills are combined (Ras et al. 2017). To meet this structural change, the ability to anticipate providing and update the necessary skills and competencies is a crucial factor.

Human resources play a crucial role in the transfer of new digital technologies. Organizations must ensure they have the necessary expertise and resources to implement and maintain the new technology, which may involve hiring new employees, attracting digital talent, or training existing staff on the new technology. Many employers are taking proactive measures to address skills shortages by offering access to reskilling and upskilling opportunities. On average, 62% of employers currently provide such opportunities to their workforce, and an additional 11% plan to do so by 2025 (WEF, 2020). Despite these efforts, employee engagement in reskilling and upskilling courses is reportedly low, with only 42% of employees taking advantage of the training programs offered by their employers. This data suggests that more needs to be done to encourage employees to participate in these opportunities and develop the skills needed to succeed in an ever-changing job market (WEF, 2020).

## **Environment**

The Emissions Gap Report 2021 (UNEP, 2021) warns of the intensifying climate crisis and the need to limit global warming to 1.5°C over pre-industrial levels. The report highlights the difference between predicted greenhouse emissions in 2030 and where they should be to avert the worst impacts of climate change.

The increasing adoption of cutting-edge technologies offers significant benefits, such as increased productivity, improved communication, and greater access to information and even helps to improve ecosystem management and habitat restoration (UNESCO, 2021). However, it also leads to a significant increase in energy consumption with negative environmental impacts. For instance, training and deploying AI models result in the consumption of energy and water and the generation of carbon emissions, whether situated in data centers, the cloud, or at the edge. Amplification in data traffic via novel "data-hungry" applications may also have an adverse impact on energy consumption patterns, culminating in unsustainability (OECD, 2022).

Therefore, there is a need to develop and adopt more energy-efficient technologies, use renewable energy sources to power digital infrastructure, and promote sustainable practices in designing, manufacturing, using, and disposing of digital devices. Additionally, there is a need to raise awareness about the environmental impact of digital technologies and encourage individuals, businesses, and governments to adopt more sustainable practices. With the aim of simultaneously pursuing environmental sustainability and digital transformation, the dual approach of green and digital transition has emerged, known as the twin transition.

According to the World Economic Forum (WEF, 2022), the twin transition approach recognizes a huge and largely untapped opportunity for technology and data to drive sustainability goals. Indeed, digital solutions can reduce global emissions by up to 20% in the three sectors with the highest emissions: energy, materials, and mobility. However, both transitions require a political and societal push to ensure their success, and it is essential to steer and support the digital transition to become an instrument for achieving a fair and just green transition (Muench et al. 2022).

## **7. Final remarks**

This chapter has contributed to the previous literature offering a better understanding of the TT strategy to foster the digital transition in nowadays complex ecosystems. TT plays a crucial role in the digitalization process by facilitating access to innovative technologies and expertise and accelerating digitalization. However, as evidenced in this study, both TT and digitalization entail difficulties. TT in the context of digitalization presents potential challenges, such as substantial cultural and language barriers, discrepancies in regulatory frameworks and intellectual property rights. Additionally, data privacy and security concerns may arise when transferring digital technologies across borders.

In addition to that, it has also contributed by offering evidence of the consequences and current implications of the real impact of TT on digitalization through the exploration of a European collaborative project based on collaboration dynamics. In this sense, TT remains an essential driving force for digitalization. By encouraging the development and adoption of new digital technologies, enabling the exchange of digital infrastructure and skills, and bolstering the expansion of digital ecosystems, TT can help unlock the full potential of the digital economy while attending to the advantages and disadvantages associated with digitalization. Therefore, we encourage policy makers, managers and scholars to consider all the challenges identified in this study to try to advance a step further in the digital transition economy by implementing TT strategies that can be helpful for this global objective.

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