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A literature review on firm digitalization: drivers and impacts

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A literature review on firm digitalization: drivers and impacts

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Abstract

The digital revolution is radically changing how modern business is conducted, leading to several transformations at the firm-level, and capturing the attention of practitioners, policymakers, and academics alike. Considering the ever-changing nature of digital technologies, the aim of this article is to provide an up-to-date review that describes the state of the art on this literature. Research suggests that the drivers linked to digital adoption can be classified into 5 groups: individual, organizational, environmental, technological, and economic factors. Intra-firm diffusion can be associated to the so-called rank, epidemic, location, stock and order effects. Firms' digitalization processes are associated with several transformations that take place through four main channels: lower communication costs, data analysis, operational transformations, and lower entry barriers. These changes are associated with firm performance gains in terms of innovation, cost reduction and new revenue opportunities, from which productivity gains and new business models arise. The bulk of empirical estimates at the firm-level support the positive impact of digitalization on business performance. However, these results are not necessarily unanimous, as some research has not been able to verify these positive effects.

JEL Classification: O31, O32, O33, D24, L25

Keywords: Digitalization, Information and Communication Technologies, Internet, Firm performance

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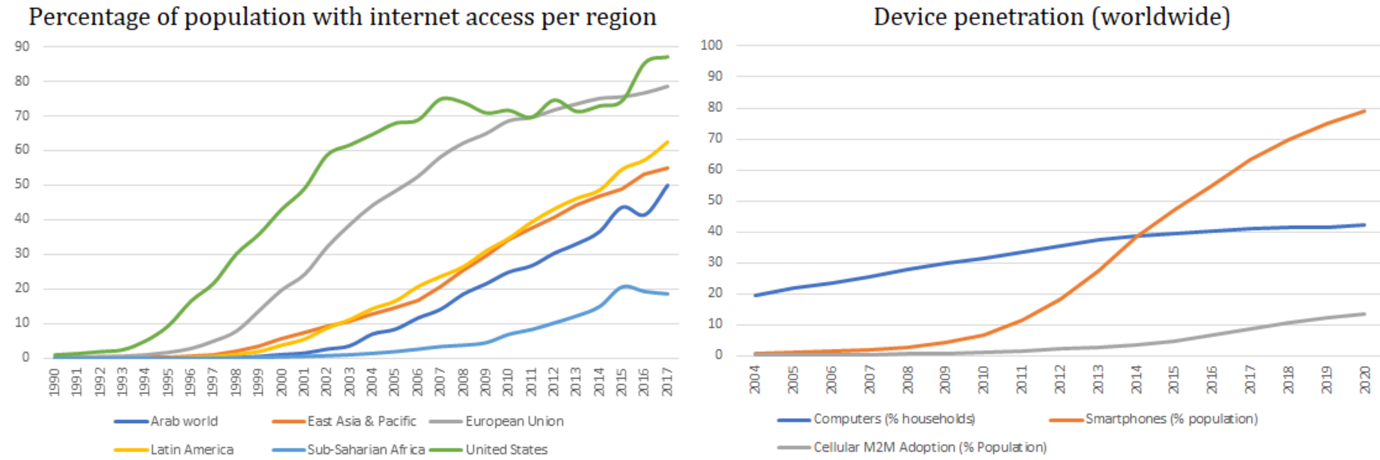
1. Introduction

Digital technologies' growth in the last 30 years has transformed the world. Firms and households have adapted their productive systems, routines and consumption patterns to a hyper-data-driven environment filled with new tools used to transmit, store, create, share, and exchange information. The depth of this process is of such magnitude that it has been compared to past disruptions as the industrial revolution, the deployment of the first transport infrastructures or the massification of electric energy (Jordan & León, 2011; Katz et al., 2013; Mack & Faggian, 2013).

The origins of this process date from long ago. The first applications of digitalization were implemented in the early stages of the XXth century. According to Ritter (2020), one of the earliest uses of "digital technologies" in a public policy environment was the registration of US citizens' working records to support the Social Security Act in 1935. 21 years later, the first Artificial Intelligence (AI) conference took place at Dartmouth.

The current relevance of this topic is based on its exponential growth since the second half of the nineties, on the appearance of more powerful uses for the existing technologies, and on the development of novel ones. The irruption of the internet has undoubtedly been the main engine behind the wave of digital development of the last 30 years. Figure 1 illustrates internet and selected electronic devices' penetration. As can be seen, the world has experienced a steady increase in computers and Machine-to-Machine (M2M) adoption, plus an exponential growth of smartphones since the early 2000s.

Figure 1. Technological development over the past decades



Source: World Bank, International Telecommunications Union, GSMA Intelligence

Two reasons explain this shift. The first one is the emergence and adoption of adequate applications for data collection and the access to the computational power and infrastructure needed to handle analytics; more data exist today than ever before in history (Smolan & Erwitt, 2012). The second one is the growing academic involvement in the topic, which mirrors the empirical trend (Bettis & Hitt, 1995), and enables firms to develop cutting-edge improvements in connection with universities and research centers.

Academic interest in this field dates from several decades ago, when computers started to be massively used, initially in the United States. Early research was inconclusive about the role of Information Technologies (IT) on firm performance, which led Solow (1987) to enunciate the so-called *Productivity Paradox*: computers "can be found everywhere except in productivity statistics". Since then, most studies have confirmed the significant effects of these technologies on firms (Vu et al., 2020). Through the years, technological advances have moved the focus from computers and IT to broadband internet, first, and to a wider concept of digitalization, more recently. Given the ever-changing nature of digital technologies, it seems necessary to provide an up-to-date review that describes the state of the art on this literature.

In this context, the main objective of this paper is to provide a systematic review of the drivers and impacts of digitalization at the firm-level, intending to structure the literature in a theoretical and conceptual framework that helps readers understand the topic. The elaboration process of this paper has benefitted from previous literature reviews such as Cardona et al. (2013), Gómez-Barroso & Marbán-Flores (2020) or Vu et al. (2020), although our approach differs from theirs in that our focus is on firms and we consider a wider range of firm-performance and digitalization metrics.

The structure of this article is the following. First, we examine the main concepts associated to digital technologies and how they have evolved over time. Second, we analyze the drivers of digital adoption and diffusion, as well as their measurement. Third, we analyze the literature on the impact of digitalization on firm performance from a theoretical viewpoint and try to disentangle all the specific channels through which internal transformations occur. Fourth, we summarize the available empirical results on digitalization's drivers and the outcomes. Finally, we present the main conclusions of this literature review.

2. Definitions and main concepts

Technological advances over the past decades are crucial to understand the current concept of digitalization. Before digitalization, the main body of literature referred to the innovations linked to computers and communications as Information and Communication Technologies (ICTs), or ITs. Baskerville et al. (2020) explain that ITs can be defined as an infrastructure system to deliver communications services.

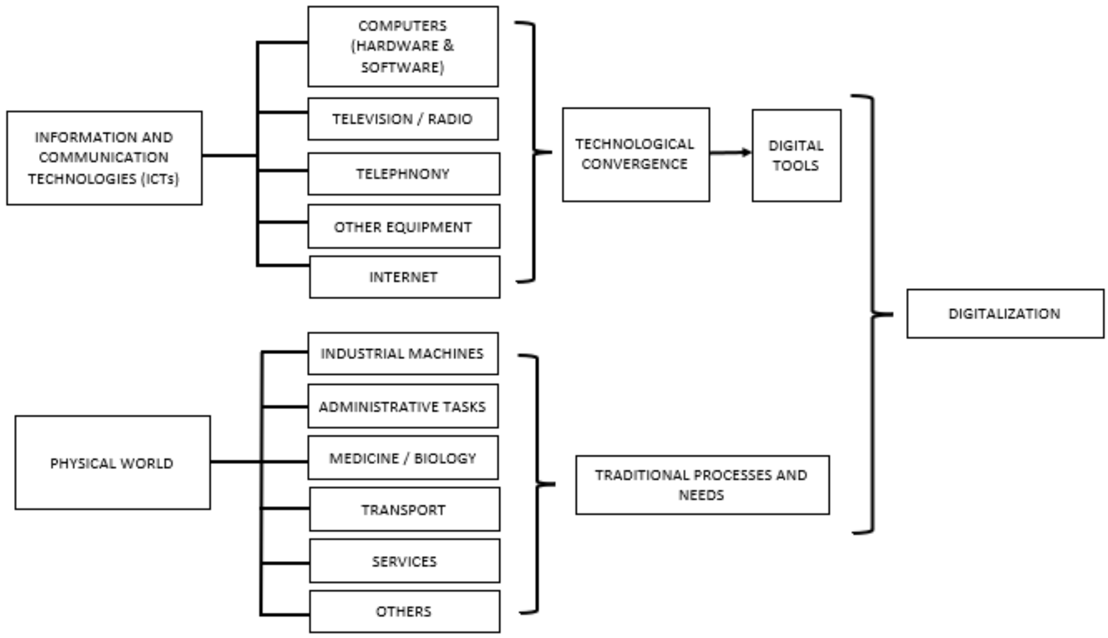
Gunday et al. (2011) and Modimogale & Kroeze (2011) define ICTs as the technological systems used to transmit, store, process, display, create, and automate information dissemination. Among these technologies were usually included items such as television, fixed and mobile phones, radio, satellite systems, video, computer software and hardware, plus the equipment and services associated with them. This was the main picture up to the mid-90s.

The massive irruption of internet since the mid-90s increased the capabilities and services associated with ICTs, initially with the development of applications such as e-mail and social networks (this process covers up to the first years of the XXIst century). Since then, the deployment of fast-speed broadband internet networks triggered a convergence process by which all those different ICTs technologies fused together into a wide range of novel digital tools.

More recently, the use of these digital tools for business management has been referred to as *digitization*, *digitalization,* or *digital transformation* (Brennen & Reiss, 2016; Ross, 2017; Weill & Woerner, 2018). In this paper, we use the term *digitalization* to refer to this latest disruption wave and disregard the small differences among these concepts that some authors prefer to highlight.[1]

Figure 2 describes digitalization as a process born from the combination of the digital tools generated by the evolution of ICTs (such as 5G mobile networks, sensors, 3D printing, and blockchain, etc.), to fuse the digital and the physical world (Baskerville et al., 2020).

Figure 2. Overview of the digitalization process



Source: Authors' own compilation.

The existence of different definitions for digitalization shows that the concept can be analyzed from different perspectives. While some authors prefer to take a narrower perspective (like Brennen & Kreiss, 2016; who define digitalization as the material process of converting analog streams of information into digital bits), others adopt a broader view of digitalization as an interactive or symbiotic process with the "physical world". In short, digitalization involves the adoption or the increase in use of digital

[1] According to Ross (2017), digitalization requires moving from analogue to digital data for streamlining existing processes where the end state is known, such as the introduction of Enterprise Resource Planning (ERP) systems (Ritter, 2020). In contrast, digitalization relates to an unknown process of ongoing testing and revising (Ross et al., 2019).

technologies by an organization, industry, or country; and because of it, as Brennen & Kreiss (2016) highlight, many domains of social life are restructured around it. In Appendix A we provide the detail of all the different definitions for digitalization reviewed in the literature.

Table 1 gathers the main technologies and applications that are part of digital transformation processes. There are more technologies that could be included in this table, but these are the most frequently found in empirical analyses on digital adoption and diffusion.

Table 1. Main digital technologies and applications

Level	Digital tool	Description
Essential / Basic	E-mail	E-mail allows companies to efficiently communicate with suppliers and customers.
	Web Sites	Web Sites allow companies to share their products and services through pictures, videos, audios; as well as their basic contact information.
	Videocalls	Platforms that allow virtual meetings, saving costs, facilitating exchanges regardless of physical distances, and facilitating telework.
	E-government	It allows firms and individuals to connect with the Public Administration to check information, print documents and carry out different procedures.
	Online Banking	Banking operations like transfers, investments, invoice payments, etc.
	Social Media	Information and instant communications with actual and potential customers.
	E-commerce	Goods and services acquisition through different electronic payments mechanisms. Disruptive process that affects even business models.
Advanced	Virtual Private Network (VPN)	VPN are private networks that use Internet's infrastructure.
	Intranet	Private and internal communication network in a company, based on internet protocols, but only accessible for allowed users.
	Extranet	Safe extension of an Intranet that allows external access.
	Management Systems	Examples: Customer Relationship Management (CRM), Enterprise Resource Planning (ERP), Business Process Management (BPM), Supply Chain Management (SCM).
	Radio-frequency Id. Systems (RFI)	RFI uses radio waves to identify people or objects.
	Storage Servers	Computers that remotely offer other computers files storage space.
	Cloud Computing	ICT services remotely accessible for software use, processing capacity or storage space.
Cutting-edge Technologies	Big Data	Extremely large data sets that may be analyzed computationally to increase competitiveness, design strategies, innovate or improve customers' experience.
	Internet of Things (IoT)	IoT represents the incorporation to physical objects of sensors, processing ability and software that connect and exchange data with other devices and systems over the internet.
	3D Printing	3D printing allows to improve and adapt products to each client's needs and to supply goods on-demand, which positively impacts stock management.
	Robotics	Robotics can transform production by increasing efficiency and productivity. Robots can be multifunction and multigoal.
	Artificial Intelligence (AI)	The science and engineering of making intelligent machines, especially intelligent computer programs.
	Virtual Reality – Metaverse	Computer technology to create simulated environments. Simulated experiences can be like or completely different from the real world.
	5G Wireless Technologies	5G wireless technology deliver higher multi-Gbps peak data speeds, ultra-low latency, more reliability, massive network capacity.
	Blockchain	Refers to a decentralized system of blocks linked together using cryptography, that is used to record information in a way that makes it difficult or impossible to change or hack it.

Source: Authors' own compilation.

Technologies can be grouped into three different categories, according to their level of sophistication. Essential and basic technologies and applications include email, web sites, video calls, online banking, social media, e-commerce, and interactions with the public sector, such as tax payments. They are adopted and diffused not only by firms, but also by individuals.

Advanced technologies are generally present in medium and large companies, with different expertise, depending on the sector in which the company operates and the skills of its workforce. They include VPN, intra/extra nets, CRMs, RFIs, and the use of storage servers and Cloud Computing. Their uses go from customer relations to remote working.

Cutting-edge innovations are currently used only by specialized companies and in specific sectors. Among them, Big Data, IoT and 5G Wireless connections are the most common. Big Data offers a solution for an increasing number of companies that rely on data analysis to make better business decisions, understand their customers, deliver better-oriented products, or improve business operations. 5G Wireless delivers higher data transmission speeds, with lower latency. This allows massive network capacity and opens the door to the appearance of other disruptive technologies.

Robotics, understood as an extension of AI technologies, is also gaining presence, not only as a facilitator of relationships with customers, but as a solver of non-digital business problems (Di Vaio, 2020). Blockchain has also the potential to transform firms' business models in different sectors, such as banking & finance, law, accounting, and healthcare. Its adoption and diffusion can boost trust-free, decentralized transactions, with lower costs and more privacy. Regulation, interoperability, scalability, security, and volatility are the main challenges that still limit the massive diffusion of this technology (Frizzo-Barker, 2020).

Finally, other technologies, like 3D printing or the use of augmented reality (AR) and virtual reality (VR) tools, are still lagging a step behind, but there is a broad consensus on the key role that they will play in the next years for business development in most sectors. Reality-enhancing applications go beyond what is currently foreseeable (Farshid et al., 2018). The metaverse is more than an online application of virtual reality; it is a digital reality that combines aspects of social media, online gaming, AR, VR, and cryptocurrencies so that users can interact virtually. Firms use this as a tool to gain presence in customers' life beyond traditional marketplaces, but also as a potential income source.

KEY IDEAS

- What we currently understand as digitalization is the result of over 50 years of technological evolution.
- The existence of different definitions for digitalization shows that the concept can be analyzed from different perspectives.
- Digitalization involves the adoption or the increase in the use of digital technologies by an organization, industry, or country.
- Digital tools and applications range from the most basic and universally used (email, internet…) to the latest cutting-edge innovations (AI, metaverse…)

3. Adoption and diffusion of digital technologies at the firm-level: factors, drivers, and variables.

In this section we present the main drivers of digital adoption and diffusion and how research measures these processes within a company. While most of the literature has focused on the demand side, technology diffusion is the result of the interaction between supply and demand factors. Models normally assume that prices decline over time without further connection with supply factors and ignore intra-firm technological diffusion, focusing only on inter-firm diffusion.

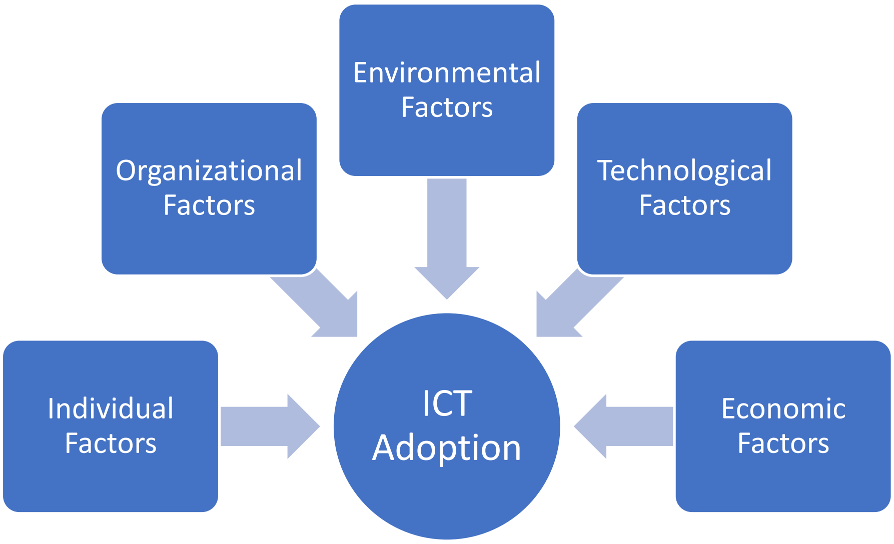
Most of the literature takes the view that adoption and diffusion should be considered independent processes, since the former is an internal decision for the organization and a first step towards diffusion. Technological diffusion would then be defined as the process by which a specific tool or application is adopted and implemented in an organization until a sufficient number of users within it internalize and transfer their acquired knowledge to their peers (Peansupap, 2004).

Taylor (2019) developed a notion of digital adoption based on the use of ICT tools including computer hardware, software, and networks required for connecting to the internet at the firm level. The literature classifies the general and managerial determinant factors of adoption into 5 groups (Skoko et al., 2007), as it can be seen in Figure 3: individual, organizational, environmental, technological, and economic.

Individual factors include the personal characteristics of top management and the general workforce. According to the literature, the drivers for this factor are top management commitment, personality traits, ICT culture, a high-skilled workforce, and the dominance of learning-by-doing processes at the organizational level (Consoli, 2012).

Organizational factors capture firm size, human capital conditions, organizational culture, and workers' participation on decision-making. Economic factors include the opportunity costs of not-adopting certain technologies, while environmental ones gather the pressure from the competition, the innovation requirements coming from the market, and the legislative pressures imposed by public policies. Finally, technological factors portray the current infrastructure that exist in a firm and how it may facilitate the adoption of new technologies.

Figure 3. Digital adoption factor groups



Source: adapted from Consoli (2012) and Skoko et al. (2017)

The adoption of the latest technological innovations needs to be explained through the complementary interaction of factors that belong to different groups. Organizational reasons, such as the existence of a parent company or the establishment of strategic alliances with other firms, goes hand in hand with the ownership of intangible assets and Research & Development (R&D) investment, for example. Lower debt and profitability ratios are also found to be relevant in determining the capacity of a firm for ICT adoption.

Regarding diffusion, Karshenas & Stoneman (1995) proposed a general conceptual framework that distinguishes five sub-models to explain technological diffusion: rank, epidemic, location, stock, and order effects. Table 2 summarizes each of them and shows some examples of the different variables used in the literature as proxies.

Table 2. Driving effects of digital diffusion, variables, and description

Effect	Drivers	Examples
Rank	Age	Age of the firm
	Size	Number of employees or firm revenue
	Human Capital	Share of workers with at least a bachelor's degree.
	Export Activity	Share of sales being exported.
	Foreign Direct Investment	Share of the firms' capital foreign owned.
Epidemic	Epidemic Technology	Share of other firms that have adopted a particular technology in the same country and/or sector
Location	Big city	Company located in a national or regional capital. Number of individuals living in the city / area.
Stock	Previous adopters	Number of previous adopters of a certain technology.
Order	Position	Position in which company has adopted a technology.

Source: Authors' own compilation.

With reference to rank models, research emphasizes the link between different firm characteristics, differentials in returns, and adoption decisions. Rank effects are captured through different variables: age, size, human capital, or internationalization. A firm's age is a proxy for its technological experience. Older firms are better prepared to evaluate the risks and benefits derived from the introduction of new technologies. But, at the same time, younger enterprises are believed to be more flexible in dealing with the organizational changes that come with digital adoption.

Size is associated with fewer financial constraints and lower risk aversion. The metric used to classify firms according to size is usually the number of employees or the volume of revenues. According to it, firms are normally categorized as micro, small, medium, and large. Larger companies are presumably in a better position to withstand the costs and risks associated with the introduction of new technologies. (Fabiani et al., 2005; Giunta & Trivieri, 2007; Haller & Siedschlag, 2011; Teo & Tan, 1998).

Human capital is sometimes captured by the percentage of skilled workers (e.g.: those with at least a bachelor's degree). A more educated workforce facilitates the early adoption of technologies (Chun, 2003). In addition, demand for skilled workers increases with the use of new technologies (Bartel & Sicherman, 1999).

Theory on international engagement suggests that firms that participate in foreign trade are more likely to adopt new technologies (Haller & Siedschlag, 2011; Hollenstein, 2004; Lucchetti & Sterlacchini, 2004). Foreign owned companies tend to be early adopters, which contributes to technology diffusion in the countries, and sectors, in which they operate (Keller, 2004; Narula & Zanfei, 2005).

Epidemic models assimilate technological diffusion to the spread of a virus. Early adopters disseminate information and incentivize other firms to adopt the same technology and to release further information. This process is repeated until a saturation point is reached. The research that introduced epidemic models was based on the concept that a technology's diffusion depends on information about its availability (Mansfield, 1963). Diffusion will gradually increase over time, since adoption costs, and the risks derived from them, decline as more firms became part of the process.

To account for epidemic impacts, the literature normally uses the percentage of firms that have adopted a given technology in the same country and / or sector. These variables are used to test for the existence of network effects in technological diffusion, which follows the hypothesis that existing adopters have positive spillover effects on other firms considering adoption.

Network effects are not strong enough to explain variations in technological adoption and diffusion among firms. Epidemic models are based on information spillovers from users to non-users, while, for network effects, the gains from adoption and the costs from non-adoption, increase with the number of users (Gourlay & Pentecost, 2002; Oulton, 2002). It is true that being part of a network reduces the risks associated with the adoption and use of a new technology, but it also increases the probability of coordination failures that can slow down adoption rates.

Regarding location, the empirical literature finds evidence that urban or densely populated locations facilitate digital adoption. This hypothesis is supported by the proximity of suppliers, lower technological prices, and the availability of a skilled labor force (Galliano et al., 2001; Karlsson, 1995).

Galliano et al. (2001) explain how the relationship between spatial and organizational factors contribute to technological adoption. They stress their combined importance since firms need to adapt their internal processes and the role that technology plays in them, to manage potential proximity problems with suppliers or consumers.

Stock models assume that the benefits from adoption decrease as the number of previous adopters increases. Consequently, for any given technological diffusion cost, there are several adopters beyond which that tool is no longer profitable. The adoption of a new technology is modelled as a strategic decision using a game theoretic approach (Reinganum, 1981). On her paper, she shows that market structure upon the schedule of adoption determines the difference in profit rates immediately preceding and following technological adoption and diffusion. Results also point to a potential problem of market concentration after non-adopters drop-out of the market.

Finally, order models emphasize the benefits for early adopters when returns depend on the order of adoption. There are advantages derived from early adoption, like the identification of better skilled labor. Furthermore, the decisions of early adopters can affect the adoption moment for newcomers. From this fact, it follows that the firm's decision to adopt a new technology considers how waiting will affect its profits (Fundenberg & Tirole, 1985).

Empirical analyses usually include the country and the sector in which companies operate as control variables. Technology diffusion varies from one country to another due to country characteristics like its size, distance to the technological frontier, domestic absorptive capacity, sectorial specialization, and international integration (Keller, 2004). The economic relevance of a sector, or the structural peculiarities of an industry, also affect adoption and diffusion. Firms that operate in more digitally advanced countries and sectors may face reduced costs and increased benefits from technological diffusion.

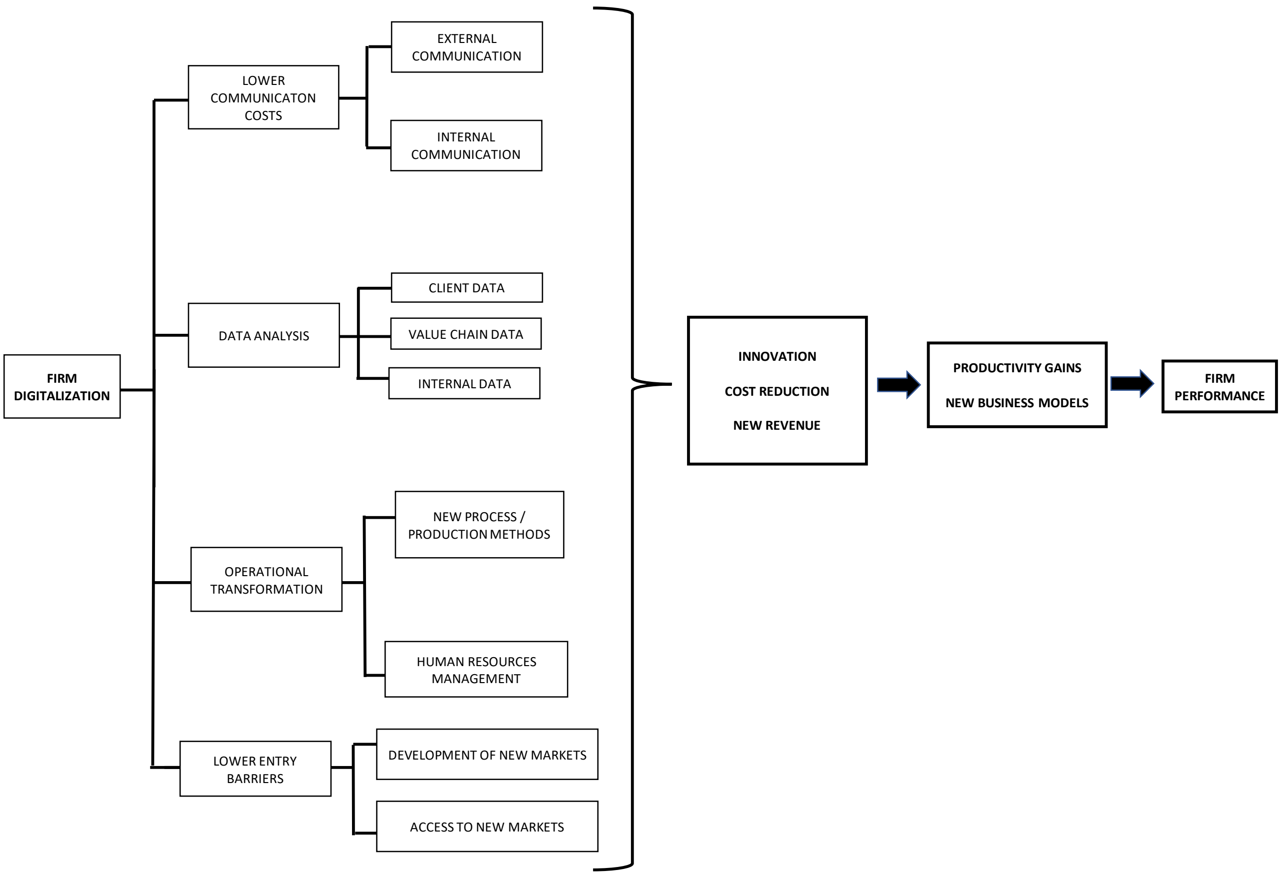
KEY IDEAS

- Digital technologies' adoption at the firm level is driven by individual and organizational factors. Environmental, technological and economic factors also play a role in this process.
- Technological diffusion is the process by which a specific application is adopted and implemented in an organization until the expected number of users internalize and transfer their knowledge on how to use it to their peers.
- 5 sub-models have been proposed to explain technological diffusion: rank, epidemic, location, stock, and order effects.
- Although there is a blurred line separating both concepts, adoption should be understood as a first step at the organizational level before its dissemination and diffusion through the whole company, sector, or country.

4. How is digitalization driving firm performance? Theoretical arguments

There are multiple paths identified in the literature through which digitalization can improve firm performance. We propose to group them into four main channels: (i) Lower communication costs, (ii) Data analysis; (iii) Operational transformation; and (iv) Lower entry barriers. Figure 4 sketches these effects.

Figure 4. Impact of Digitalization on Firm Performance – Main channels



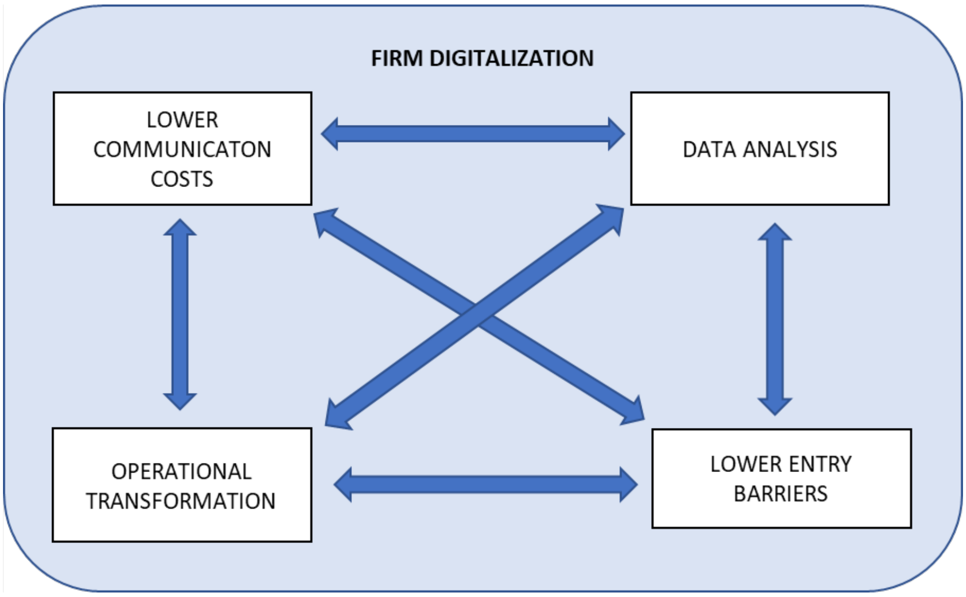
Source: Authors' own compilation.

Digitalization can lower the costs of external communication (with clients, suppliers, or other firms), as well as those of intra-firm communication. Data analysis is one of the main disruption factors in recent years. It paves the way to a deeper analysis of externally collected information (from clients, or value-chain enterprises) and of internal-process data. Thus, all forms of data analysis (Big Data, Business Intelligence, analytics, etc.) can help in the process of firm optimization.

Within-firm operational transformations can result in new processes and production methods, as well as improved human resources management. Finally, lower entry barriers facilitate the development and the access to new markets, either national or international. All in all, the effects of digitalization through these four channels can impact positively on the firm, through product and process innovations, cost reductions, and new revenues. This is expected to yield productivity gains and facilitate the development of new business models.

The channels depicted in Figure 4 are expected to be closely interrelated among them, with developments in one field nourishing other areas, in an inter-dependent ecosystem (Figure 5). Just to name a few: data analytics can identify opportunities for operational transformation. Similarly, lower communication costs facilitate the reduction of entry barriers to other markets. Thus, the channels from Figure 4 are separated purposely for the sake of clarity, but inter-channel relations exist.

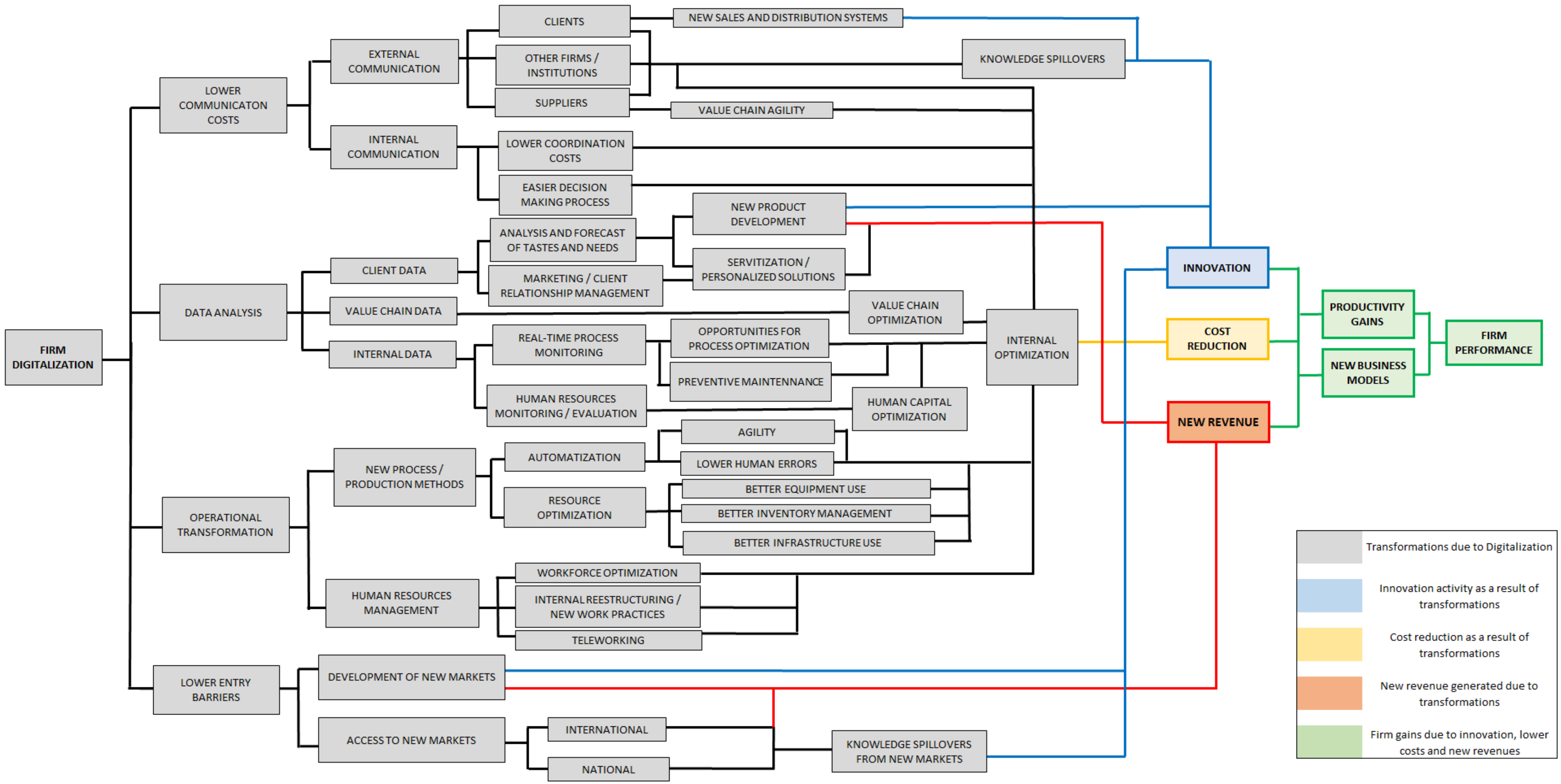
Figure 5. Interrelations between Digitalization main channels



Source: Authors' own compilation.

Figure 6 provides an expanded version of Figure 4. It develops how each channel affected by digitization ends up yielding an innovation, a cost reduction, or new revenues, therefore, impacting positively on firm performance. Next, we analyze each channel in detail.

Figure 6. Impact of Digitalization on Firm Performance – Detailed channels



Source: Authors' own compilation.

i) Lower communication costs

The introduction of digital technologies provides the potential to substantially reduce firm's communication costs (Jorgenson, 2001). An easier dissemination of information can dramatically improve communication channels and interactions to better search, share, store, and analyze information and resources (Li et al., 2019). Moreover, dispersed knowledge and capabilities can be more easily coordinated through digital technologies (Williamson & Meyer, 2012). Considering the critical importance of information for firm decisions (Arrow, 1985 and 1996) and the relevant role played by transaction costs in economic activity (Williamson, 1989 and 2010), reduced interaction costs should contribute substantially to firm performance. Improved communication channels can help both inter-firm (i.e., with external firms) and intra-firm communications (i.e., with employees).

By using digital technologies, firms can strengthen their relationship with external stakeholders, such as clients, suppliers, distributors, and other firms (Yu et al., 2010; Tarn et al., 2014; Matt et al., 2015; Li et al., 2019; Orji, 2019; Wang & Bai, 2021). Better information flows to the outside world can eliminate physical and temporal constraints (Nambisan et al., 2019), and greatly improve the firm's operating efficiency (Zhai et al., 2022). Improved communication channels, such as the use of social media, can be an important tool to interact with customers (Bouwman et al., 2018), and potentially, to increase sales (Ribeiro-Navarrete et al., 2021).

From these advances, potential new sales and distribution systems (Czernich et al. 2011) and the reduction of intermediation costs can emerge (Sutherland & Jarrahi, 2018; Heredia et al., 2022), improving the competitiveness of firms. E-commerce platforms are an example of this. They facilitate economic exchange between buyer and seller, through customer ordering and payment (Hagsten & Kotnik, 2017). Orji et al. (2022) highlight the possibility of strengthening links between clients and service providers and the accelerated implementation of e-commerce.

Low communication costs with clients and e-commerce platforms represent examples of reduction in barriers to access to other markets, something that we will detail in channel (iv). Digitalization allows for timely and close interaction with customers, which allows firms to obtain external information in a convenient and efficient way (Zhai et al., 2022), from where customer feedback can be analyzed. This provides a first-hand source of ideas for product development and business opportunities (Zhao et al., 2008; Jayaram & Tan, 2010; Wang & Bai, 2021), which represents a second interrelation, in this case with data analysis (ii).

Better communication with suppliers and other firms or institutions makes the transmission of information easier, which generates knowledge spillovers. As knowledge is becoming increasingly crucial for economic activity, digital technologies have the potential to generate more efficient external collaborations; they facilitate the adoption of new technologies devised elsewhere and promote the creation of new knowledge (Forman & van Zeebroeck, 2012; Zhai et al., 2022).

Knowledge integration from external sources can help firms in their learning processes, in managing risks, and in identifying new growth opportunities (Chege et al., 2020). Access to relevant knowledge can also be a necessity for declining firms to successfully implement turnaround strategies (Wang & Bai, 2021). Knowledge flows may be related to a variety of new technologies, resources, demands, and potential changes in the market (Zhai et al., 2022).

Lower communication and replication costs induced by digital technologies can potentially facilitate innovation processes (Brynjolfsson & Saunders, 2010; Chege et al., 2020; Galindo-Martín; Zhai et al., 2022). Chen et al. (2015) argue that digital technologies influence innovation by enhancing corporate entrepreneurship. Similarly, Koutroumpis et al. (2020) state that digital technologies can influence the creation of innovative ideas because of their complementarity with R&D activity. This is due to the nature of digitalization as a general-purpose technology that facilitates the invention of new goods and services in other sectors.

Another source of efficiency gains generated by reduced communication costs with suppliers and distributors is the possibility of improving value chain agility, which results in quicker responses and lower costs. Furthermore, reduced communication costs can help in the communication with the public administration.

Digitalization can also improve intra-firm communication (management and shareholders, management and workers, and management and other stakeholders), saving costs (Zhai et al., 2022). The reduction of internal communication costs allows quicker information processing, lower coordination costs, fewer supervisors required (reduction in labor costs), and easier decision-making processes (Gilchrist et al. 2001; Atrostic et al. 2004; Arvanitis & Loukis 2009; Cardona et al. 2013). It can also prompt additional investments (Colecchia & Schreyer 2002), the introduction of innovations, and the development of new business models.

In the directive process, digitalized firms can build better information exchange channels, speeding up the flow of information, facilitating the communication between different internal areas, and reducing unnecessary delays (Zhai et al., 2022). In short, improved communication can result in cost reductions, better management, and enhanced innovation, and nourish other channels as depicted in Figure 5.

ii) Data Analysis

Digital tools allow firms to continuously generate, process, and analyze significant volumes of useful information (Heredia et al., 2022), thus creating opportunities for organizations to reap the benefits from analyzing these massive influxes of data (Benitez et al., 2022) and radically improving firm performance (McAfee & Brynjolfsson, 2012). This is facilitated by the strong cost decrease associated with storing, processing, and transmitting Big Data (Gu et al., 2021).

Big Data analytics provide enterprises with the means required to integrate and manage these large volumes of information. It is usually characterized by some specific dimensions such as volume, variety, and velocity (Feijóo et al., 2016).[2] The challenge is that adequate skills are needed to successfully interpret data and extract value from it (Benitez et al., 2022). This can lead to the reshaping of business activities, particularly in knowledge-intensive sectors (Loebbecke & Picot 2015; Ribeiro-Navarrete et al., 2021).

Cappa et al. (2021) state that the collection and use of data allow firms to conduct "innovation from data". However, data need to present high variety levels for firms to be able to generate value that outweighs the associated costs. Naturally, the collection of these data is facilitated by the lower communication costs from channel (i), as shown above in Figure 5.

Information collected from consumers can help firms to identify first-hand feedback and potential changes in their tastes and needs (Wang & Bai, 2021), and to improve the quality of the products and services provided (Heredia et al., 2022). Abou-foul et al. (2020) argue that Big Data facilitates the process of demand forecasting.

A successful use of customer interactions can contribute to improve marketing activities and communication processes, enhancing customer attraction, satisfaction, and loyalty, and increasing sales (Park & Kim, 2014; Serravalle et al., 2019; Mariani & Borghi, 2020; Ribeiro-Navarrete et al., 2021). In this sense, Chege et al. (2020) argue that digitalization can allow firms to become more client-oriented, reacting better to changes in market trends.

Therefore, digital transformation in industry creates new ways of competing to meet the needs of customers who seek personalized solutions (Martín-Peña et al., 2019). Bouwman et al. (2019) argue that Big Data is a relevant tool for marketing and customer relationship management, but also for new data-driven revenue models. The authors link the digital transformation processes with the opportunity for experimenting and changing firms' business models.

[2] According to Feijóo et al. (2016), "volume" refers to the threshold above which a dataset could be considered big data; "variety" refers to the different types of data involved, while "velocity" consists in the need to manage and analyze big data as much as possible in real time.

In this respect, several authors have highlighted the close link that arises between digitalization and *servitization*, defined as a process by which firms shift from simply selling products to supplying a wide range of services around them, which adds further value for the customer (Opresnik & Taisch, 2015; Martín-Peña et al., 2019; Abou-foul et al., 2020; Kharlamov & Parry, 2021).

Data collected from interactions with suppliers and distributors can be potentially analyzed to improve logistic and value-chain efficiencies. In this respect, Gu et al. (2021) highlight the importance of Big Data for supply chain management, as analytic practices are expected to monitor trends more precisely, to provide more accurate predictive models, and to optimize business processes.

Similarly, data obtained from internal operations can be a powerful tool for firms' optimization. The possibility of collecting, analyzing, integrating, and interpreting high quality, real-time data, fuels automation processes, predictive and forecasting tools, artificial intelligence, and robotics in many industrial sectors (Abou-foul et al., 2020). An adequate use of data can help to reduce the costs of firms, optimize resources and assets utilization, and to redesign processes (Abou-foul et al., 2020; Heredia et al., 2022).

Digital technologies provide the potential for firms to monitor production processes, locations, conditions, or uses, as well as to improve product quality (Bouwman et al., 2018; Martín-Peña et al., 2019). Big Data can also be a relevant tool for preventive maintenance, helping companies to avoid losing time and achieve smoother operations (Abou-foul et al., 2020). Human resources management is another source of internal optimization generated by data analytics (Zhou et al., 2021). As a result of all the above, internal data can promote intra-firm performance, which triggers the operational transformations depicted in channel (iii).

In short, business intelligence fueled by Big Data presents the potential to notably create firm value and to achieve competitive performance advantage, which results in increased firm performance (Opresnik & Taisch, 2015; Mariani and Borghi, 2020; Orji et al., 2022).

iii) Operational transformation

Digital disruption facilitates a more efficient incorporation of technological changes into the firm (Karimi & Walter, 2015), which prompts severe internal transformations. The so-called *Industry 4.0* can be interpreted as an interdependent system of technologies, such as the IoT, Big Data, blockchain technology, digital traceability, cybersecurity, and virtual reality.

These digital advances, when incorporated in the production processes, can generate competitive advantages in enterprises (Ribeiro-Navarrete et al., 2021). Digital transformation is a constant process that aims to improve a firm's value proposition by prompting significant changes to its resources through combinations of digital tools (Wielgos et al., 2021). This allows companies to select, develop, and provide new smart and connected goods and services that transform their competitiveness (Abou-foul et al., 2020).

Digital technologies enable the development of new production processes and practices (Mack & Faggian 2013; Zhai et al., 2022). Automatization is a key transformation in this respect (Martín-Peña et al., 2019). It can make internal processes more flexible, rational, and efficient. Agility improvements are a crucial gain derived from the incorporation of such technological advances (Škare & Soriano, 2021; Benitez et al., 2022; Orji et al., 2022). Consequently, firms can introduce standardized processes, increasing reliability, decreasing operational costs, and improving the quality of their outputs (Benitez et al., 2022).

Digital transformation contributes to improve the allocation of resources and to reduce costs (Ribeiro-Navarrete et al., 2021; Heredia et al., 2022; Zhai et al., 2022). This happens because of a better use of resources and a reduction of capital requirements, thanks to better equipment utilization and reduced inventories. From an internal perspective, digital transformation allows firms to achieve more efficient delivery and output, organization, and docking, as well as to avoid unnecessary waste of time, manpower and resources (Zhai et al., 2022). AI reduces repetitive processes in the supply chain (Abou-foul et al., 2020). Martín-Peña et al. (2019) highlight the ability of robots, flexible systems, and numerical control systems to simultaneously standardize and customize process.

Kaur & Sood (2015) suggest that digital technologies can improve a firm's performance through energy-efficiency improvements induced by technological advances such as the IoT. Another important consequence from automation are substantial reductions in human errors (Ribeiro-Navarrete et al., 2021).

Human resources management is another source of internal optimization thanks to digitalization (Soltis et al., 2018; Zhou et al., 2021). Operational transformation prompts substantial firm restructuring (Brynjolfsson & Hitt 2000) and the adoption of new work practices, with the possibility of reduced labor costs and with the development of new roles.

Digital technologies open the door to telecommuting and hybrid working schemes, which promotes time saving, workers' happiness, and, consequently, higher labor productivity (Kazekami, 2020).

In addition, digital applications can be used to manage employee competencies, behavior, and attitudes, and to conduct strategic decisions for the development of comparative advantages based on better employee's management (Soltis et al., 2018). From the managerial perspective, digitalization and automation allows decision-makers to focus their attention on firms' strategy and in the analysis of the trends changing in the marketplace (Benitez et al., 2022).

However, Zhai et al. (2022) argue about the complexities associated to digital transformation, due to the learning curve involved and the associated adjustment costs. An effective digital transformation plan must contemplate the development of digital capabilities in different areas such as leadership, operations, client needs, and innovation (Benitez et al., 2022).

iv) Low entry barriers

From a market perspective, digitalization can contribute to lower entry barriers, promote transparency, and foster competition (Czernich et al. 2011). Lower barriers induced by digital developments can help firms to enter new markets (Chege et al., 2020), develop new networks, and create new growth opportunities for companies. Moreover, Wang & Bai (2021) argue that digitalization can help declining firms change their business domain and find new market opportunities.

Zhai et al. (2022) alert that digital transformation promotes international competitiveness, as firms may be able to offer services on a global basis. Hagsten & Kotnik (2017) highlight the important role of digital technologies to enhance the international performance of firms, both in terms of the decision to export and in terms of export intensity. They argue that online presence enables a firm to share information and to communicate with clients abroad.

Similarly, e-commerce attracts new clients across different geographical locations (Hagsten & Kotnik, 2017; Orji et al., 2022). From the perspective of logistic service providers, e-commerce can help to internationalize their business, improving operational efficiency and increasing the competitiveness of global value chains (Gingerich & Maoh, 2019; Orji et al., 2022).

Furthermore, reduced barriers induced by digitalization can potentially transform existing markets, or even develop new ones, through innovative business models. An example of this is the collaborative or sharing economy models represented by firms such as Uber or Airbnb. Easier access to markets is expected to deliver a source of new revenues for firms, and possibly, of knowledge spillovers that can be translated into a more intense innovation activity.

KEY IDEAS

- The impact of digitalization on firm performance can be grouped into four main channels:
  - **Lower communication costs** affect both external (with clients, suppliers, or other firms) and internal communication (e.g., with employees). Better communication reduces costs and may also prompt knowledge spillovers.
  - **Data analysis** paves the way to a deeper study of externally collected information (from clients, or value-chain enterprises) and of internal-process data, prompting firm optimization.
  - **Operational transformations** can result in new processes and production methods, as well as improved human resources management practices.
  - **Lower entry barriers** facilitate the development and access to new markets, either national or international.
- The effects of digitalization through these channels impact firms positively through more innovation, cost reductions, and new revenue sources. This is expected to yield productivity gains and facilitate the development of new business models.

5. Empirical findings

In this section we analyze the empirical findings of the research conducted at the firm level. The selection procedure consisted, first, in a keyword search in Google Scholar, combining terms such as "digitalization", "ICT", "firm-level", "firm-performance", and mentions to specific technologies such as those described in Table 1. As a next step, we checked the publishing date: papers published after the year 2000 were prioritized. This means that our sample covers what Gómez-Barroso & Marbán-Flores (2020) call the "the consolidation years" (2000-2008), and "the broadband years", since 2009. To those definitions, we add from 2015 on, the so-called "digitalization" years.

Furthermore, we analyzed the classification metrics of each journal, discarding all papers belonging to those positioned in lower quartiles according to either Journal Citation Reports (JCR) or Scimago Journal & Country Rank (SJR). We start our analysis with those articles whose results are aligned to the "rough consensus". In 5.1 we summarize the main literature, referred to digitalization drivers, while in 5.2 we analyze the evidence focused on the positive impact of digitalization on firm performance. However, the previous results do not necessarily represent unanimity, as some pieces of research argue that the economic effect of digitalization is not straightforward. In section 5.3 we present the nuances to the broader literature.

5.1. Digital adoption and diffusion

Empirical analyses on the adoption and diffusion drivers of digital technologies characterize the specific indicators behind the broad theoretical categories defined in section 3. Table 3 summarizes the reviewed literature, with full details reported in the

Appendix B for each article. We stress the specific variables that capture technological innovations, as well as the indicators found to determine their adoption and diffusion.

From the perspective of the technological tools, there is not much difference between articles' focus on adoption and/or diffusion. Most the literature uses hardware acquisition or technology investment indicators, the use of specific tools at the firm-level (internet, e-commerce, Radio Frequency Interference, …), or some indicators constructed with a specific research purpose (Hollerstein, 2004) to assess firms' technological situation. Research that analyzes a firm in a particular sector or industry, use more specific tools capable of capturing technological advancements in a relatively narrow environment. That would be the case of the total number of Automated Teller Machines (ATMs) at the financial sector, as Gourlay & Pentecost (2002) do.

Adoption drivers are often mixed with diffusion ones since empirical research tend to analyze both phenomena jointly. Among the indicators that capture purely adoption patterns across firms, the literature tends to focus on organization capabilities (through surveys and other ad-hoc indicators), workforce composition, type of companies, board characteristics (age, motivation, values…) and even family ownership. Results confirm what the theory predicts; organizational, individual, technological, environmental, and even macroeconomic factors affect the adoption rate of new technologies at the firm level.

Diffusion is characterized by two elements. First, the particularities (age, size, profitability…) of the firm or sector that considers the adoption of a given technology is often affected by environmental factors, such us where the firm is located, market expectations or internationalization. Second, the decision of a firm to adopt a new tool is conditioned by the behavior of its competitors. Early-adopters assume more risks but tend to generate more revenues derived from adoption in the long-run.

When adoption and diffusion are analyzed together, researchers group individual adoption patterns with rank and epidemic diffusion drivers. That's the case for Teo & Tan (1998), Bayo-Moriones & Lera-López (2007), Giunta & Trivieri (2007), and Haller & Siedschlag (2015). Under this perspective, empirical evidence is often inconclusive. For example, several studies find either a nonsignificant (Bayo-Moriones & Lera-Lopez, 2007; Giunta & Trivieri, 2007) or negative impact (Gambardella & Torrisi, 2001; Haller & Siedschlag, 2011) of age on ICT diffusion.

From the methodological point of view, surveys and case studies dominate a big part of this empirical literature (see, for example, Damaskopoulos & Evgeniou, 2003; Cesaroni et al., 2010). They are used as a tool to validate the different theories of adoption and diffusion presented in Section 3. In the 90s and early 2000s, case studies and surveys dominated the research on technological adoption due to the lack of adequate data. Survey data is also used to build econometric specifications that enhance the theoretical results obtained in this literature (Galliano et al., 2001). Methodologies have improved and evolved since the early stages of academic interest on digitalization. During the last decade, web scrapping[3] and other tools have allowed researchers to produce their own aggregate data on the adoption patterns and on the impacts at the firm level of the different technologies.

Table 3. Research analyzing the adoption and diffusion drivers of digitalization

Category	Drivers – Specific Variables	Technology Variable	References
Adoption	IT adequacy; Internal expertise; Attention by management	Hardware acquisition; Hardware use	Cragg & Zinatelli (1995)
	Organization capabilities; Knowledge-creating capabilities; Regulatory frameworks	Internet firm penetration; Electronic payments	Damaskopoulos & Evgeniou (2003)
	Entrepreneurs' motivations	Investment in emerging radical technologies	Zahra (2005)
	Introduction of business practices and new organizational practices	Knowledge Management Solution (KMS), Customer Relationship Management (CRM) systems	Falk (2005)
	Size; Human capital; Workforce composition; Organizational indicators; Industrial structure.	PCs, ICT expenditure, years with internet access, turnover, human capital.	Fabiani et al. (2005)
	Existence and efficiency of domestic computer-making industry	Computers per worker; Imports of Computers	Caselli & Coleman (2001)
	Organizational: decentralization of authority, delayering of managerial functions, increased multitasking…	New technology use (survey-obtained)	Caroli & Van Reenen (2001)
	Adoption intensity own indicator	Internet adoption; Internet-based selling	Hollerstein (2004)
	Business processes transformation	B2B e-commerce adoption	Lefebvre et al. (2005)
	Types of organizations from different industry sectors	IT investment as a percentage of turnover	Love et al. (2005)
	Environmental: external pressure. Organizational: perceived benefits, organizational readiness	Internet adoption	Mehrtens et al. (2001)
	Efficiency; Organization context; Investment cost; Market environment; Technology characteristic	RFID adoption	Wen et al. (2009)
	Age; Skills and education; successor in family companies	Technological training and skills	Cesaroni et al. (2011)
	Economic crisis	Different indicators: investment, infrastructure, web 2.0, etc.	Cesaroni et al. (2010)
Diffusion	Spatial environments (urban, periurban, or rural areas) and internal triggers (knowledge, practices, and relations)	JIT logistics system certification	Galliano et al. (2001)
	Endogenous learning; Cumulative learning-by-doing; Firm size; Growth; Profitability; Price expectations	Automated Teller Machines (ATMs)	Gourlay & Pentecost (2002)
	Productivity and growth	Software investment	Oulton (2002)
Adoption & Diffusion	Organizational and individual characteristics; Rank	Internet access	Teo & Tan (1998)
	Sector; International / Domestic; Size; Multinational ownership; Youth of the workforce; Competitive strategy	PCs, Internet, Extranet, Intranet, email, videoconference, website	Bayo-Moriones & Lera-López (2007)
	Firm size; Location; Workforce composition; R&D; Subcontracting; Exports; Collaboration between firms	PC + email + web site	Giunta & Trivieri (2007)
	Size; Age; Growth; Skill-intensity; Exporting; Capital city	Web, online transactions, computer use	Haller & Siedschlag (2015)
	Employees; Size; Exporter; Multinational; Education Level; Industry; Group.	Different variables: Internet access, website, online sales	Lucchetti & Sterlacchini (2004)

Source: Authors' own compilation.

[3] Web scrapping refers to a technique used for extracting data from websites. Gathered data from the web is copied into a database or spreadsheet for later retrieval or analysis.

Results show that the theoretical distinction between adoption and diffusion is harder to trace from the empirical point of view. For example, research confirms that adoption factors, such as the composition of the workforce, play a crucial role in determining the success of a new tool within a company. However, those individual-firm adoption patterns tend to be complemented by technological diffusion drivers like the location, the size of the company or the sector in which it operates.

5.2. Studies that found a positive impact of digitalization on firm performance

Several empirical articles have analyzed some of the links represented in Figure 6. The selected digital variable of interest evolves with technological advances through the years. In Table 4 we summarize a list of the reviewed studies that were able to find a positive impact from digitalization on firm performance (the full detail, study by study, is reported in Appendix C). In this section we focus on the broader literature that generally agrees on a positive effect from digital technologies on firm performance, leaving the discussion of discording cases to be analyzed in section 5.3.

Studies approach the empirical question either using a broad definition of digitalization / ICT, or focusing on a specific technology (Broadband, Big Data, IoT, etc.). Among the first ones, the challenge arises in finding a single variable that represents the broad technological concept. This has been typically resolved using ICT capital or investment (Cline & Guynes, 2001; Gilchrist et al., 2001; Brynjolfsson et al., 2002; Brynjolfsson & Hitt, 2003; Bertschek & Kaiser, 2004; Hempell, 2005; Polder et al., 2010) or applying factor analysis to build synthetic indicators from several variables (Byrd & Davidson, 2003; Ilmudeen & Bao, 2018; Cuevas-Vargas et al., 2022).

In general terms, these studies conclude that digital technologies have a positive effect on firm performance, something that has been verified using different firm performance metrics, such as Profits, Revenue, Productivity, Return on Assets (ROA), Return on Equity (ROE), Return on Sales (ROS), or Innovation.

Given the complexities of the specific channels represented in Figure 6, most studies choose to focus on performing empirical estimates only for a specific link among those relations, rather than assessing the broad picture. For instance, those studies that analyze the impact of internet on innovation, or the effects from social media and e-commerce on firm performance, are implicitly focusing on the channel i) related to reduced communication costs.

Similarly, those papers that analyze the economic impact of Big Data, assess the links depicted in channel ii). Effects of automatization or IoT on firm performance are naturally related to the operational transformations as represented by channel iii). Finally, those papers that address the impact of digitalization on export activity effectively study the capability of these technologies to reduce barriers, as in channel iv).

Table 4. Research finding a positive impact of digitalization on firm performance

Technology	Measure of firm performance	References
Digitalization / Industry 4.0	ROA / ROE / Profits	Li et al. (2019), Kharlamov & Parry (2021), Zhai et al. (2022)
	Capital market anual return	Lin & Song (2019)
	Turnaround performance	Wang & Bai (2021)
	Revenue / Sales / Turnover	Martín-Peña et al. (2019), Kharlamov & Parry (2021),
	Innovation	Li et al. (2019), Ardito et al. (2021)
	Firm Performance (latent variable)	Abou-foul et al. (2020), Rahman et al. (2020), Singh et al. (2021)
ICTs/IT	Profits / Gross margin	Shin (2006), Škare & Soriano (2021)
	Market value	Brynjolfsson et al. (2002), Henderson et al. (2010)
	Exports	Hagsten & Kotnik (2017)
	Value added	Hempell (2005)
	Innovation	Joshi et al. (2010), Polder et al. (2010), Fernández-Mesa et al. (2014), Scuotto et al. (2017), Cuevas-Vargas et al. (2022)
	Productivity	Cline & Guynes (2001), Gilchrist et al. (2001), Brynjolfsson & Hitt (2003), Hempell (2005), Bertschek & Kaiser (2004), Arvanitis & Loukis (2009), Moshiri (2016)
	Quality	Bardhan et al. (2006)
	Tobin's Q	Chari et al. (2008)
	Costs	Bardhan et al. (2006)
	Firm Performance (latent variable)	Byrd & Davidson (2003), Wu et al. (2006), Ilmudeen & Bao (2018)
Internet / Broadband	Innovation	Forman & van Zeebroeck (2012), Bertschek et al. (2013), Paunov & Rollo (2016)
	Revenue / Value added	Colombo et al. (2013), Bartelsman et al. (2018) DeStefano et al. (2018), Canzian et al. (2019)
	Productivity	Arvanitis (2005), Arvanitis & Loukis (2009), Majumdar et al. (2009), Grimes et al. (2011), Bertschek & Niebel (2016), Hagsten (2016), Paunov & Rollo (2016), Canzian et al. (2019), Chen et al. (2019), Haller & Lyons (2019)
	Exports	Bianchi & Mathews (2016)
E-commerce	Firm efficiency	Romero & Rodríguez (2010)
	Delivery times, savings, social influence, market participation, quality, profits, client satisfaction	Orji et al. (2022)
Big Data	ROA / ROE / Profits	Huang et al. (2018)
	Turnover / sales / Value added	Tambe (2014), Huang et al. (2018), Muller et al. (2018)
	Innovation	Johnson et al. (2017)
	Supply chain agility	Dubey et al. (2018)
	Expected benefits	Dalenogare et al. (2018)
	Productivity	Tambe (2014), Müller et al. (2018)
	Tobin's Q	Huang et al. (2018), Cappa et al. (2021)
	Firm Performance (latent variable)	Akter et al. (2016), Wamba et al. (2017), Bouwman et al. (2018), Ferraris et al. (2018), Bouwman et al. (2019), Rahman et al. (2020), Gu et al. (2021).
IoT	Profits / ROE	Tang et al. (2018)
	Sales	Tang et al. (2018)
	Tobin's Q	Tang et al. (2018)
	Firm Performance (latent variable)	Rahman et al. (2020)
Automation	Expected benefits	Dalenogare et al. (2018)
Cloud Computing	Firm Performance (latent variable)	Khayer et al. (2020)
	ROA / Expected benefits	Dalenogare et al. (2018), Chen et al. (2022)
	Tobin's Q	Chen et al. (2022)
Capability / leadership / expertise	Firm Performance (latent variable)	Ravichandran, & Lertwongsatien (2005), Liu et al. (2013), Heredia et al. (2022)
	Competitive adv. (latent variable)	Bhatt & Grover (2005)
	Costs	Radhika & Hartono (2003)
	Operating income	Radhika & Hartono (2003)
	ROA / ROS	Radhika & Hartono (2003), Wielgos et al. (2021)
	Innovation	Soto-Acosta et al. (2014), Chen et al. (2015), Benitez et al. (2022)
Blockchain	Profits / ROI	Stranieri et al. (2021)
Social media	Perception of long-term goals	Ribeiro-Navarrete et al. (2021)
	Firm Performance (latent variable)	Bouwman et al. (2019)
Online reviews	Revenue	Mariani & Borghi (2020)
HR digit.	Revenue / Sales / Turnover	Zhou et al. (2021)
Telework	Productivity	Kazekami (2020)

Note: acronyms in the firm performance column refers to Return on Assets (ROA), Return on Equity (ROE), Return on Investment (ROI), and Return on Sales (ROS). All references cited refer to firm-level empirical estimates excepting Kazekami (2020) who used an individual survey.
Source: Authors' own compilation.

Among the first contributions of the reviewed period, we can highlight the seminal research of Brynjolfsson et al., (2002) and Brynjolfsson & Hitt (2003). In the first one, the authors provide evidence of computer assets being a driver of market value for a sample of over 1,200 American firms between 1987 and 1997. Brynjolfsson & Hitt (2003), analyze the impact of computerization on multifactor productivity and output growth for 527 large American enterprises over 1987-1994. They found significant effects of computerization on firm performance, even in the short term, and much larger effects over longer periods of time.

Since then, more recent contributions have been able to test the effects from newer technologies, and to provide more granular evidence of impact paths. Recent findings show that the materialization of these positive effects of technology on firm performance can take place either directly or indirectly.

Among the latest, we can highlight the research conducted by Bouwman et al. (2019), who found that the positive impact of social media and Big Data on firm performance is influenced by business model experimentation and company innovativeness. Similarly, Bianchi & Mathews (2016) found that the positive effect of internet on exports is explained by information availability and business network relationships.

Chen et al. (2015) found that corporate entrepreneurship fully explains the process through which IT capabilities affect product innovation performance. In turn, Cuevas-Vargas et al. (2022) found that absorptive capacity (defined as the ability of a company to acquire, absorb, transform and exploit knowledge) partially explains the effect between ICT adoption and innovation. Other authors found that supply chain capabilities are relevant to explain the effect of IT on firm performance (Liu et al., 2013; Wu et al., 2016). All this evidence suggests that the link between digitalization and firm performance present some relevant nuances that will be analyzed in more detail in section 5.3.

As for the empirical strategy, some studies have relied on Ordinary Least Squares (OLS) estimates (that is the case of Arvanitis & Loukis, 2009; Tambe, 2014; Hagsten, 2016; Bartelsman et al., 2018; Dalenogare et al., 2018; Huang et al., 2018; Tang et al., 2018; Haller & Lyons, 2019; Martín-Peña et al., 2019; Cappa et al., 2021). Other studies follow a different strategy to address the potential presence of endogeneity, a concern that may arise because of omitted variable bias or reverse causality. In particular, the effect of digitalization on firm performance could reflect a mere correlation rather than a causal effect, as investments in technology can be considered as a driver, but also a result of productivity and economic growth (Cardona et al., 2013).

The most common strategy to address endogeneity at the firm level has been the use of Instrumental Variable (IV) estimators, using instruments that are expected to affect digital diffusion in the firm without having a direct effect on firm performance (Brynjolfsson & Hitt, 2003; Atrostic et al., 2004; Arvanitis, 2005; Majumdar et al., 2009; Forman & van Zeebroeck, 2012; Bertschek & Niebel, 2016; Muller et al., 2018; Zhai et al., 2022).

To a lesser degree, other authors have relied on other estimation techniques, such as the Generalized Method of Moments (GMM) approach (Gilchrist et al., 2001; Hempell, 2005; Bertschek et al., 2013; Colombo et al., 2013; Škare & Soriano, 2021) or differences in differences methodologies (Canzian et al., 2019; Chen et al., 2019; Lin & Song, 2019; Kazekami, 2020) to mitigate endogeneity problems.

More recently, the preferred empirical approach seems to be the development of structural equation modeling (SEM). This methodology relies on factor analysis to build complex constructs, and introduces several moderating and mediating effects in the link between digital technologies and firm performance (Byrd & Davidson, 2003; Wu et al., 2006; Joshi et al., 2010; Liu et al., 2013; Fernández-Mesa et al., 2014; Soto-Acosta et al., 2014; Chen et al., 2015; Bianchi & Mathews, 2016; Johnson et al., 2017; Scuotto et al., 2017; Wamba et al., 2017; Bouwman et al., 2018; Dubey et al., 2018; Ferraris et al., 2018; Ilmudeen & Bao, 2018; Bouwman et al., 2019; Abou-foul et al., 2020; Gu et al., 2021; Wielgos et al., 2021; Singh et al., 2021; Benitez et al., 2022; Cuevas-Vargas et al., 2022; Heredia et al., 2022).

This empirical evidence provides strong support for the theoretical arguments that link digitalization with firm performance, and for the materialization of these effects through the four channels depicted in Figure 6.

5.3.Firm diversity and heterogeneous effects

While Table 4 summarized the firm-level empirical studies that found a positive effect from digital technologies on firm performance, the literature has not been unanimous about these findings. There are also studies in which no significant positive effects have been found. For example, Haller & Lyons (2015) found no statistically significant effect of broadband adoption on firms' productivity for a sample of Irish manufacturing firms.

DeStefano et al. (2018) find a non-significant impact of the ICT capital stock on productivity when using IV estimates for a sample of UK firms. Similarly, Bertschek et al. (2013) show no impact from broadband on firms' labor productivity for a sample of German firms. Aral & Weill (2007) find for a sample of American firms that total IT investment is not linked with firm outcomes, although investment in specific assets and organizational IT capabilities contribute to strengthen the effects of IT.

There are also examples of negative digitalization effects, such as Lui et al. (2021). They find that AI investments had a negative impact on firms' market value. In the same vein, Cappa et al. (2021) show a negative effect of Big Data volume (in terms of quantity) on firm performance, suggesting the difficulty of successfully managing very large databases and highlighting the need to complement data volume with variety (differences in the type of data) to be able to deliver positive results.

All this means that the positive economic effects from digital technologies may not be as straightforward as it may appear at first sight. Investments in digital technologies have a cost, and if a firm is not prepared to use them productively, then there is no reason to expect an increase in performance.

Most studies have estimated the impact of digitalization for an average or representative firm. This approach implicitly assumes a homogeneous effect, an assumption not considered to be realistic. In that sense, the impact of digital technologies may be conditional on certain characteristics of the firm. This means that not all firms may be able to extract the same gains from digitalization, which leads in some cases to unsatisfactory results, despite positive expectations (Fitzgerald et al., 2014). Different firms should probably adopt different strategies based on their different internal capabilities.

Some authors underline the importance of complementary investments, since technological adoption needs to be combined with human capital or internal restructuring to increase firm performance (Brynjolfsson & Hitt, 2000). Knowledge stock and skills are usually considered drivers of absorptive capacity, which can influence firm capabilities to make the most of new technologies (Cohen and Levinthal, 1990).

Organizational complements and intangible assets are considered crucial for the digital effects on firm performance. Ross (2017) complements those views with the necessary leadership and vision skills that digitalization processes require to become effective and to transform organizations. Similarly, David-West et al. (2020) suggest that these technologies need to be complemented with other capabilities to achieve successful results. In turn, Ritala et al. (2021) state that the success of a firm's digital strategy depends on employees' proactiveness, risk-taking, innovativeness, and relational capital within the organization.

External factors can also be relevant. Potential gains derived from digital technologies may depend on the firm's linkages to the external world. Network externalities may also be present when the benefits of technology adoption depend on the decisions made by other users. In addition, the magnitude of the digitalization effects may depend on the firm's previous access to knowledge (Paunov & Rollo, 2016).

The more sophisticated the technology, the more challenging the process of extracting benefits from it may be. We can exemplify this with the case of Big Data, where some authors have highlighted a risk of *InfoObesity*, with some firms not being capable to productively process large amounts of data, which results in dysfunctional outcomes (Cappa et al., 2012; Whitler, 2019).

Another important source of heterogeneous results can be associated with the industrial sector. Naturally, some economic sectors are more intensive in digital technologies, thus, different impacts should be expected. As an example, for the case of the Spanish economy, Mas & Quesada (2009) identified electricity, gas, and water supply; pulp, paper, printing, and publishing; electric, electronic, and optic equipment; transport and communications; financial intermediation; business services; private health and social services as the more ICT-intensive industrial sectors.

This selection may evolve over time if new technologies prove to be more relevant to some sectors in comparison to others. An example of this is the agricultural sector, not closely related in the past to digital technologies, but currently being revolutionized by digitalization.

Regarding SMEs, technological advances among them are usually slower than in large firms (Ntwoku et al., 2017). However, the empirical literature has suggested that digital solutions can be crucial for their growth (Colombo et al., 2013; Hagsten & Kotnik, 2017). Chege et al. (2020) argue that SMEs can use digital tools to open new markets for their business.

Smaller business may be able to perform activities which previously were exclusive of the biggest, like enlarging its interactions with external organizations or increasing the scope of its diffusion activities. Hagsten & Kotnik (2017) highlight that the new marketing channels and cost reduction potential from digital technologies are especially relevant for firms with limited resources. This is especially relevant in the case of underdeveloped countries, as digitalization can help lagging firms to overcome constraints derived from socioeconomic and institutional frameworks. For instance, digitalized procedures for obtaining permits may overcome barriers such as bureaucracy, transaction costs, and even corruption.

KEY IDEAS

- The theoretical distinction between adoption and diffusion is harder to trace from the empirical point of view. Empirical research confirms that adoption factors tend to be complemented by diffusion drivers like the location, the size of the company or the sector in which it operates.
- Most empirical papers provide evidence on the positive effects of digitalization on firm performance, validating the relevance of the four channels represented in Figure 6. These results stand despite the use of diverse methodological approaches and very different definitions for digital and firm performance variables.
- There are research pieces that have not been able to verify those impacts. This suggests that the relationship between digitalization and firm performance is complex and may require specific conditions to be optimized.

6. Conclusions and final reflections

Through this paper we have provided an up-to-date overview of the literature related to digitalization at the firm level. First, we addressed the definitions for the key concepts involved, and reviewed the main digital tools currently considered crucial for firm development. Next, we provided theoretical arguments about the drivers of digitalization and the expected economic effects and disentangled the specific transmission channels identified in the literature. Finally, we summarized the main empirical research conducted in recent years that has provided evidence on digitalization dynamics.

The literature on digitalization identifies two main categories of drivers for ICT adoption and diffusion. The first one, more general and with a management perspective, establishes 5 groups of digitalization triggers at the firm-level: individual, organizational, environmental, technological, and economic reasons. The theoretical literature clearly separates digital adoption from diffusion. However, empirical analyses tend to cover both processes as a combined one.

The second category of drivers is focused on the models that explain diffusion within a firm or sector: rank (captured by variables such as age or the size of the company), epidemic (measured as the percentage of similar firms that have adopted a particular technology), location (being in a densely populated area), stock (number of previous adopters of a certain technology), and order effects (position in which the company has adopted a technology) fall under this category.

In terms of economic impact, the literature provides several paths of internal transformation that are expected to yield economic gains. We summarized the theoretical arguments and grouped them into four main segments: lower communication costs (internal and external), data analysis (information collected from internal processes, clients, or value-chain), operational transformations (internal optimization than can led to reduced costs and better human resources management), and lower entry barriers (development and access to new markets, either national or international). The bulk of the empirical research reviewed accredited that digital technologies have a positive effect on firm performance; this has been verified in studies using very different firm performance metrics, such as profits, revenue, productivity, or innovation.

However, some issues remain unsolved which will require future research. First, while most studies were able to find a positive economic impact from digitalization, some papers find it only for some specific groups of firms, while others do not find evidence of any impact at all. This leads to the conclusion that the impact of digital technologies may be conditioned on certain characteristics of the firm (e.g., skills, internal capabilities, complementary investments, organizational restructuring, etc.).

Second, as the technological tools linked to the digitalization process are rapidly evolving, there is a lack of reliable datasets covering the availability and use of recent advances such as Big-Data, IoT, AI at the firm level. In that respect, we urge the statistical authorities in charge of conducting firm-surveys to update their questionnaires at the pace marked by technological advances, and to facilitate the access to this information for academic research purposes.

Finally, and linked to the later, there are important possibilities for improvement in terms of the empirical approaches followed. Related to data limitations, some studies have addressed the analysis of the impact of cutting-edge innovations though case studies or qualitative approaches. Considering the limitations of these methodologies, more robust econometric approaches will be needed to analyze the role of these latest advances once richer datasets become available.

From a policy perspective, the barriers faced by some firms to adopt and intensively use digital technologies, suggests the need to promote specific public programs oriented to overcome them. These policy interventions should address the challenges faced by SMEs, help them to assess the risks and financial challenges linked to digitalization, and provide the necessary support in terms of strategic planning and processes' optimization.

Human capital is crucial in this aspect. In most countries there is a shortage of skilled workers with the necessary ICT capabilities (e.g., senior programmers, data analytics specialists, engineers, etc.). To overcome those difficulties, a careful monitoring of the labor market is needed with a mid- and long-run perspective, aiming to match training to the economy's needs. Given the important disparities in terms of the digital divide, public authorities should increase their efforts to bridge that gap. To be successful, digitalization requires that firms have access to reliable high-speed broadband infrastructure (e.g., fiber optic or 5G), which is mostly available at the bigger cities, but this is not necessarily the case in some of the small ones and in rural areas.

Digitalization and ICT adoption are changing the landscape in which firms operate. Companies need to adjust their business models if they want to remain competitive. The latest technological advancements still affect "physical" elements in traditional business models. However, emerging forms of business models are prominently based on the adoption of digital infrastructures and the dematerialization of processes. This requires the adoption of strategies capable of attaining the highest degree of resource efficiency. New forms of ventures are starting to play a novel role as a hub between buyers and sellers in the exchange of goods and services (Caputo et al., 2021).

The transition to new business models derived from digitalization is characterized by a high degree of complexity. The success of business models' adaptation to new technologies depends on the characteristics and capabilities of firms and on the overall quality of the model to be transformed. Some companies are characterized by their barriers to change, based on prior experience, for example. According to Caputo et al. (2021) and Chesbrough (2010), an ordinary technology applied to great business models might be more effective than a cutting-edge technology implemented in ordinary business models.

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Appendix A - Definitions for Digitalization

Definition	Study
Digitalization is a transition where traditional production processes are enhanced or replaced by digital technology leading to the implementation of new business activities, increased competitiveness, and new distribution channels.	Amit & Zott (2001)
Digitalization describes a firm's transition to use digital technologies in order to implement its business activities and generate revenue.	BarNir et al. (2003)
Digital transformation refers to the use of technology to radically improve performance or reach of enterprises.	Westerman et al. (2011)
Digitization, as a social process, refers to the transformation of the techno-economic environment and socio-institutional operations through digital communications and applications.	Katz & Koutroumpis (2013)
Digital transformation is the use of new digital technologies to enable major business improvements, such as enhancing customer experience, streamlining operations, or creating new business models.	Fitzgerald et al. (2014)
Digital transformation is a process of major change in the business to enhance customer experience and innovate business models by leveraging new digital technologies.	Piccinini et al. (2015)
Digitalization refers to the material process of converting analogue streams of information into digital bits.	Brennen & Kreiss (2016)
Digital transformation refers to the role of information and communication technologies within the scope of societal challenges.	Majchrzak et al. (2016)
Digitalization refers to the increasing use of digital technologies for connecting people, systems, companies, products, and services.	Coreynen et al. (2017) and Hsu (2007)
Digital transformation is defined as the process that is used to restructure economies, institutions, and society on a system level.	Unruh & Kiron (2017)
Digitalization describes the de-materialization of physical products.	Vendrell-Herrero et al. (2017)
Digital transformation is the integration of digital technology into all sectors of a business, fundamentally altering how they perform and bring value to customers.	Gebayew et al. (2018)
Digitalization is defined as the adoption of digital technologies to facilitate business operations.	Banalieva & Dhanaraj (2019)
Digitalization is considered a way to improve the ability to search, store, analyze, and share information and resources among business organizations.	Li et al. (2019)
Digital transformation is a process where digital technologies create disruptions triggering strategic responses from organizations that seek to alter their value creation paths while managing the structural changes and organizational barriers that affect the positive and negative outcomes of this process.	Vial (2019)

Source: Authors' own compilation.

Appendix B – Detailed list of research studies studying the drivers of digital adoption and diffusion at the firm level

Reference	Technology Variable	Category	Drivers	Sample	Methodology
Cragg & Zinatelli (1995)	Hardware acquisition; Hardware use	Adoption	Individual	18 firms - New Zealand	Longitudinal case, Data collection
Teo & Tan (1998)	Internet access	Adoption & Diffusion	Individual & Rank	500 companies - Singapore	Survey; Data collection
Caselli and Coleman (2001)	Computers per worker; Imports of Computers	Adoption	Organizational	Country-level; Worldwide approach	OLS
Caroli & Van Reenen (2001)	New technology use (survey-obtained)	Adoption	Organizational	Over 2000 British establishmen ts	OLS
Galliano et al. (2001)	JIT logistics system certification	Diffusion	Location	5107 firms - France	Survey; Data collection; bivariate probit model
Mehrtens et al. (2001)	Internet adoption	Adoption	Environmental	Seven small firms	Case Study
Gourlay & Pentecost (2002)	Automated teller machines (ATMs)	Diffusion	Epidemic	Stock of retail banks and building societies at the end of 1997 - UK	OLS; Lognormal; Log-logistic Model
Oulton (2002)	Software investment	Diffusion	Epidemic	Country-level; UK vs. US approach	Growth accounting
Chun (2003)	Office, computing, and accounting machinery	Diffusion	Rank	56 U.S. industries for the period 1960–1996	OLS; Cost functions
Damaskopoulos & Evgeniou (2003)	Internet firm penetration; Electronic payments	Adoption	Individual	Eastern Europe countries' firms	Survey; Data collection
Hollerstein (2004)	Adoption intensity own indicator	Adoption	Organizational	1667 small and medium firms - Switzerland	Survey; OLS
Lucchetti & Sterlacchini (2004)	Different variables: Internet access, website, online sales	Adoption & Diffusion	Macroeconomic & Rank	Italian SMEs	Survey; Data collection
Zahra (2005)	Investment in emerging radical technologies	Adoption	Individual	209 family companies - US	Survey; Data collection

Falk (2005)	e-business practices	Adoption	Individual	e-business w@tch data for EU-4	Data collection; OLS
Fabiani et al. (2005)	PCs, ICT expenditure, years with internet access, turnover, human capital.	Adoption	Individual & Organizational	1500 firms with more than 50 employees	Survey; OLS; Probit
Lefebvre et al. (2005)	B-to-B e-commerce adoption	Adoption	Organizational	122 SMEs	Pilot Study; Survey; Case Study
Love et al. (2005)	IT investment as a percentage of turnover	Adoption	Organizational	30 small-to-medium-sized enterprises (SMEs) in Australia	Survey
Bayo-Moriones & Lera-López (2007)	PCs, Internet, Extranet, Intranet, email, videoconference, website	Adoption & Diffusion	Individual & Rank	337 Spanish workplaces	Survey; OLS; Tobit
Giunta & Trivieri (2007)	PC + email + web site	Adoption & Diffusion	Individual & Rank	17,000 firms - Italy	Probit
Wen et al. (2009)	RFID adoption	Adoption		50 manufacturing companies - China	Survey; Interviews
Cesaroni et al. (2011)	Technological training and skills	Adoption	Technological	2 italian companies	Case Study
Cesaroni et al. (2010)	Different indicators: investment, infrastructure, web 2.0…	Adoption	Macroeconomic	50 SME's in the Marche Region (Italy)	Survey; Interviews
Haller & Siedschlag (2015)	Web, online transactions, computer use	Adoption & Diffusion	Individual, Rank & Epidemic	European Union	OLS; Probit

Note: OLS acronym in the methodological column refers to Ordinary Last Squares.
Source: Authors' own compilation.

Appendix C – Detailed list of research studies finding a positive impact of digital technologies on firm performance

Reference	Technology variable	Firm performance variable	Sample	Methodology
Cline & Guynes (2001)	IT investment (strategic, tactical, transactional, threshold)	Productivity	United States (1990s)	Correlation analysis
Gilchrist et al. (2001)	IT investment and PCs	Productivity (Solow residual)	Fortune 1000 companies (1986-1993)	GMM
Brynjolfsson et al. (2002)	Computer assets	Market Value on Asset	United States (1995-1996)	OLS - LAD
Brynjolfsson & Hitt (2003)	Computarization	Multifactor Productivity / output growth	United States (1987-1994)	OLS - IV
Byrd & Davidson (2003)	IT constructs and IT impact on supply chain construct	Firm performance construct	United States (2002)	SEM
Radhika & Hartono (2003)	IT capability	Profit Ratio, ROS, ROA, Operating income ratios, Cost Ratios	United States (1991-1997)	Matched sample comparison group methodogy
Atrostic et al. (2004)	IT (Network use / availability)	TFP / Labor productivity	Japan (1997) and United States (1999)	OLS - IV
Bertschek & Kaiser (2004)	ICT investment	Labor productivity	Germany (2000)	ML
Arvanitis (2005)	Internet and intranet	Labor productivity	Switzerland (1999)	OLS - IV
Bhatt & Grover (2005)	IT Business expertise construct	Competitive advantage construct		SEM
Hempell (2005)	ICT capital	Value added	Germany (1994-1999)	OLS - GMM
Ravichandran, & Lertwongsatien (2005)	IT infrastructure, IS capability, IT support	Firm performance construct	Fortune 1000 firms (1997-1999)	PLS-SEM
Bardhan et al. (2006)	IT spending	Costs / Quality	United States (2004)	Ordered probit / OLS
Shin (2006)	IT with strategic direction	Gross margin	Information Week firms (1995-1997)	OLS
Wu et al. (2006)	IT aligment and IT advncement constructs	Financial performance construct	United States	SEM
Chari et al. (2008)	IT investment	Tobin's Q	Information Week firms (1997)	OLS
Arvanitis & Loukis (2009)	Internet and intranet	Labor productivity	Greece and Switzerland (2004)	OLS
Majumdar et al. (2009)	Broadband	Productivity	United States (1995-2000)	IV
Henderson et al. (2010)	IT expenditure	Market value	Information Week firms (2001-2005)	Prais Winsten model / OLS

Joshi et al. (2010)	IT	Innovation	(2002-2005)	SEM
Polder et al. (2010)	ICT investment, ICT use	Innovation	Netherlands (2002-2006)	CDM model
Romero & Rodríguez (2010)	Use of internet in buying process	Firm efficiency	Spain (2000-2005)	Stochastic Frontier Model / ML
Grimes et al. (2011)	Broadband	Labor productivity	New Zealand (2006)	Matching - IV
Forman & van Zeebroeck (2012)	Internet	Collaborative patents	United States (1992-1998)	OLS -IV
Bertschek et al. (2013)	Broadband	Innovation	Germany (2001-2003)	OLS - IV/GMM
Colombo et al. (2013)	Broadband adoption and specific uses	Value added	Italy (1998-2004)	GMM
Liu et al. (2013)	IT capability construct	Firm performance construct	China	SEM
Fernández-Mesa et al. (2014)	IT competency	Innovation	Spain and Italy (2006)	SEM
Soto-Acosta et al. (2014)	IT expertise	Innovation	Spain (2012)	SEM
Tambe (2014)	Big Data	Value added	United States (2006-2011)	OLS
Chen et al. (2015)	IT capability construct	Product innovation	China (2013-2014)	PLS-SEM
Hagsten (2015)	Broadband	Labor productivity	Firms from 14 European countries (2001–2010)	OLS
Akter et al. (2016)	Big Data	Firm performance construct	United States (2014)	PLS hierarchical model
Bertschek & Niebel (2016)	Mobile internet	Labor productivity	Germany (2014)	OLS - IV
Bianchi & Mathews (2016)	Internet	Exports construct	Chile (2011)	SEM
Paunov & Rollo (2016)	Internet use / cell phones	Innovation, labor productivity, investment	Firms from 117 countries (2006-2011)	OLS – Probit – Logit - Quantile Regressions
Hagsten & Kotnik (2017)	ICTs/IT	Probability to export and export intensity	Firms from European countries (2010)	Probit - OLS
Johnson et al. (2017)	Big Data	Product innovation construct	United States (2017)	SEM
Scuotto et al. (2017)	ICT use	Innovation	Italy (2017)	SEM
Wamba et al. (2017)	Big Data construct	Firm performance construct	China (2016)	PLS SEM
Bartelsman et al. (2018)	Broadband (share of employees using)	Value added	European firms 10 countries (2002-2010)	OLS
Bouwman et al. (2018)	Big Data	Firm performance construct	European firms (2017)	PLS-SEM
Dalenogare et al. (2018)	Big Data, Digital Product-Services, Additive manufacturing,	Product, Operational and Side-effects expected benefits	Brazil (2016)	OLS

	Cloud services, Computer-Aided Design integrated with Computer-Aided Manufacturing, Digital automation with sensors			
DeStefano et al. (2018)	Broadband	Revenue	United Kindgom (2000)	IV
Dubey et al. (2018)	Big Data	Supply chain agility construct	India (2015)	PLS-SEM
Ferraris et al. (2018)	Big Data	Firm performance construct	Italy (2018)	SEM
Huang et al. (2018)	Big Data	Tobin Q, ROA, ROE, Profit margin, Turnover	Fortune 1000 companies (2010-2014)	OLS
Ilmudeen & Bao (2018)	IT management construct	Firm performance construct	China (2016-2017)	PLS-SEM
Muller et al. (2018)	Big Data	Sales	United States (2008-2014)	OLS - IV
Bouwman et al. (2019)	Social Media, Big Data	Firm performance construct	European firms (2017)	PLS-SEM
Tang et al. (2018)	IoT	Profit, sales, ROE, Tobin's Q	United States (2015)	OLS
Canzian et al. (2019)	Broadband availability	Reveue and TFP	Italy (2008-2014)	DiD
Chen et al. (2019)	Broadband	TFP	China (1998-2007)	DiD
Haller & Lyons (2019)	Broadband	TFP	Ireland (2006-2012)	OLS
Martín-Peña et al. (2019)	Digitization	Revenue / sales	Spain (2014-2017)	OLS
Lin & Song (2019)	Industry 4.0	ROE, patents, Capital market annual return	China (2017)	DiD
Abou-foul et al. (2020)	Digitization	Firm performance construct	US and European firms (2016-2017)	SEM
Kazekami (2020)	Telework	Labor productivity	Japan (2017-2018)	OLS - DiD - Logit
Khayer et al. (2020)	Cloud Computing construct	Firm performance construct	China (2018-2019)	PLS-SEM
Mariani & Borghi (2020)	Online review helpfulness	Average revenue per room	London, United Kingdom (2015-2016)	Hierarchical model
Rahman et al. (2020)	IoT, Big Data, Smart factory, and CPS constructs	Firm performance construct	Bangladesh and Canada	PLS-SEM
Ardito et al. (2021)	Digitization	Innovation	United States and Canada (2014)	Probit
Cappa et al. (2021)	Big Data	Tobin's Q	United States (2018)	OLS
Gu et al. (2021)	Big Data	Firm performance construct	China (2021)	SEM
Kharlamov & Parry (2021)	Digitization	Profits / Revenue	United Kindgom (2007-2016)	Mean comparison / Multinomial logit

Ribeiro-Navarrete et al. (2021)	Social Media	Perception of long-term goals	Valencia, Spain (2019)	Fuzzy-set qualitative comparative analysis
Singh et al. (2021)	Digitization	Firm performance construct	India (2021)	PLS-SEM
Škare & Soriano (2021)	ICTs/IT	Profit marign	Firms from 15 European countries (2009-2018)	GMM
Stranieri et al. (2021)	Blockchain	Profit and ROI	2019	Qualitative (Case studies)
Wang & Bai (2021)	Digitization	Turnaround performance	China (2012-2019)	2 Stage Probit / Heckman
Wielgos et al. (2021)	Digital business capability	ROS / ROA		SEM
Zhou et al. (2021)	HR digitization	Revenue / sales	China (2017)	Hierarchical regression
Benitez et al. (2022)	Digital leadership construct	Innovation construct	Spain and Bulgaria (2014)	PLS-SEM
Chen et al. (2022)	Cloud Computing	ROA / Tobin's Q	Worldwide firms (2010-2016)	DiD
Cuevas-Vargas et al. (2022)	ICT adoption construct	Innovation construct	Colombia (2018)	PLS-SEM
Heredia et al. (2022)	Digital capability / leader	Firm performance construct	Firms from 27 countries (2020)	PLS-SEM
Orji et al. (2022)	E-commerce	Profits, delivery time, cost savings, social influence, service quality, and customer satisfaction	Nigeria (2020)	IF- DEMATEL - MULTIMOORA - SAW
Zhai et al. (2022)	Digitization	ROA, ROE	China (2009-2019)	OLS -IV

Note: acronyms in the methodological column refer to Ordinary Last Squares (OLS), Partial Least Squares (PLS), Structural Equation Modelling (SEM), Instrumental Variables (IV), Maximum Likelihood (ML), Generalized Method of Moments (GMM); Least Absolute Deviation (LAD), Differences in Differences (DiD), and the model proposed in Crépon et al. (2000) (CDM).
Source: Authors' own compilation.