Science and Public Policy, 2024, **51**, 1212–1226
DOI: https://doi.org/10.1093/scipol/scae023
Advance Access Publication Date: 29 July 2024
Special section

OXFORD

SME digital transformation and the COVID-19 pandemic: a case study of a hard-hit metropolitan area

Adelheid Holl[1] and Ruth Rama[2,*]

[1]Institute of Public Goods and Policies (IPP), CSIC—Consejo Superior de Investigaciones Científicas, C/Albasanz, 26-28, Madrid 28037, Spain
[2]Institute of Economics, Geography and Demography (IEGD), CSIC—Consejo Superior de Investigaciones Científicas, C/Albasanz, 26-28, Madrid 28037, Spain

*Corresponding author. Institute of Economics, Geography and Demography (IEGD), CSIC—Consejo Superior de Investigaciones Científicas, C/Albasanz, 26-28, Madrid 28037, Spain. E-mail: ruth.rama@cchs.csic.es

Cities and regions are facing diverse challenges, and the transformation to a digital economy is a core issue. The coronavirus disease-2019 (COVID-19) pandemic has had widespread impacts on business, and it has heightened the need for digitalization. We analyse if and to what degree the COVID-19 pandemic has accelerated the digital transformation of small and medium-sized enterprises (SMEs) in the metropolitan region of Madrid. Our research strategy is based on a quantitative analysis of survey data at the company level. Our results show that a large share of SMEs invested in digital technologies as a response to the pandemic, but there are also important differences between basic and more advanced digital technologies and between manufacturing and service sector firms. SMEs' previous knowledge and technological resources and capabilities, as well as their collaboration networks with providers are found to trigger adoption of digital technology. Implications for postpandemic policies are highlighted.

Keywords: SMEs; digitalization; technology adoption; COVID-19 effects; post-COVID-19 policies; resilience.

1. Introduction

Cities and regions are facing diverse challenges, and the transformation to a digital economy has become a core issue. At the same time, the coronavirus disease-2019 (COVID-19) pandemic strongly affected firms across the globe and it has further heightened the need for digitalization. This is particularly true for small and medium-sized enterprises (SMEs) that have been hit by the pandemic more so than large business. According to a World Bank report (Apedo-Amah et al. 2020), all over the world, the likelihood of a business being open 6 weeks after the peak of the COVID-19 crisis was 89 per cent for large firms, 86 per cent for medium-sized firms, 82 per cent for small firms, and only 79 per cent for microfirms. In the European Union (EU), size has been related to whether firms lost sales during the pandemic, even after controlling for country and sector effects (EIB 2022). A survey conducted by the Central Bank of Spain in November 2020 also found that small Spanish firms, that is, companies with fewer than fifty employees, were more likely than their larger peers to report a turnover decline as compared to the precrisis period, even if other firm specific characteristics were controlled for (Fernández-Cerezo et al. 2021). According to the abovementioned survey, within each sector and region, the smaller, younger and less-productive Spanish firms were worst hit by the pandemic. Smaller businesses tend to be less resilient to crises, and the COVID-19 pandemic has been no exception. On the one hand, they are less able to capture the opportunities opened by crises. On the other hand, their smaller resources, the limited geographical scope of their activities, and their dependence on their input–output networks make them more vulnerable (Holl and Rama 2016; Fernández-Cerezo et al. 2021; Kumar and Ayedee 2021; Zutshi et al. 2021; Belitski et al. 2022).

In this context, certain studies call for innovation and digitalization as means to improve the resilience of small business (Zutshi et al. 2021). Juergensen, Guimón, and Narula (2020) emphasizes that the COVID-19 crisis has raised the importance for SMEs to invest in digital technologies (DTs). After reviewing the literature on SMEs, Kumar and Ayedee (2021) conclude that robotics and automation can help to minimizing physical contact during a pandemic, while e-commerce contributes to promoting sales even during a lockdown. Preliminary surveys seem to corroborate this point of view. Bianco et al. (2023) find that the implementation of Industry 4.0 (I4.0) technologies helped Brazilian manufacturers to maintain performance during the pandemic. In Spain, most younger firms declared that the adoption of basic DTs, such as work-from-home schemes and e-commerce, was useful to mitigate the effects of the pandemic (Fernández-Cerezo et al. 2021). Italian manufacturing SMEs perceived I4.0 and digital reorganization of production as an effective strategy to recover prepandemic output levels (Cugno et al. 2022). European SMEs that, during the pandemic, prioritized and used digital tools significantly more than other European SMEs tended to hire more employees and to display better revenue (Digitally Driven Europe 2021). A report from EIB (2022) notes that firms that had already a strong digital involvement were better able to keep their contacts with suppliers, clients, and employees during the pandemic. In contrast, many firms that had not adopted DT, mainly small local business, had to stop their activities for weeks or even for months.

Despite the clear benefits of digitalization, many SMEs face difficulties that impede adoption. However, little is still known about the drivers for digitalization among small business and, consequently, the identification of the most important triggers in times of crisis remains an underexplored area of research (Cugno et al. 2022; Kinkel, Baumgartner, and Cherubini 2022). A better understanding of adoption levels of digitalization by small businesses is important given their substantial contribution to employment and economic growth. Belitski et al. (2022) mention digitalization among their suggestions for postpandemic research. However, to date, very few studies have analysed whether the pandemic stimulated adoption in SMEs. Certain studies on digitalization in this type of companies are based on evidence gathered during the pandemic (Ogrean and Herciu 2021; Munongo and Pooe 2022; Trinugroho et al., 2022), but in some cases, the evidence was collected actually during a span of time comprising both a prepandemic period and a pandemic period (Ogrean and Herciu 2021). Other studies failed to specify whether DT was implemented actually after the pandemic hit the respective countries. Despite the relevance of these studies, it is difficult to conclusively determine whether COVID-19 accelerated digitalization.

The aim of the present article is to fill this gap in the literature and to study if the COVID-19 crisis has accelerated the DT adoption of SME located in the metropolitan region of Madrid, one of the European cities worst hit by the pandemic (Fernández-Cerezo et al. 2021; Ramiro Fariñas et al. 2022). Different triggers of adoption are analysed. The research strategy is based on a quantitative analysis of survey data at the company level. A regional focus regarding the impact of the COVID-19 crisis on the adoption of DT can help to improve our understanding of the phenomenon since the effects of the pandemic differed markedly across regions (Bartik et al. 2020; Siuta-Tokarska 2021; Ramiro Fariñas et al. 2022), with urban areas generally being more strongly affected and having experienced stricter lockdowns (Fernández-Cerezo et al. 2021). Improvement of work at home capabilities, access to appropriate technology for remote working, and adoption of DT need to be observed in specific industrial and regional contexts (Okorie et al. 2020; Anzolin, Andreoni, and Zanfei 2022). Location is an important consideration also due to its influence on regulation, measures of support, digital infrastructure, the cultural environment, and the availability of skilled labour (Fernández-Cerezo et al. 2021; Hrivnák, Moritz and Chreneková 2021; Sandulli, Gimenez-Fernandez, and Rodriguez Ferradas 2021; Kinkel, Baumgartner, and Cherubini 2022; Rietmann 2022; Roffia and Mola 2022) According to the economic history literature, in regions with higher disease prevalence, people tend to avoid to a greater degree interaction, which in turn leads to detrimental economic effects and limited innovativeness in the medium run (Bürgel et al., 2023). Hence, there is added value in examining the impact of the pandemic on technology adoption, particularly in a city severely affected by the crisis.

Moreover, the literature has shown that adoption patterns of digitalization are influenced by firms' external environment related to industry concentration (Kelley and Helper 1999), the number of prior adopters (No 2008) in the local environment of companies, local competitive pressure (Bayo-Moriones and Lera-López 2007), or city size (Holl, Pardo, and Rama 2013). Therefore, the analysis of SMEs in a homogeneous external context, such as a specific region or metropolitan areas, has the advantage to minimize the interference of external factors that could influence the investigation of DT adoption at the company level.

Another motivation for our study is the recent allocation of funds for Spain's recovery, highlighting the imperative to address vulnerabilities within the national innovation system (NIS). Specifically, the country has been granted €140 billion in loans and subsidies through the NextGeneration EU program, as it was one of the EU countries most severely hit by the pandemic.[1] At the core to this program is the promotion of the digital transition, and the allocation of the funds further underscores the importance of our focus on policies aimed towards fostering recovery, including initiatives in digitalization. As emphasized by Coveri et al. (2020), the inclusion of the regional level in recovery policies is crucial.

Using the lens of the resource-based view (RBV) of the firm and of the theory of innovation diffusion, we test the proposition that DT adoption in the context of the COVID-19 crisis depended on two main determinants: the resources of SMEs, especially their knowledge and network resources, and their dynamic capabilities, that is, their resilience. To the best of our knowledge, the present article constitutes the first analysis on triggers of DT adoption in SMEs during the pandemic in a homogeneous area.

2. Related literature and hypotheses

2.1 Resilient small business

The still scarce literature on the effects of the pandemic on DT adoption is related to other research fields, such as the literature of urban resilience and smart cities and, specifically, the literature on the resilience of SMEs in the context of crises (for reviews, see Büyükzkan and Arsenyan 2012; Sharifi, Khavarian-Garmsir, and Kummitha 2021). While the latter field of research provides interesting insights, the majority of it is conceptual or constitutes reviews. Only a limited number of studies involve quantitative or empirical analyses at the company level (for a review, see Wahid and Zulkifli 2021). As noted by Bürgel, Hiebl, and Pielsticker (2023), we still lack a detailed understanding of what makes firms resilient to pandemic crises.

The responses adopted by firms to confront the pandemic crisis seem to have been influenced by their degree of vulnerability. Fernández-Cerezo et al. (2021) found that, during the COVID-19 crisis, Spanish firms that were less affected predominantly embraced remote work as their primary strategy to mitigate the repercussions on their businesses. In contrast, severely affected firms primarily opted for a reduction in investment. In our view, the vulnerability of certain sectors and companies may have reduced, in turn, their willingness to invest, specifically, in DT. As stated, an important aspect of the question is the industrial composition of different locations and their relative resilience faced to the pandemic. Certain studies suggest that, in order to account for the relative effects of the lockdown on SMEs, the consideration of the specific sector in which they are active is essential

(Fernández-Cerezo et al. 2021; Pedauga, Sáez, and Delgado-Márquez 2022). Belitski et al. (2022) believe that, during the pandemic, social distancing norms could have affected the services to a greater extent than manufacturing since they depend, in many cases, on physical interaction and involve a substantial number of micro and small business. In contrast, another study for Poland finds that, during the pandemic, the least affected SMEs were those engaged in business services (Siuta-Tokarska 2021). Other authors note that manufacturing is more vulnerable to this type of crisis (Okorie et al. 2020).

Miklian and Hoelscher (2022) synthesize related literature that present points of complementarity regarding the nature of SMEs during shocks, such as wars and the COVID-19 crisis. They conclude that company size correlates with the ability to survive such events since small firms possess fewer resources and are less able to influence their environment. During a recession, economic impacts are not equally distributed across sectors or companies and small business tend to be more affected than large firms (Holl and Rama 2016; Bartik et al. 2020). In the current article, we examine the sector in which the DT adopter is active and distinguish various size categories within the SME group.

In addition to the global pattern unveiled during the pandemic, which underscored vulnerabilities arising from the vertical disintegration of production and the fragility of international supplies (Coveri et al. 2020), Madrid has been contending with enduring vulnerabilities in certain industries. These vulnerabilities have roots preceding the COVID-19 crisis, dating back to the Great Recession and earlier. Sánchez-Moral et al. (2019) describe the gradual dismantling of the manufacturing industry in Madrid accompanied by a concurrent trend of tertiarization in the regional economy since the early 2000s. Considering the prolonged vulnerability of the manufacturing sector, it becomes imperative to specifically address the position of manufacturing SMEs and how they responded to the crisis in terms of digitalization. This is specifically important for postpandemic policies.

2.2 Digital technology adoption

Technology adoption consists of the decision of a consumer, a business, or another agent to start using a new technology (Skare and Riberio Soriano 2021). At the firm level, technology adoption has been related to a wide range of factors, including firms' internal resources, organizational and technological competences, knowledge resources, and networking (Dosi 2000; Hall 2005; Bayo-Moriones and Lera-López 2007; Foster and Rosenzweig 2010; Giotopoulos et al. 2017; Buer et al. 2021; Kinkel, Baumgartner, and Cherubini 2022).

The RBV conceptualizes firms as heterogeneous organizations encompassing different bundles of resources, such as physical capital, accumulated experience, absorptive capacity, and knowledge capabilities (Miotti and Sachwald 2003; Lockett 2005). This vision is extended by Lavie (2006) to networked resources, that is, to resources embedded into the firm's network.[2] The availability of networked resources, he claims, affects the value and behaviour of the focal company since an interconnected firm may gain access to resources that are not fully owned or controlled by its internal organization. Among other types of networks, he specifically mentions R&D partnerships and co-developments of technologies. In such partnerships, he claims, each firm possesses a subset of nonshared resources and a subset of shared resources.

As shown later, certain studies suggest that resource availability influences DT adoption. According to the general literature on technology diffusion, large firms are more likely to be early adopters than small business due to their greater absorptive capacity and the possibility to spread the costs of new technology over a large production (Dosi 2000; Hall 2005). Large firms seem more prone than SMEs to adopt, specifically, DT and, particularly, advanced DT (Buer et al. 2021; Hizam-Hanafiah and Soomro 2021; De la Fuente et al. 2022; Kinkel, Baumgartner, and Cherubini 2022). Particularly interesting for the scope of the current article is the literature that focuses on heterogeneity *within* the group of small business facing exogenous shocks (Juergensen, Guimón, and Narula 2020). Certain studies emphasize the positive effects of size on DT adoption (Kossaï et al. 2020; Clampit et al. 2021; Wieczorek-Kosmala, Błach, and Doś 2021) and note that, within the small business group, larger SMEs fare better during crises and profess more optimistic views about their business prospects (Digitally Driven Europe 2021). However, the literature on the role of size in DT adoption mostly focuses on the prepandemic period. In a sample of fifty Tunisian SMEs in the Electric and Electronics sector, for instance, a relatively large size is a predictor of the adoption of advanced manufacturing technology (Kossaï et al. 2020). Analyses into the case of Italian SMEs disclose that size has not been a significant driver of the adoption of certain basic DT, such as the Internet, but may have influenced adoption of advanced DT (Lucchetti and Sterlacchini 2004; Corrocher and Fontana 2008). An article that considers digitalization as one reaction to the COVID-19 crisis also finds a positive effect of size on adoption: Polish SMEs that adopted teleworking and online sales after the inception of the pandemic tended to be medium-sized rather than small (Siuta-Tokarska 2021).

Age not only reflects the accumulated experience of a firm (Lockett 2005) but may also influence patterns of DT adoption in SMEs (Wieczorek-Kosmala, Błach, and Doś 2021). In analysing a sample of Polish small business, the aforementioned authors find that younger firms had more pessimistic perceptions about the possible economic effects of the pandemic. During the pandemic in Spain, negative perceptions have been found to disincentive investment (Fernández-Cerezo et al. 2021). However, there is no consensus on the probability of younger SMEs being less prone to invest, specifically, in DT. In fact, Vavrecka et al. (2021) in their study on adoption of digital marketing tools finds that younger Czech SMEs are more inclined to adoption than older Czech SMEs; however, no significant effect of age is found for Slovak and Hungarian SMEs Another study detects that younger Indonesian firms (and younger owners) are especially inclined to adopt online marketing; although not necessarily online payment (Trinugroho et al. 2022). Moreover, according to a qualitative study, the pandemic appears to have fuelled digital entrepreneurship in India (Modgil et al. 2022).

As stated, value-creating resources may also be owned and controlled within networks of firms, not exclusively within the focal firm (Lavie 2006), which makes it important to consider also social and economic connectedness (Hall 2005). In a sample of Korean manufacturing SMEs, Hwang and Kim (2021) observe that those involved in alliances are more inclined to invest in I4.0 and conclude that networking is a driver of DT adoption. In analysing Greek SMEs, Giotopoulos et al. (2017) observe that previous engagement in R&D collaborations constitutes a trigger of ICT adoption. The propagation of information concerning a technology depends, among other factors, on corporate cultures and organizational structure of firms (Dosi 2000). This suggests that the availability of networked sources may influence adoption. One reason is that the tacit knowledge base of an establishment may increase through the exchange of ideas and socialization within a network (Kim 1998). In turn, these circumstances could lessen the learning costs of adoption incurred by a small business. Finally, a major barrier to the adoption of DT in SMEs is internal resistance to change (Garzoni et al. 2020). In our view, this difficulty may be more easily surmounted in networked SMEs, thanks to the socialization of their staff with that of companies already familiar with the new technology. Consequently, we expect that networked SMEs are more prone than isolated SMEs to adopt DT due to better access to technological information.

2.3 Knowledge and technological resources

An extension of the RBV states that knowledge is, actually, the most crucial resource of the firm (Lockett 2005). Absorptive capacity (Cohen and Levinthal 1990) is a key element given its positive impact on the diffusion of technology and its mitigating effect on firms facing crises and disasters (Belitski et al. 2022). Prior knowledge base and intensity of innovative efforts denote absorptive capacity, and a crisis may accelerate the assimilation of new knowledge (Kim 1998). However, in empirical studies of the prepandemic period, consensus is lacking regarding the effects of absorptive capacity—as measured exclusively by R&D—on DT adoption. In analysing a worldwide sample of companies of all sizes, Kinkel, Baumgartner, and Cherubini (2022) find that R&D intensity displays a strong positive effect on adoption of advanced DT. In contrast, in a sample of Tunisian SMEs, R&D was not found to influence adoption of advanced manufacturing technology (Kossaï et al. 2020).

However, the consideration of R&D is just a first step to assess the knowledge resources needed in adoption processes (Kinkel, Baumgartner, and Cherubini 2022). Technology adoption may initially place very high demands on the capabilities of the prospective adopter, such as, for example, the analysis of literature and catalogues of alternative technologies, in-depth study of adoption of the targeted technology in other firms, the socialization of tacit knowledge within the prospective adopter, and routines to dealing with suppliers (Kim 1998; Dosi 2000). Specifically, SMEs are often non-R&D innovators. Accordingly, a fine-grained analysis of knowledge resources is needed since DT acquisition requires the presence of a specific kind of capacity, beyond the performance of R&D. Therefore, we approximate the knowledge resources of SMEs by R&D performance but also by their recent experiences concerning technological change and innovation. We expect that the availability of knowledge resources is a trigger of DT adoption.

2.4 Resilience and technology adoption

Organizational adaptive capacity as a means to managing emerging challenges and exploiting new opportunities is related to resilience and, hence, to the ability of firms to overcome a crisis (Bergami et al. 2022). Although certain authors strongly recommend the consideration of dynamic capabilities in analyses of DT adoption (Kinkel, Baumgartner, and Cherubini 2022), this question has been rarely tackled by previous empirical studies. According to the RBV of the firm, competitive heterogeneity depends, as stated, on the different resources and capabilities possessed by companies. However, both resources and capabilities may change (Helfat and Peteraf 2003). Teece, Pisano, and Shuen (1997: p. 516) define dynamic capabilities as ‘the firm’s ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments.’ Dynamic capabilities are activated by a variety of changing events (Helfat and Peteraf 2003). During the pandemic, for instance, changes strongly affected the demand level, supply chains, and the organization of work, among others. As noted by Winter (2000), a crisis may encourage the company to improve its capability level.

The presence of dynamic capabilities is usually observed ex post, for instance, by the analysis of productivity improvements over time (Helfat and Peteraf 2003). Clampit et al. (2021), in their study of US SMEs, measure their dynamic capabilities by their ability to stay in business and meet customer needs during the pandemic. Trinugroho et al. (2022) conclude that Indonesian SMEs that enjoyed the highest income and sales during the pandemic, that is, those that had dynamic capabilities in terms of the Clampit et al. (2021) methodology, were more likely than other Indonesian SMEs to adopt DT. Therefore, we expect that resilient SMEs with dynamic capabilities are more prone to resort to DT.

Patterns and drivers of technology adoption also significantly differ across different types of technology (Bayo-Moriones and Lera-López 2007; Foster and Rosenzweig 2010; Skare and Riberio Soriano 2021, Holl and Mariotti, 2022). In this paper, we focus on DTs and distinguish between basic and advanced DTs. We define basic DTs as those associated with establishing digital channels through e-mail and the web. In contrast, advanced DTs encompass cutting-edge computing and information technologies, including artificial intelligence, cloud computing, robotics, intelligent devices, big data, blockchain, and investments in high-speed data infrastructure.

DT adoption has been mostly studied in papers focusing on ICT adoption (see, for example, Galliano, Roux, and Filippi 2001; Bayo-Moriones and Lera-López 2007; Giotopoulos et al. 2017). Amankwah-Amoah et al. (2021) analyse conceptually how the COVID-19 pandemic has accelerated the wider digitalization of firms but, as stated, the empiric literature in this respect is scarce. Moreover, studies that have distinguished basic and advanced DT adoption of SMEs are still rare.

2.5 Hypotheses

Building on the reviewed literature, we put to test the following hypotheses:

H1: SMEs that had both firm-level resources and resources available within their network were more prone than other SMEs to adopt DT after the inception of the pandemic.

H2a: SMEs that had performed R&D were more prone than other SMEs to adopt DT after the inception of the pandemic.

H2b: SMEs that had made previous substantial technological changes were more prone than other SMEs to adopt DT after the inception of the pandemic.

H2c: SMEs that had performed product or process innovation were more prone than other SMEs to adopt DT after the inception of the pandemic.

H3: SMEs that displayed dynamic capabilities during the pandemic have been more prone than other SMEs to resort to DT adoption.

All hypotheses are put to test for any type of DT as well as specifically for advanced DT. Details about the operationalization of the variables used to test the hypotheses are provided in Section 4.

3. Context setting

The digital transition is a key priority in the EU policy agenda. Digitalization ranks high in the recent Recovery and Resilience Program which stipulates that member states need to allocate at least 20 per cent of the total budget of 672.5 billion Euros to the digital transition. The recently adopted Digital Europe programme (2021–7) with a budget of 7.6 billion Euros constitutes a further important financial instrument dedicated specifically to supporting the digital transition in the EU. The *Kit Digital* programme, which specifically focuses on SMEs, accounts for a 3 billion Euros budget.

According to a report, in 2020, only 63 per cent of EU firms had adopted at least one DT, compared to 73 per cent in the USA (EIB 2022). The difference in digital adoption rates between the EU and the USA was particularly significant for small firms (ten to forty-nine employees). The aforementioned report notes that SMEs tend to display lower rates of digital adoption than larger firms '…the level of adoption for firms with less than fifty employees is particularly low in Europe, where firms tend to be smaller than in the United States' (p. 11). The report concludes that 'while large and medium European firms have digitalized almost as fast as their US counterparts, small and micro firms continue to lag behind'.

There is some evidence that many of the strong adopters of DT are in Northern Europe (EIB 2022). According to data of the Flash Eurobarometer 486, differences in the types of DT preferred by SMEs located in different countries are clear and probably depend on their national production structure. Spain, for instance, is not a leading country concerning DT adoption; however, it displays one of the highest percentages of adopters for, specifically, robotics, probably due to its strong position as an exporter of cars and machine tools (Holl and Rama 2023). At the same time, according to the Regional Innovation Scoreboard of the EU,[3] the index for individuals with above basic digital skills in Spain is well above the EU average and comparable to Denmark's.

The Regional Innovation Scoreboard of the EU also sheds light on Madrid's strengths and weaknesses in innovation, providing further insights into the characteristics of the regional innovation system (RIS) both before and after the pandemic. Despite the challenges posed by the COVID-19, the Madrid region transitioned from a Moderate Innovator status, as indicated by 2019 data, to achieving the status of a Strong Innovator, comparable to Northern Italy or Rhône-Alpes (France), in 2023. According to the prepandemic data, the region presented important innovation assets such as a relatively high percentage of people with college education, a high percentage of employment in knowledge-intensive services and in medium-tech and high-tech manufacturing, and a substantial number of trademark applications. However, it also presented weaknesses, such as a low percentage of SMEs engaged in internal R&D. According to the 2023 data, the previously mentioned strengths endure, but weaknesses persist as well, notably in low R&D expenditures in the business sector and the hesitancy of innovative SMEs to collaborate. The latter issue aligns with the constrained support for interfirm R&D collaborations in Madrid (Flor, Blasco Díaz, and Lara Ortiz 2020). In contrast, as indicated by the aforementioned authors, regional policies have promoted the mobility of industrial PhDs and provided funding for high-tech start-ups.

Overall, the discussion suggests that the Madrid region provides a favourable environment for DT adoption.

4. Data and some stylized facts

4.1 Data

Our analysis is based on a telephone survey among SME firms in the manufacturing sector and RIS3 service sectors[4] of the Madrid metropolitan region, sponsored by the Spanish National Research Council (CSIC). SMEs are defined as firms with less than 200 employees. Nevertheless, we excluded microestablishments with less than five employees.

In Spain, the COVID-19 crisis is considered to have started with the official declaration of alarm in March 2020. Our pilot survey was conducted in March 2021, and the final survey was conducted between the second half of Abril and the first half of July 2021. Consequently, there was a sufficient delay of time for the SMEs to having decided and implemented new DT when they responded the questionnaire.

The sample of firms included in the survey was selected by consulting SABI (Sistema de Análisis de Balances Ibéricos) .[5] The SABI database was compared to the Central Directory of Companies (DIRCE), and this showed that SABI in the employee strata of 5 to 200 employees includes practically the universe of companies and establishments in the Madrid region. 5386 SMEs were contacted yielding 895 completed questionnaires, which corresponds to a response rate of about 17 per cent.

The survey was based on a structured questionnaire that included different sections on company characteristics, relations with other companies, technology necessities and adopted technologies, R&D activities and difficulties, information sourcing, and the impact of the COVID-19 pandemic for the adoption of DTs.

4.2 Some descriptives of the sample and stylized facts

Most of the sample SMEs are unaffiliated domestic firms not attached to a business group (82 per cent); 12 per cent are small establishment pertaining to a domestic business group, and 6 per cent are small establishments pertaining to a foreign business group. While 55 per cent of the sample are mainly service SMEs, 45 per cent are mainly manufacturing SMEs.

The sample SMEs are well embedded in the regional economy: The percentage of those firms that, in the three previous years, had sold their production or services in the Madrid region was around 94 per cent for domestic companies and 86 per cent for small establishments pertaining to foreign multinationals (multiple responses). More than 50 per cent of the SMEs had cooperated with suppliers in technical aspects, and 67 per cent had cooperated with clients. Collaborations with both types of partners tend to be assiduous. Asked about the frequency of their technological collaborations in the three previous years, only a few SMEs declared that they collaborated rarely with clients (6 per cent of the sample) and/or with suppliers (15 per cent). The rest of the SMEs declared frequent technological collaborations with both types of partners. The input–output tables of the Madrid region suggest that the downward local linkages of certain ICT industries and knowledge-intensive services, telecommunications included, are strong (Sánchez-Moral et al. 2019). This circumstance suggests that our sample SMEs are colocated with important suppliers of DT. As argued by theories of proximity, cultural and physical proximity between sellers of technology or services, and user companies favours diffusion and the adaptation of technology to the needs of adopters (Ciarli and Rabellotti 2007).

Our survey data suggest that a substantial share of the sample SMEs participate in networks of firms This type of organization is typical of certain sectors of the Madrid region, such as telecommunications and aerospace (Alfonso-Gil and Vazquez-Barquero 2010; Rama and Ferguson 2007; Sánchez-Moral et al. 2019). This is a relevant consideration in times of crisis since social resources, such as the sharing of information and cross-collaborations with other companies, seem to be important drivers of resilience (Trunk and Birkel 2022). In their multicase study of German SMEs in the context of the pandemic, the aforementioned authors conclude: ‘No resilience without partners’ (p. 567).

Around 53 per cent of the sample had never performed R&D. Nevertheless, 50 per cent had introduced new products into the market, 53 per cent had introduced new processes, and 85 per cent had made some technological change, even if small, in the three previous years. This pattern seems to corroborate previous analyses in that the technical orientation of Madrid SMEs is practical and collaborative rather than R&D oriented (Rama and Ferguson 2007).

After reviewing the literature on the general effects of the COVID-19 crisis on small business and entrepreneurship, Belitski et al. (2022) note that most available publications on this subject are national studies for the USA, China, and the UK; hence, the interest of presenting some stylized facts concerning the impact of COVID-19 on SMEs in Madrid. Our survey results show important differences among SMEs. Service SMEs were less likely than manufacturing SMEs to have fully stopped operations due to the pandemic (21 per cent versus 35 per cent) (Table A.2).[6] This is in line with Okorie et al. (2020), an international multicase study. Moreover, service SMEs in Madrid were more likely than manufacturing SMEs to declare that the pandemic had no effect on their operations (37 per cent versus 28 per cent). This aligns with the findings of Siuta-Tokarska (2021) for Polish SMEs in that professional service SMEs coped better with the COVID-19 crisis, but contrasts the point of view of Belitski et al. (2022) about social distancing having greater negative effects on service firms. A possible reason is that our sample does not include SMEs engaged in personal services, nor restaurants or hotels, which are more dependent on physical proximity.

As noted by Chowdhury et al. (2021), although scholars have turned their attention to the effect of the pandemic on supply chains, the specific case of SMEs has been largely overlooked. One of the few previous studies tackling this question reports supply chain constraints and shortages of raw materials during the pandemic in Sichuan Province (China) (Lu et al. 2021). In analysing Slovak high-tech SMES, another study found that nearly one third reported a worsened access to supplies (Hrivnák, Moritz and Chreneková 2021). During the pandemic in Poland, disruptions of supply chains were the greater challenges for manufacturing SMEs (Siuta-Tokarska, 2021). In contrast, in our sample, obtaining of inputs from either foreign or domestic suppliers posed no serious threats to the survey SMEs (Table A.3). In Madrid, the importance of location proximity and regional supply chains (Rama and Ferguson 2007; Alfonso-Gil and Vazquez-Barquero 2010; Sánchez-Moral et al. 2019) may have contributed to reducing the impact of such difficulties. As stated, the sample SMEs are well embedded in the region. In the case of our survey SMEs, the reduction in the demand and the impossibility of carrying out face-to-face work due to the lockdown were the main problems during the pandemic. Similar results have been found for the USA (Bartik et al. 2020), China (Dai et al. 2021), Zimbabwe (Munongo and Pooe 2022), and Poland (Siuta-Tokarska 2021): for SMEs, the contraction of the demand caused by the pandemic was the main source of concern.

Unlike the 2008 global crisis, funding conditions for SMEs did not deteriorate substantially during the COVID-19 crisis, thanks to measures adopted in the EU such as guaranteed credit and deferment of payments (EIB 2022). Yet, despite these measures, around 32 per cent of manufacturing SMEs and 29 per cent of service SMEs reduced or ceased their R&D projects during the pandemic (Table A.4). These percentages are higher than those found by Hrivnák, Moritz, and Chreneková (2021) for Slovak knowledge-intensive SMEs.

As noted by Roffia and Mola (2022) in their study on the Veneto region (Italy), the shift to digitalization as a reaction to the COVID-19 crisis requires the regional availability of infrastructure. A perspective from a developing country shows that high prices of Internet services and the high cost of imported ICT products were largely to blame for low levels of I4.0 adoption in Zimbabwe during the pandemic (Munongo and Pooe 2022). In the Madrid sample, barriers to digitalization coming from lack of information technology infrastructure, such as high-speed Internet (10–9 per cent) (Table 1), are below those affecting the EU average-SME (19 per cent) (Ogrean and Herciu 2021). Moreover, in the Madrid sample, only 13–14 per cent of SMEs declared that uncertainty about future digital standards was an obstacle to digitalization, versus 24 per cent of EU SMEs. This suggests that the barriers to digitalization declared by the survey SMEs tend to be mainly of an internal nature.

Table 1. Barriers to digitalization.

	Manufacturing		Services	
Barriers	No.	%	No.	%
Lack of finance	150	40.2	154	33.4
Lack of skills	61	16.4	73	15.8
Lack of infrastructure	36	9.7	43	9.3
Regulative obstacles	48	12.9	62	13.4
IT security reasons	28	7.5	39	8.5
Uncertainty about future regulations	52	13.9	60	13.0
Internal resistance to change	67	18.0	67	14.5
No need for digitalization	109	29.2	89	19.3
Not implanted but plans for the future	25	6.7	26	5.6
No answer	40	10.7	100	21.7
Total number of firms	373		461	

Source: Own elaboration.

Table 2. Investment in digitalization after the inception of the pandemic.

	Manufacturing		Services	
Investments	No.	%	No.	%
Invested in digital technologies	112	30.7	212	46.5
Not invested in digital technologies	251	68.8	225	49.3
No answer	2	0.5	19	4.2
Total	365		456	

Source: Own elaboration.

Compared to service SMEs, manufacturing SMEs were less prone to resort to digitalization to face the crisis (Table 2). The process of digital transformation runs, however, through different stages, and our survey allows us to distinguish between the adoption of basic and advanced DTs. Of the manufacturing SMEs that invested in DT after the pandemic hit Spain, more than 75 per cent adopted basic DT and only 43 per cent advanced DT, while percentages were, respectively, 66 per cent and 57 per cent for service SMEs (multiple responses). Cloud computing emerged as the most frequent type of investment in terms of advanced DT for both types of SMEs, followed by robotics in the case of manufacturing SMEs and by big data in the case of service SMEs (Table 3). Both service and manufacturing SMEs declared that the main barrier to digitalization was the lack of finance, followed in importance by internal resistance to change in the case of manufacturing SMEs and by lack of skills in that of service SMEs (Table 1). According to a Eurobarometer survey performed during the pandemic in the months from February to May 2020, financial difficulties were also the main barrier to digitalization in EU small business (Ogrean and Herciu 2021). However, according to the aforementioned source, only 23 per cent of the EU small business experienced such difficulty versus 33 per cent to 40 per cent of the Madrid SMEs. Concerning opportunities opened by the pandemic, in our sample, manufacturing SMEs were less optimistic than service SMEs (Table 4). Probably, this perception was one of the reasons for these companies being less prone to invest in DT. Perceptions and prospects certainly play a role in technology acceptance (Agarwal and Prasad 1998).

Table 3. Type of digital technology adopted after the inception of the pandemic.

	Manufacturing		Services	
P241: Multiple responses	No.	%	No.	%
Invested in basic digital technologies	85	75.9	120	56.6
Invested in advanced digital technologies	48	42.9	139	65.6
Artificial intelligence	12	25.0	48	34.5
Cloud computing	26	54.2	113	81.3
Robotics	24	50.0	26	18.7
Smart devices	18	37.5	42	30.2
Big Data	12	25.0	75	54.0
Blockchain	6	12.5	36	25.9
High-speed infrastructure	17	35.4	54	38.8
Others	7	14.6	10	7.2
No answer	0	0.0	4	2.9

Source: Own elaboration.

Table 4. COVID-19 pandemic as a new opportunity.

	Manufacturing		Services	
	No.	%	No.	%
New opportunities: yes	117	32.1	223	48.9
New opportunities: no	222	61.0	199	43.6
No answer	25	6.9	34	7.5
Total	364		456	

Source: Own elaboration.

5. Estimation approach

We are interested in the probability that a SME has adopted DTs in response to the COVID-19 crisis. The firm adopts a new DT if the anticipated benefits of adoption exceed the cost. However, we only observe adoption or non-adoption of technology τ.

Adoption$y_{i\tau}$ of firm i of technology $\tau, \tau = 1,2$ is then captured by a binary choice model:

$$y_{i\tau} = \begin{cases} 1 & if\ y^*_{i\tau} \geq 0 \\ 0 & else \end{cases} \quad (1)$$

where the latent variable $y^*_{i\tau}$, representing firm i's net value from adopting the new technology τ, is a linear function of observable firm specific characteristics c_i and industry characteristics p_i, and ν_i is a standard normal term.

$$y^*_{i\tau} = c_i\beta_1 + p_i\beta_2 + \nu_i \quad (2)$$

5.1 Variables

5.1.1 Dependent variables. In our survey, firms were asked whether they had invested in DTs since the declaration of the state of alarm in March 2020.The survey also distinguished between adoption of basic DTs such as e-mail and the web and adoption of advanced DTs. The latter include artificial intelligence, cloud computing, robotics, big data, blockchain, intelligent devices, and high-speed infrastructure (Table 3). Our dependent variables are as follows: digi_all, which takes on the value of 1 if the SME had invested in any type of DT (including basic and advanced DTs) after the inception of the pandemic in Spain and 0 (otherwise), and digi_advanced, which takes on the value of 1 if the SME had invested in advanced DT after the inception of the pandemic in Spain and 0 (otherwise).

5.1.2 Main independent variables. We use the following variables to approximate the entrepreneurial resources available to the firm and its network (H1):
size: To measure the size of SMEs, we include a variable on the number of employees.
age: Following previous research on drivers of DT adoption (Fernández-Cerezo et al. 2021; Modgil et al. 2022; Trinugroho et al. 2022), we include the age of the SME in our model plus its square term to account for non-linearities.
coop_supplier: This dummy variable indicates whether the SME maintains frequent technological collaboration with suppliers.
coop_client: This dummy variable indicates whether the SME maintains frequent technological collaboration with clients.

We employ the following variables to approximate the knowledge and technological resources available to the SME (H2):
R&Dnever: This dummy variable indicates whether the SME has never performed R&D. According to Cohen and Levinthal (1990), the performance of R&D suggests that the firm enjoys absorptive capacity.
prodinno: Product innovation has been related to greater adoption of DTs (Blichfeldt and Faullant 2021; Lee, Falahat and Sia 2021). After reviewing the literature, Kinkel, Baumgartner and Cherubini (2022) suggest that innovativeness of the product and design may positively affect the adoption of advanced DT. We include a dummy variable that specifies if the SME has introduced new products into the market during the three previous years.
procinno: Process innovation has also been stated in the literature as a driver of DT adoption (Lee, Falahat and Sia 2021; Sieber et al., 2008). We include a dummy variable that specifies whether the SME has implemented new processes during the last 3 years.
no-tech-change: This dummy variable indicates whether the SME has made no significant technological changes in the last 3 years.

We employ the following variable to approximate the dynamic capabilities of the firm and, hence, resilience (H3):
resilient: This indicates whether the SME was able to increase its sales after the onset of the COVID-19 crisis or, at least, having been able to avoid temporarily closing. As stated, this variable constitutes an approximation to resilience.

5.1.3 Control variables. export: This indicates whether the SME has sold its products and services in foreign markets during the last 3 years. In analysing firms of all sizes active in the automobile value chain, Anzolin, Andreoni and Zanfei (2022), for example, note that exporter countries are more likely to adopt robotics. In analysing SMEs in Lombardy (Italy), Denicolai, Zucchella and Magnani (2021) also find that exporters are more likely than other SMEs to adopt AI.
import: This indicates whether the SME has acquired products and services in foreign countries during the last three years. The trading partners of the SME may exercise pressures towards the adoption of DT.
Technological environment: The environment of the firm seems to influence adoption of advanced DT (Kinkel, Baumgartner and Cherubini 2022). To evaluate it, we use the OECD classification of manufacturing:
hightm: This dummy variable takes value 1 if the firm is engaged in high-tech manufacturing.
medhigh: This dummy variable takes value 1 if the firm is engaged in medium-high technology manufacturing.
medlow: This dummy variable takes value 1 if the firm is engaged in medium-low technology manufacturing.
lowt: This dummy variable takes value 1 if the firm is engaged in low-tech manufacturing.
manuf: this dummy variable takes value 1 if the main activity of the SME is manufacturing, with services being the base sector.

Table A.5 shows the correlation matrix.

6. Results and discussion

Table 5 shows our probit estimation results. The coefficients presented are the marginal effects. In Columns 1 and 2, we show the results for the adoption of DT in general, and in Columns 3 and 4, the results for advanced DT adoption. Columns 2 and 4 introduce more detailed controls for the technological sector of firms compared to Columns 1 and 3.

The coefficient of the size variable is not statistically significant, meaning that size differences of SMEs are not a significant trigger of digitalization among SMEs in our context.[7] Hence, our results do not support those of Siuta-Tokarska (2021) for Polish SMEs who finds that medium-sized firms were more prone to adopting DT during the pandemic. For the adoption of DTs in general, the coefficient of the age variable is negative and statistically significant, while its square term is positive and significant. This reflects that older firms have a lower probably of adopting DTs, but the relationship is not linear—as firms get older the negative relationship weakens. Our results concerning the age variable support those of Vavrecka et al. (2021) for Slovak and Hungarian SMEs but not those for Czech SMEs. However, the age of a firm is not significantly related to the adoption of advanced DT.

The coefficient of the coop_client variable is not statistically significant. Maintaining technological collaborations with clients did not relate to adopting DT after the inception of the pandemic. In contrast, the coefficient of the coop_ supplier variable is positive and statistically significant in all models. The SMEs that had maintained assiduous technological collaborations with suppliers in the three previous years displayed a 20 per cent higher probability of adopting all types of DT and a 13 per cent higher probability of adopting advanced DT after the inception of the pandemic. Hence, H1 is partially supported by our results.

SMEs previously involved in substantial technological collaborations with suppliers were clearly more prone to adopting DT, advanced DT included, during harsh economic times. A possible reason is that technology adoption is, as stated, a process of information gathering (Agarwal and Prasad 1998). SMEs involved in networking with their suppliers could have better access to information than their peers. The sociological literature on diffusion emphasizes the importance of two features of innovation that favour adoption: tryability, which is the ease with which the innovation can be tested by a potential adopter, and observability, which is the ease with which the innovation can be evaluated after trial (Hall 2005). In a study on UK manufacturing, ease of use and usefulness of

Table 5. Estimation result: probability of digital adoption after the inception of the pandemic (marginal effects).

Variables	(1) digi_all	(2) digi_all	(3) digi_ advanced	(4) digi_ advanced
size	0.001	0.001	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)
age	−0.009**	−0.008**	−0.003	−0.003
	(0.004)	(0.004)	(0.003)	(0.003)
age2	0.000**	0.000*	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
coop_supplier	0.197***	0.195***	0.125**	0.129**
	(0.068)	(0.068)	(0.060)	(0.059)
coop_client	−0.062	−0.069	−0.079	−0.065
	(0.085)	(0.085)	(0.071)	(0.070)
R&Dnever	−0.099***	−0.110***	−0.099***	−0.083***
	(0.036)	(0.037)	(0.030)	(0.031)
no-tech-change	−0.183***	−0.180***	−0.153***	−0.155***
	(0.034)	(0.034)	(0.029)	(0.028)
prodinno	−0.009	−0.008	−0.030	−0.038
	(0.037)	(0.037)	(0.032)	(0.032)
procinno	0.123***	0.122***	0.108***	0.115***
	(0.036)	(0.035)	(0.031)	(0.031)
resilient	0.034*	0.032*	0.023	0.022
	(0.019)	(0.019)	(0.017)	(0.017)
export	0.019	0.029	0.038	0.026
	(0.036)	(0.036)	(0.030)	(0.030)
import	0.103***	0.107***	0.044	0.035
	(0.037)	(0.037)	(0.032)	(0.032)
hightm		−0.251***		−0.060
		(0.079)		(0.061)
medhigh		−0.193***		−0.114**
		(0.066)		(0.055)
medlow		−0.243***		−0.211***
		(0.055)		(0.053)
lowt		−0.100**		−0.275***
		(0.044)		(0.048)
manuf	−0.169***		−0.191***	
	(0.035)		(0.031)	
Observations	706	706	706	706

Standard errors in parentheses.
***$P < 0.01$.
**$P < 0.05$.
*$P < 0.1$.

the technology are associated to adoption of I4.0 (Rodríguez-Espíndola et al. 2022). However, prospective adopters are often unsure about the usefulness and ease of use of a technology, especially in an atmosphere of uncertainty such as a crisis (Kumar and Ayedee 2021). Small businesses that are engaged in technological cooperation with suppliers could enjoy greater opportunities to observe such attributes in connected firms. Synergies may exist between resources available to a firm and resources available to its suppliers. Furthermore, training is an important consideration for a prospective adopter of new technology. In this respect, firms having strong supplier networks report more in-house training and teamwork than their peers (Pérez Pérez and Martínez Sánchez 2002). Our results confirm the view of Hall (2005) in that the decisions of firms concerning technology adoption need to be analysed in the context of their social and economic connections and not as a mere individual decision.

The R&Dnever variable exhibits negative and statistically significant coefficients in both the digi_all and the digi_advanced models. SMEs that had never performed R&D activities had around 10 per cent less probability of adopting any type of DT and also of adopting advanced DT after the inception of the pandemic. Conversely, SMEs that had performed R&D, even if not recently, were more likely to invest in DT. H2a is thus substantiated. The no_tech-change variable also has a negative and statistically significant coefficient in all the models. If an SME had introduced no significant technological change in the three previous years, its probability of having adopted any type of DT after the inception of the pandemic was significantly reduced. These SMEs were probably unable to resort to digitalization due to their insufficient experience in implementing new technologies. Conversely, previous experience of technology change, whatever the nature of the technology, strongly predisposed the sample firms to adopt DT after the inception of the pandemic. This provides support to H2b.[8]

Finally, the coefficients for the prodinno variable are not statistically significant in any of the models. Hence, we do not find evidence that product innovation enhances the adoption of DT among SMEs. Our findings differ from those of other authors (Kinkel, Baumgartner, and Cherubini 2022; Blichfeldt and Faullant 2021) who found, for the prepandemic period, an association between product innovation and DT adoption in firms of all sizes. In contrast, the procinno coefficient is positive and statistically significant in all our models. SMEs that had previously performed process innovation had 12 per cent more probability of adopting any type of DT and 11 per cent more probability of adopting advanced DT. H2c is therefore partially supported.

Our results suggest that the capacity to perform process innovation together with technological changes shows a greater influence on DT adoption than performing internal R&D. Methodologically, this result confirms the interest of employing different types of indicators of knowledge resources to analyse triggers of DT adoption in SMEs. Our results suggest that different types of knowledge resource have a different impact on the propensity to adopt DT. The most decisive is clearly previous experience regarding technological change. Confirming the point of view of Lockett (2005), entrepreneurial experience and financial resources, as approximated by age and size, were of lesser consequence to trigger adoption in times of crisis, while the most important resources of SMEs in this respect were clearly knowledge resources. Moreover, the external resources available to SMEs through upstream networking remained vital.

The coefficient of the resilient variable is positive and marginally statistically significant but only in the digi_all models. SMEs that managed to avoid closing and those that even managed to increase their sales after the pandemic hit Spain had a somewhat higher probability of adopting any type of DT but no more probability of adopting advanced DT. Hence, H3 is partially supported. Table 6 shows our main results and how they relate to our research hypotheses. Regarding our control variables, the coefficient of the export variable is not statistically significant, but the import variable is positive and statistically significant for DG adoption in general (Columns 1 and 2). Thus, foreign trade appears as a stimulus to digitalization only in the case of importers. Our results do not support those of Denicolai, Zucchella, and Magnani (2021) who find that small Italian exporters were more likely than other small business to adopt AI during the prepandemic period. They only support partially those of Skare and Riberio

Table 6. Hypotheses and findings.

	Hypotheses	Results
H1	*Adoption of DT after the outset of the crisis depends on resources related to the SME, and resources available within the company's network*	Partially supported. Resources of the SME itself as approximated by size and age were of little consequence to trigger adoption but resources available through networking with suppliers remained vital
H2a	*SMEs that had performed R&D were more prone than other SMEs to adopt DT after the inception of the pandemic*	Supported
H2b	*SMEs that had made substantial technological changes were more prone than other SMEs to adopt DT after the inception of the pandemic*	Supported
H2c	*SMEs that had performed product or process innovation were more prone than other SMEs to adopt DT after the inception of the pandemic*	Partially supported. Product innovation is not associated to DT adoption but process innovation is
H3	*SMEs that displayed dynamic capabilities were more prone than other SMEs to invest in DT after the inception of the pandemic*	Partially supported. Dynamic capabilities are not associated to adoption of advanced DT and only weakly associated to adoption of any type of DT

Soriano (2021) who find, also for the prepandemic period, that globalization is associated with DT adoption.

Finally, the dummy variable manuf has a negative and statistically significant coefficient. Compared to the average service SME, the average manufacturing SME had 17 per cent less probability to resort to any type of digitalization and 19 per cent less probability to resort to advanced digitalization after the inception of the pandemic. A possible reason is that manufacturing SMEs tend to be unaffiliated domestic firms not attached to a business group, while service SMEs tend to be small establishments attached to a business group (Pearson X^2 = 7.110, P = 0.29). Groups may, probably, contribute finance for technology adoption. When controlling in greater detail the technological level of the firms' sector, the results still show that, manufacturing firms have a lower probability of DT adoption compared to services. However, for high-tech manufacturing firms, the difference in the probability of advanced DT adoption to services is not significant. Our findings expose a noteworthy challenge in adopting DT among independent SMEs in the manufacturing sector in Madrid, especially in low-tech and medium-tech industries. This difficulty is likely linked to their historical and current vulnerabilities.

7. Conclusions

There is still little knowledge about the triggers of digitalization in SMEs during the pandemic. This article analysed, in the context of the COVID-19 pandemic, drivers of digitalization in SMEs located in the Madrid metropolitan region. Previous assiduous technological collaboration with suppliers was the most important driver of both generic and advanced digitalization adoption during harsh economic times. This finding supports the point of view of Hall (2005) emphasizing that technology adoption needs to be analysed in the context of the company's social connections and its integration into supply chains, rather than being viewed as an exclusively individual decision. In line with Trunk and Birkel (2022), our finding contributes to resilience theory by highlighting the role of upstream partnerships in the resilience of SMEs facing a crisis. Second, SMEs that enjoyed knowledge resources were more prone to adoption DT that SMEs that did not enjoyed them. The most decisive resource in this respect, even more important than the performance of R&D, was previous experience with technological change. The ability to continue with business during the pandemic and even to profit from new opportunities that emerged during this period was not associated significantly with adoption of advanced DT and only weakly associated with adoption in general. Preparedness in terms of knowledge and networking resources constituted a more significant trigger of adoption. To bolster digitalization efforts, our research underscores the significance of implementing recovery policies that focus on nurturing resilient and innovative networks between SMEs and their suppliers. Additionally, it highlights the importance of enhancing SMEs' knowledge base as a key aspect of this strategy.

Our findings also show that the digitalization of independent manufacturing SMEs, especially those in low-tech and medium-tech sectors, remains a challenge. It is clear that these companies cannot achieve digitalization through individual efforts alone, underscoring the necessity for targeted interventions and support.

The implementation of mission-oriented policies involving different actors such as the central government, regional authorities, firms and their suppliers, and trade unions may be useful to promote the diffusion of the new technology (Mazzucato 2018). Mission-oriented policies are characterized as comprehensive public policies that leverage cutting-edge knowledge, particularly in areas such as digitalization, to achieve specific objectives. These policies focus on the practical implementation of advancements, involving private stakeholders in the process.

In this context, mission-oriented policies should encompass various facets that propel digitalization while eliminating obstacles that impede the adoption of new technology. Examples of targeted policies include financial assistance for digitalization, workforce training, a deeper exploration of the reasons behind resistance to change within SMEs, and, especially, the reinforcement of regional networks of firms. Given the importance of upstream partnerships as drivers of digitalization, postpandemic regional policies need to foster innovative networking, which was little supported in the past (Flor, Blasco Díaz, and Lara Ortiz 2020). These policies would be especially opportune in the current context of postpandemic recovery industrial projects funded by the NextGeneration EU programme since, in Spain, such projects involve public–private partnerships and large consortia of firms, including manufacturing SMEs (García-Sánchez and Rama 2022). Furthermore, the notion that the decision to digitize is often interconnected with other decisions made by the firm has recently been gaining ground (Holl and Rama 2023; Katona, Birkner, and Péter 2023; Montresor and Vezzani 2023). Firms decide to embark on digitalization within the specific context of their market strategy and the challenges they encounter. Therefore, innovation policies should not be developed in isolation; instead, they should go hand in hand with sector-specific policies. This highlights the need for 'effective policy mixes' as recommended by the European Commission (Domnick et al. 2023), particularly at the regional level. For instance, prioritizing independent manufacturing SMEs is crucial, considering their heightened vulnerability. In this scenario, innovation policies aimed at enhancing regional levels of digitalization should be aligned with policies focused on de-risking European supply chains and promoting reindustrialization.

Our findings also have some policy implications for countries where knowledge bases lag behind leading countries and the R&D internal resources of SMEs are limited. They show that, in one of the cities worst hit by the pandemic, SMEs were nevertheless able to resort to digitalization. This was so even if their pattern of knowledge was collaborative and practical, rather than R&D intensive. However, it needs to be observed that, in Madrid, the process of technology adoption took place in a favourable regional milieu in terms of the availability of internet infrastructure and the co-location of digital technology manufacturers and service firms. Regarding developing countries, this circumstance also suggests the need of mission-oriented postpandemic policies that would involve both private and public funding. Solely relying on the effort of the SMEs alone would be insufficient to achieve digitalization in cities and regions lacking infrastructure.

Our article has some limitations as well. The cross-sectional nature of our data presents several challenges. Despite our efforts to control for a wide set of factors in our estimations, the possibility of unobserved factors influencing technology adoption remains. Concurrently, DT adoption itself can have an impact on variables such as networking, innovativeness, and resilience. This makes it difficult to establish a causal link between technology adoption and its determinants during the COVID-19 pandemic. Future research with panel data would be highly desirable as it would also allow us to control for the pre-existing level of technology adoption. This, in turn, would facilitate a more robust analysis, allowing us to consider how the baseline technology adoption level influences the likelihood of further adoption, particularly in the unique context of the COVID-19 pandemic. The use of panel data in future studies can provide better insights into the dynamic and nuanced nature of technology adoption.

Finally, it would be useful to consider collaborations of SMEs with knowledge centres, given the substantial presence of universities and research centres in Madrid, and the support to industrial PhD mobility provided by regional policies (Flor, Blasco Díaz, and Lara Ortiz 2020). Spillovers from such centres may have played some role in the digitalization of SMEs. This is certainly an avenue for future research.

Acknowledgements

The authors are grateful to Ángela Ribeiro and Patricia Thomas for their support and advice in the preparation and implementation of the survey. Usual disclaimers apply.

Conflict of interest statement. None declared.

Funding

Project ImPrYME – CSIC – Vicepresidencia de Transferencia de Tecnología financed by the Autonomous Community of Madrid-ERDF (European Union).

Data availability

The data cannot be made available at this time. The companies who provided the data did so under the understanding that it would be used solely for scientific activities conducted by CSIC (Spanish National Research Council). Thus, out of respect for the agreements made with the contributing companies, we are unable to share the data externally at this time.

Notes

1. https://commission.europa.eu/strategy-and-policy/recovery-plan-europe_en November2023.
2. In this context, the term 'networked resources' does not refer to Information and Communication Technology (ICT) networks commonly associated with data and communication infrastructure. Instead, it pertains to a broader concept within the Resource-Based View (RBV) framework, as extended by Lavie (2006).
3. https://ec.europa.eu/assets/rtd/ris/2023/ec_rtd_ris-regional-profiles-spain.pdf November 2023.
4. A list of the included service sectors is provided in Table A.1.
5. The list of firms was downloaded in February 2021.
6. While international comparisons are problematic due to the very different restrictions that were imposed in different nations, Madrid SMEs seem to have fared better than those reported by studies on the USA and China (Bartik et al. 2020; Dai et al. 2021).
7. In unreported estimations, we have also included the squared term of size accounting for a nonlinear relationship, but both coefficients turn out statistically not significant, while our main results remain unchanged.
8. The no_tech-change variable will partly proxy for the pre-existing level of DT adoption by the firm, which affects the likelihood of a firm adopting DT in the current period.

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Appendix

Table A.1. RIS 3 service sector firms in the Madrid region.

D.35—Electricity, gas, steam, and air conditioning supply
E.36—Water collection, treatment, and supply
E.38—Waste collection, treatment and disposal activities; materials recovery
E.39—Remediation activities and other waste management services
H.49—Land transport and transport via pipelines
H.51—Air transport
H.52—Warehousing and support activities for transportation
J.58—Publishing activities
J.59—Motion picture, video and television programme production, sound
J.60—Programming and broadcasting activities
J.61—Telecommunications
J.62—Computer programming, consultancy and related activities
J.63—Information service activities
M.72—Scientific research and development
M.74—Other professional, scientific, and technical activities
Q.86—Human health activities

Table A.2. COVID-19: impact on SMEs.

	Manufacturing		Services	
	No.	%	No.	%
Total stop of operations	129	35,0	99	21,4
Partial stop of operations	119	32,2	161	34,8
No impact on operations	103	27,9	171	37,0
Increase in business	18	4,9	31	6,7
Total	369		462	

Source: Own elaboration.

Table A.3. Reasons for COVID-19 impacts.

	Manufacturing		Services	
	No.	%	No.	%
Lack of inputs from abroad	4	1,6	2	0,7
Lack of inputs from the domestic market	9	3,7	3	1,2
Reduction in demand	99	40,2	133	51,4
Impossibility of carrying out face-to-face work	110	44,7	107	41,3
Other	24	9,8	14	5,4
Total	246		259	

Source: Own elaboration.

Table A.4. COVID-19 and R&D projects.

	Manufacturing		Services	
	No.	%	No.	%
Stopped R&D projects totally	24	6,9	29	7,1
Affected, but continued with R&D projects	87	25,0	90	22,1
Not affected	77	22,1	123	30,1
Increased dedication to R&D projects	8	2,3	26	6,4
No answer	152	43,7	140	34,3
Total	348		408	

Source: Own elaboration

Table A.5. Correlation matrix.

Variables	–1	–2	–3	–4	–5	–6	–7	–8	–9	–10	–11	–12	–13	–14	–15	–16	–17	–18
(1) digi	1.000																	
(2) digi_advancd	0.643	1.000																
(3) size	0.103	0.073	1.000															
(4) age	–0.116	–0.122	0.035	1.000														
(5) age2	–0.069	–0.095	0.077	0.928	1.000													
(6) coop_supplier	0.071	0.045	0.015	0.017	0.035	1.000												
(7) coop_client	–0.003	–0.024	0.035	–0.012	0.001	0.221	1.000											
(8) prodinno	0.116	0.078	0.043	–0.054	–0.050	–0.013	0.003	1.000										
(9) procinno	0.218	0.197	0.081	–0.087	–0.081	–0.069	–0.023	0.326	1.000									
(10) R&Dnever	–0.240	–0.238	–0.101	0.059	0.055	0.103	0.063	–0.275	–0.233	1.000								
(11) no_tech-change	–0.333	–0.329	–0.098	0.142	0.120	0.042	0.018	–0.206	–0.319	0.335	1.000							
(12) export	0.116	0.112	0.083	–0.030	–0.035	–0.091	–0.011	0.212	0.156	–0.275	–0.125	1.000						
(13) import	0.169	0.114	0.061	–0.033	–0.022	–0.068	0.035	0.295	0.108	–0.294	–0.172	0.369	1.000					
(14) resilient	0.132	0.124	0.021	–0.039	–0.030	–0.030	–0.030	0.004	0.058	–0.148	–0.055	0.113	0.060	1.000				
(15) hightm	–0.035	0.043	0.046	0.062	0.045	–0.112	–0.114	0.124	0.053	–0.225	–0.032	0.163	0.169	–0.004	1.000			
(16) medhigh	–0.034	–0.012	–0.010	0.104	0.096	–0.040	–0.017	0.136	0.008	–0.139	0.012	0.136	0.184	0.009	–0.069	1.000		
(17) medlow	–0.155	–0.139	–0.016	0.149	0.122	0.024	0.037	–0.004	0.041	0.065	0.094	–0.004	–0.011	–0.137	–0.089	–0.114	1.000	
(18) lowt	–0.075	–0.206	–0.058	0.078	0.079	0.023	0.011	–0.000	0.019	0.117	0.110	–0.108	–0.055	–0.097	–0.113	–0.145	–0.188	1.000