



Research article

Digital transformation and European small and medium enterprises (SMEs): A comparative study using digital economy and society index data

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ABSTRACT

Digital transformation is profoundly transforming SMEs' business activities, bringing about comparative advantages and associated risks. Previous studies on digital transformation and SMEs focus on technology adoption, innovation, new value creation, and dynamic capabilities. However, it is unclear how digital technology affects SMEs' specific business activities. We study SMEs' customer access, increasing competition, external funding or access to finance, rising input costs, skilled labor shortages, exogenous shocks, global crises, and regulatory issues. This study aims to fill the literature gap by exploring the impact of digital technology, using digital economy and society index (DESI) as proxies for the SME issues. We use DESI and SME data from a survey on European enterprises' access to finance. We find that digital transformation strengthens SMEs' ability and flexibility to address main business issues. Furthermore, findings reveal that digitally transformed SMEs have fewer concerns about access to new and traditional customers, competition changes, access to finance, increasing input costs, external shocks, and regulatory changes. However, digital transformation also brings risks, such as the shortage of skilled labor and experienced managers and loss of inherent competitiveness. The novelty of our work lies in supplying quantitative knowledge on the link between digital transformation and European SMEs' critical business concerns. These findings substantially increase our understanding of the impact of digital change on European SMEs' business activities.

1. Introduction

Digital transformation is reshaping corporate strategies, business models, innovation policies, and marketing strategies, driving the digital society on the wave of information technology (Verhoef et al., 2021). Evidence supports the hypothesis that global socioeconomic and market changes also force small and medium-sized enterprises' digital transformation. In addition, it can be assumed that the present speed of digital transformation is significantly influenced by the risks and uncertainties faced by businesses, which include pandemics that cause global supply chain disruptions (Papadopoulos, Baltas, & Balta, 2020). Pressing inflation, associated uncertainty, and the possibility of a recession force SMEs to adapt their business models and strategies (Kraus et al., 2022; Skare & Soriano, 2021; Xie et al., 2022). In addition, the end of the low-interest rate era is altering firms' access to finance conditions. Unfortunately, the war in Ukraine and the energy crisis are

becoming critical drivers of digital and business model transformation today.

Previous research aims to identify different patterns in the introduction of two technology layers of Industry 4.0: basic technologies and front-end technologies. Companies with advanced implementation of Industry 4.0 tend to adopt most front-end technologies and not just a specific subset (Frank et al., 2019). Digital transformation is changing SMEs' traditional business model and customers' value creation process (Matarazzo et al., 2021; Müller et al., 2021).

European SMEs are experiencing the effects of digital transformation. Customer relationships with SMEs are examined in digital transformation studies focusing on SMEs. SMEs use digital technologies to produce new digital products and services, expand the consumer base, and improve business performance (Khin & Ho, 2019). Through high-speed networks, SMEs and entrepreneurs connect with suppliers and consumers, access real-time information, and immediately respond

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to rapidly changing markets and supply chains (Kergroach, 2021). New digital products and services may be developed using digital technology, which expands the client base and improves the SMEs' performance (Khin & Ho, 2019). In addition, companies often use remote experts and digital assistants to meet customers' needs (Parise et al., 2016).

The digital transformation of management work also benefits the ongoing transformation of operational work-production efficiency and lowers input costs (Gal et al., 2019). The digital transformation of SMEs improves business results and increases the productivity and output of the workforce (Hai, 2021). In addition, digital transformation facilitates new forms of financial management and payment. To help SMEs obtain financing, digital finance helps increase financial inclusion (Shofawati, 2019).

Europe's competitiveness in global markets is significantly influenced by the SMEs' speed and degree of digitization. Therefore, exceptional prospects for European SMEs and economic growth are expected as digital technologies change market dynamics. This expansion is intensifying, and the technology industry is growing five-fold faster than the rest of the European economy. As a result, SMEs are competing, scaling, and disrupting unimaginably due to the rapid technological transformation (European Investment Bank, 2019; Garzoni et al., 2020; Perla et al., 2015).

Existing literature on digital transformation focuses on changes in structure and value creation, digital technologies use, dynamic capabilities, consumer behavior, and strategic responses (Kraus et al., 2022). However, the empirical link between digital transformation and the business activities of European SMEs remains unclear. Studies on how digital transformation impacts European SMEs with regards to customers, input costs, access to finance, regulatory burden, exogenous shocks, and skilled labor shortages are not available. Fewer studies use the digital and society index (DESI) to explore digital transformation in Europe. DESI is a composite index that tracks economies' digital transformation by connectivity, human capital, Internet use, digital technology integration, and digital public services. DESI allows us to explore the impact of the country's digital transformation on SMEs' main business issues.

To study the impact of digital transformation on European SMEs' business activities, we use the Survey on the Access to Finance of Enterprises in the Euro Area (SAFE) database. However, our panel sample is limited by the availability of data from DESI and SAFE, constraining the choice of econometric modeling. In addition, the data structure shows cross-sectional dependence and time-variant indicators. Under such conditions, panel data modeling is restricted to panel data random effects using the Driscoll and Kraay (1998) modeling technique to obtain the best-fit and robust estimation results. Using a random effect panel data model (Driscoll & Kraay, 1998), we explore the impact of digital transformation on SMEs' business activities. We examine how digital transformation in Europe affects SMEs' concerns, such as the availability of skilled staff or experienced managers, cost of production or labor, access to finance, exogenous shocks (policy crisis), customers, and competitiveness under regulatory burdens (Grover et al., 2020; Aladwani and Dwivedi, 2018).

This study addresses the research gap in the empirical link between digital transformation and the business activities of European SMEs present in previous studies. It is among few comprehensive studies using a DESI index to study digital transformation's impact on the European SMEs' business activity. A novel aspect of our research was to supply empirical knowledge on the advantages/disadvantages of digital transformation for European SMEs. We use DESI in Europe to study digital transformation holistically and investigate the impact of digital transformation on the SMEs' ability to reach customers. We find that digital transformation affects SMEs' competitiveness. We also show that input costs, including labor, are closely linked to digital transformation and are critical to SMEs' performance. Finally, we address the impact of digital transformation on SMEs' external funding and access to finance, vulnerability to exogenous shocks, and adaptability to skilled labor

shortages.

This study provides key insights into digital transformation and European SME performance. The results of this study greatly contribute to the understanding of digital transformation effects on SMEs' business models, managerial practices, competitiveness, and business activities. While most studies focus on using different proxies for digital transformation, we use the comprehensive DESI developed by the European Commission. The present study helps explain how and to what extent digital transformation affects European SME business activities.

The remainder of this paper is organized as follows: Section two summarizes the relevant studies on digital transformation and its link to SMEs. Section three elaborates the theoretical framework of our research. Section four discusses the study's data and methodology and Section five presents the empirical results. Section six discusses the results and compares them with previous studies. The section also includes the theoretical and practical implications and limitations of the research. The last section contains the conclusion, which includes observations on the link between digital transformation and European SMEs, and summarizes the quantitative knowledge from this study.

2. Literature review

We offer an overview of the available literature on the influence of digital technologies on performance and its application in various organization types. According to Verhoef et al. (2021), digital transformation and the resulting innovation in business models have fundamentally changed consumer expectations and habits, put pressure on established companies, and disrupted various markets. They focus on three major exogenous factors driving digital transformation and business model innovation: digital technology, digital competition, and digital consumer behavior. According to them, digital transformation follows three distinct phases: digitization, digitalization, and digital transformation. Moreover, there are other exogenous drivers of digital transformations, such as business cycles, pandemics, financial cycles, climate change, and armed conflicts. Digital technology is the primary driver of digital transformation. Changes in how industry workers think and operate are among the most critical obstacles to digital transformation adoption (Morze & Strutyńska, 2021). Digital transformation, as the key to social value creation, steers global public sector service change (Lourenço Andrade & Cavalcante de Souza, 2020).

Digital transformation significantly impacts European SMEs' business activities. Studies on digital transformation and SMEs have investigated the effects of digital technologies on SMEs' customer relationship management (CRM). Digital technologies create innovative digital products and services, broaden customer bases, and improve business performance for small and medium-sized enterprises (Kin & Ho, 2019). High-speed networks enable SMEs and entrepreneurs to connect with suppliers and customers, obtain real-time information, and respond to rapidly changing markets and supply chains (Kergroach, 2021). Furthermore, digital technology contributes to the innovation of SMEs' business models by creating new distribution channels and ways to create and deliver value to customer segments (Matarazzo et al., 2021).

Digital transformation significantly improves SMEs' competitiveness. SMEs adopting digital technology strengthen competitiveness through innovations in value creation, value proposition, value delivery, and value capture (Teoh et al., 2022). However, several constraints to SMEs' competitive advantage from using digital technology exist. Digital technology adoption, as a critical competitiveness factor, demands significant skilled labor; stakeholders are aware of the importance of digital technology, and managers are ready to adopt such technology (Proksch et al., 2021). Moreover, if the alignment of digital skills and tools with the vision for broader digitalization/digital transformation of SMEs is not clarified, the full potential of such technologies for competitiveness are not realized (Nguyen et al., 2015; Ko et al., 2022).

Access to external funding is critical for the business activities and

development of SMEs. A company's capital ability reflects satisfactory development conditions (Bouwman et al., 2019). Capital capacity drives business model innovation, which, in turn, facilitates financial performance. The ability to invest in a company is important, and total assets are the basic security of a company (Piacentini, 2021; Shi, 2021). Our findings support the importance of financial inclusion in SMEs' business activities and performance (Arner et al., 2020). Digital finance improves SMEs' business market position through servitization (Chen S, 2021). Digital transformation boosts supply chain finance, improving SMEs' position and access to finance (Chen L, 2021).

Digital transformation significantly impacts input costs for SMEs. There is less concern about managing input costs in SMEs that are undergoing digital transformation. Digital transformation boosts the output of small businesses and lowers input costs, as companies use cutting-edge technologies to produce and deliver innovative goods and services. Digital transformation includes product and process innovation, which leads to higher company productivity and lower production costs (Zhu et al., 2021). Digital transformation enables SMEs to gain access to ideas, capitalize on existing knowledge, and utilize technologies from external stakeholders. It allows SMEs to cut costs and compete in a globalizing economy (Albats et al., 2020).

Regulatory burdens are continuous growth constraints on SMEs. Electronic invoicing helps SMEs comply with tax rules and reduces the administrative burdens. Digital technology significantly shifts the regulatory burdens SMEs traditionally face. Digital platforms, cloud computing (CC), one-stop shops, and related infrastructure facilitate administrative burden through one-stop government shops, digital platforms, e-invoicing, e-signature and e-taxes, and open government data (OECD Publishing, 2021). The digital government architecture facilitates the rapid adaptation of SMEs to changes in the regulatory framework, which allows managers and owners to spend more time on business activities and encourages decision-making rather than administrative work to meet a constantly changing regulatory burden (Agostino et al., 2021; Baheer et al., 2020).

Compared to larger firms, SMEs are more vulnerable to exogenous economic and non-economic shocks. As a result, digitalized firms are more likely to adopt short- and long-term crisis responses and enjoy better performance outcomes than other firms. The increased competitiveness of SMEs enables them to adapt and increase flexibility in response to exogenous shocks, such as taxes, cash flow/liquidity, bureaucracy, exchange rate fluctuations, political instability/economic crisis, and Brexit (Guo et al., 2020). Empirical findings demonstrate that with the help of digitization, SMEs adapt successfully to public concerns by using their dynamic capacities. In addition, digitalization helps improve SMEs' performance (Kirtley & O'Mahony, 2020). Digitally transformed SMEs use their dynamic capacities to detect a crisis, capitalize on opportunities during a crisis, and reorganize resources to cope with a crisis; hence, they are more likely to respond swiftly and effectively to emergencies (Vial, 2019; Warner & Wäger, 2019). Digital transformation contributes to companies' performance through the introduction of digital technologies, business model innovation, and changes in value creation. Resilience and anti-fragility measures are widely used to describe how companies survive and prosper in volatile business environments. Resilience is the ability to absorb shocks and recover despite the temporary alteration, while anti-fragility is the ability of a system to absorb and recover from shocks (Corvello et al., 2022).

The biggest concern of European SMEs is the shortage of skilled labor, and digital transformation is making this issue more pressing. The lack of competent workers is a significant impediment to the commercial activities of European SMEs. Short-term digital transformation exacerbates this challenge by expanding the gap between the SMEs' demand and supply for skilled workers. According to Nguyen et al. (2015), a significant impediment to digital transformation in SMEs is the lack of human resources with the knowledge and skills required to meet the criteria of the digital transformation process. In essence, digital

transformation increases the complexity and abstraction of problems to be solved, necessitating digital capabilities in an organization's human resources. Digital adoption rates for a specific country reflect the skill gaps within the country. The strong complementarity between digital technologies and skills and the presumed effect of competitive policies that promote business dynamism and market discipline align with the tendency to adopt (Nicoletti et al., 2020). Therefore, the lack of skilled labor is a critical constraint for the SMEs' successful digital transformation (Eller et al., 2020; Scutto et al., 2021).

Table 1 displays previous research on digital transformation and SMEs.

3. Theoretical background and hypothesis development

Evidence supports the hypothesis that global socioeconomic and market changes also force SMEs' digital transformation. We focus on European SMEs' digital transformation issues by studying the bidirectional link between digital transformation and a challenging business environment. Existing literature on digital transformation lacks empirical knowledge on the issues facing European SMEs and the critical determinants of SMEs' digital transformation. We attempt to fill this gap by providing empirical knowledge on the link between digital transformation and European SME performance.

The firm's actual performance drives the board to consider capital directing, such as total assets and shareholder funds. The company's operation is linked to operational models and the external environment through its links to digital technology and adequate allocation of resources. Limited access to finance creates business risks for European SMEs. SMEs attempt to mitigate these risks by drastically accelerating digital transformation. Moreover, European SMEs view digital transformation as a tool to overcome the current crisis and challenges. However, the issue remains regarding the speed and conditions of digital transformation and what the new business models based on digital transformation can do against the current crisis. Digital transformation is critical for the development of SMEs' new business models. Business model innovation helps European SMEs adequately face business issues, such as finding new customers, increased competition, higher cost in production of labor, availability of skilled staff or experienced managers, and changing regulations.

Hypothesis 1. (H1): Digital transformation significantly impacts SMEs' business activity in Europe.

Customer expectations have changed drastically in recent years and the world is becoming increasingly digital. We study the impact of digital transformation on SMEs' difficulty in finding customers. Digital technologies help create breakthrough digital products and services, which broaden the customer base and improve SMEs' business performance (Khin & Ho, 2019). This is particularly visible in the health industry, fintech, and Industry 4.0. Digital transformation allows SMEs to develop new models that attract customers and retain traditional ones. With an increasing understanding of customer involvement in service design and delivery, there is a greater emphasis on constructing customer-centric businesses. Digital technologies play vital roles in customer-centric businesses (Setia, Setia, Venkatesh, & Joglekar, 2013). Current digital technologies create highly personalized and immersive environments that enable interaction and rich information exchange between brands and consumers. Digital technologies enable customers to produce more value for other consumers, require businesses to re-examine their positions in creating marketing value (Dellaert, 2019).

Hypothesis 2. (H2): Digital transformation can significantly improve SMEs' competitiveness.

Adopting digital technologies requires a higher investment demand, and adopting firm units incur substantial sunk costs. Digital technologies enable organizations to reduce transaction costs, such as coordination and communication costs (Alcácer et al., 2016). Stakeholders choose to

Table 1
Main Literature on Digital Transformation and SMEs.

Study	Design	Methods	Findings
Moeuf et al. (2017)	This study examined existing research on Industry 4.0-related changes to SME production planning and control functions.	Meta-analysis.	Cloud Computing is the most used means of implementing Industry 4.0 practices in SMEs.
Li et al. (2017)	This study examines how small and medium-sized business owners with limited resources promotes digital transformation.	Qualitative research.	It presents insights into how digital platform service providers can help SMEs transform and compete.
Matarazzo et al. (2021)	This study explores digital transformation's impact on customer value creation in Made in Italy SMEs.	Multi-case study research.	The results show that, for the selected SMEs, digital instruments contribute to the innovation of their business model.
Isensee et al. (2020)	This study aimed to integrate SME organizational culture, environmental sustainability, and digitization.	Systematic literature review and meta-analysis.	The authors advocate that the relationship between digitalization and organizational agility has a bidirectional character.
Bouwman et al. (2019)	Whether SMEs perform better if they dedicate more resources to business model experimentation and plan implementation.	Structural equation modeling on 321 SMEs from 12 countries.	Study shows that allocating resources for business model experimentation pays off, leading to increased levels of business model experimentation and, indirectly, to higher firm performance.
Müller et al. (2021)	This study integrates business model design, absorptive ability, and innovation strategy to assess the redesign of established business models in response to Industry 4.0.	Structural equation modeling on 221 SMEs from Germany.	The results show that corporations can participate in exploratory and exploitative innovation through the acquisition, assimilation, transformation, and exploitation of environmental information.
Stentoft et al. (2020)	This article evaluates the impact of Industry 4.0 drivers and impediments on preparedness and practice.	A mixed-method approach that combines elements of qualitative and quantitative research approaches.	Analysis shows a mismatch between SMEs' organizational preparation for and adoption of Industry 4.0 technologies, created in part by reactive technology investments.
Eller et al. (2020)	The study examines three SME resources: IT, personnel skills, and digital strategy on digitalization.	Survey analysis on 193 SMEs.	Digitalization affects performance, mediated through IT.
Garzoni et al. (2020)	The article investigates Industry 4.0 enablers in a region with slow R&D and innovation.	The case study of Smart District 4.0 Italy.	SMEs' adoption of digital technologies depends on digital awareness, digital requirements, digital collaboration, and digital transformation.
Garbellano and Da	This paper examines how leading Italian SMEs have	Qualitative analysis.	Implementing Industry 4.0 requires a renewal

Table 1 (continued)

Study	Design	Methods	Findings
Veiga (2019)	transferred Industry 4.0 technology.		of the leading executive team.
Yu et al. (2022)	How re-internationalized SMEs digitally transform.	Inductive data analysis.	Strategic digital transformation and new product creation create complicated tensions in re-internationalization.
Kraft et al. (2022)	A study looked at Swiss SMEs' digital transformation.	Multiple-case study.	Digital transformation demands change in Swiss SME management policies.

Source: Authors' research

invest money in implementing these technologies, especially during internationalization processes (Chen & Kamal, 2016). In addition, these funds participate in practical operations and employ digital technologies to assist their business strategies in essential areas such as new product development, marketing, and cross-border logistics (Elia, Margherita, Ciavolino, & Moustaghfir, 2021). Digital transformation enables close and real-time involvement between managers and the board and promotes the culture and management through improved communication. Directors who lack equipment or are less digitally savvy can misinterpret and neglect external competition changes (Oliveira, Kakabadse, & Khan, 2022), decreasing SMEs' competitiveness (Cambrea, Gabriellson, Khlif, & Yamak, 2021).

Hypothesis 3. (H3): Digital transformation has a significant impact on input costs for SMEs'.

Digital transformation positively impacts the business results of SMEs, improves employees' productivity and output, benefits the ongoing transformation of operational work-production efficiency, and lowers input costs (Gal et al., 2019; Hai, 2021). This necessitates the modification of how SMEs are managed (Kraft et al., 2022). The productivity premium at the company level of an adopting company is consistently positive and significant across different digital technologies and skill intensity measurements. Evidence also suggests positive spill-over effects or productivity gains in manufacturing sectors and sectors with high routine task content; thus, they have high automation potential (Mosiashvili and Pareliussen, 2020). The transfer of information and data through the Internet reduces production costs and expands the demand for a firm's goods and services, which increase demand for these factors. Buyers and sellers of products or services obtain better access to the other side of the market by increasing the speed or efficacy with which firms find workers or input suppliers (Cusolito, Lederman, & Pena, 2020). The digitization of business processes and the increase in the share of organizations using Internet technologies increase labor productivity (Varlamova & Larionova, 2020).

Hypothesis 4. (H4): Digital transformation significantly improve SMEs' access to finance.

The introduction of digital technologies increases investment requirement, and companies that adopt them incur high sunk costs. However, digital technologies positively affect firms' returns on capital performance. In terms of company performance and development ability, digital transformation helps managers develop a shared understanding. Therefore, digital technologies and the intelligent environment allow companies to meet consumer requirements, adapt to rapidly changing environments, increase operating revenues, and promote company development. The most significant value of digital transformation in the fintech sector is the promotion of financial inclusion, which allows SMEs and low-income households to access financial services (Hua & Huang, 2021). For businesses, new ways of managing finance or providing payments are opened through digital transformation. Digital finance promotes financial inclusion, easing

SMEs' access to finance and promoting SME growth (Shofawati, 2019). In addition, digital transformation helps solve liquidity issues by supporting supply chain finance through digital platforms (Chen L, 2021).

Hypothesis 5. (H5): Digital transformation significantly lowers SMEs' regulatory burden.

Digital transformation of the public sector decreases the regulatory pressure on SMEs (Agostino et al., 2021). Digital governments study and use Internet-based information and communication technologies in the public sector. Service, quality, productivity, and legality are highly prioritized, whereas engagement values are less prioritized (Sundberg, 2019). Digital government architecture helps SMEs quickly adapt to regulatory framework changes, allowing more time for managers and owners to focus on business activities and foster decision-making instead of administrative work to comply with the continuously changing regulations (Baheer et al., 2020). Digital platforms enable SMEs to integrate their accounting, tax, payroll, compliance, and performance metrics. Moreover, digital platforms and governments reduce SMEs' concerns regarding the regulatory burden.

Hypothesis 6. (H6): Digital transformation significantly influence flexibility in response to SMEs' exposure to exogenous shocks.

Digital transformation changes SMEs' business model and overall business activity, including supply and demand chains, secure communication and collaboration, dynamic capacity, and increasing competitiveness (Marx, de Paula, & Uebernickel, 2021). Increased competitiveness allows SMEs to adapt and increase the flexibility of response to exogenous shocks (Guo et al., 2020). Productivity-internationalization premium can be attributed to enterprises' technological decisions, and to an idiosyncratic total factor productivity (TFP) measure that, being net of this technological component, might be understood in terms of expertise and ability to use the adopted technology. On the contrary, the technology premium is substantial for medium and large enterprises. It is even greater for firms operating in country sectors that are subject to import competition (Battisti et al., 2021).

Digital transformation, resilience engineering, and knowledge management principles are essential tools for adaptation during and after the pandemic (Klein & Todesco, 2021). Servitization and the adoption of new knowledge and skills support SMEs' resilience to exogenous crises (Bikse et al., 2021; Rapaccini et al., 2020).

Hypothesis 7. (H7): Digital transformation significantly impact SMEs' skilled labor demand.

Servitization and digital transformation deteriorate SMEs' position toward skilled labor in the labor market. Consequences of digital transformation include escalating emigration of the nation's intellectual capital, shortage of appropriately prepared professionals with digital skills, widening inequities in the labor market, and escalation of social deterioration (Irtysheva et al., 2020). Pressing adjustments in the required skills and competencies lead to a gap between the professional profiles available in the labor market and what companies need (Goulart et al., 2022). European SMEs are already facing a lack of skilled labor, which is a critical constraint on their business activities. Digital transformation worsens this issue in the short run, widening the gap between SMEs' demand for and supply of skilled labor. According to Nguyen et al. (2015), a significant obstacle to digital transformation in SMEs is the shortage of human resources with the necessary knowledge and ability to meet the criteria of the digital transformation process. Essentially, digital transformation increases the complexity and abstraction of problems, necessitating digital skills in the human resources of these organizations. To promote digital transformation processes, highly sophisticated cognitive- and process-oriented skills are required (Butschan et al., 2019).

Table 2 presents the hypotheses logic and structure.

Table 2
Research hypothesis structure.

Hypothesis	Logical structure	Relationship	Supporting evidence
H1 Digital transformation significantly impacts SMEs' business activity in Europe.	Fast-evolving supply chains, real-time information, broadening customer base.	Digital transformation through remote experts and digital assistants creates more marketing value, decreasing the difficulty of finding new customers.	(Kergroach, 2021) (Khin & Ho, 2019) (Setia et al., 2013) (Parise et al., 2016) (Dellaert, 2019) Saura et al. (2021b)
H2 Digital transformation can significantly improve SMEs' competitiveness.	Reducing transaction costs, new product development, cross-border logistics, real-time management, and improved communication.	Digital transformation improves SMEs' competitive advantage by reducing transaction costs, effective real-time management, and the development of new products and services.	(Alcácer et al., 2016) (Chen & Kamal, 2016) (Elia et al., 2021) (Oliveira et al., 2022) (Gabrielsson et al., 2021) (Grover et al., 2020)
H3 Digital transformation has a significant impact on input costs for SMEs'.	Increasing production efficiency lowers input costs and productivity gain, expands the demand for a firm's goods and services, rising labor productivity.	The productivity premium at the company level of an adopting company is consistently positive and significant across different digital technologies	(Hai, 2021) (Gal et al., 2019) (Kraft et al., 2022) (Mosiashvili et al., 2020) (Cusolito et al., 2020) (Varlamova & Larionova, 2020) (Saure et al., 2022)
H4 Digital transformation significantly improve SMEs' access to finance.	Increasing return to capital, promoting financial inclusion, easing access to finance, and promoting SMEs' growth, build supply chain finance.	Digital finance promotes financial inclusion easing SMEs' access to finance and promoting SME growth. In addition, digital transformation can help solve liquidity issues by supporting supply chain finance through digital platforms.	(Hua & Huang, 2021) (Shofawati, 2019) (Chen L, 2021) (Saura et al., 2021a)
H5 Digital transformation significantly lowers SMEs' regulatory burden.	In addition, SMEs benefit from e-government through the increased ability to adapt to exogenous shocks.	Digital government architecture helps SMEs quickly adapt to regulatory framework changes, allowing more time for managers and owners to focus on business and fostering decision-making.	(Agostino et al., 2021) (Sundberg, 2019) (Baheer et al., 2020) (Saura et al., 2021a)
H6 Digital transformation significantly influence flexibility in response to SMEs' exposure to	Digital transformation alters small and medium-sized enterprises' business models and activity,	Digital transformation builds resilience engineering and knowledge management principles as	(Marx et al., 2021) (Guo et al., 2020) (Battisti et al., 2021) (Klein &

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Table 2 (continued)

Hypothesis	Logical structure	Relationship	Supporting evidence
exogenous shocks.	increasing flexibility and adaptation to exogenous shocks.	crucial adaptation tools during a crisis.	Todesco, 2021) (Bikse et al., 2021) Rapaccini et al. (2020) (Irtysheva et al., 2020) (Goulart et al., 2022) (Nguyen et al. (2015) (Butschan et al., 2019)
H7 Digital transformation significantly impact SMEs' skilled labor demand.	Servitization and digital transformation weaken the position of SMEs in the labor market.	European SMEs are already confronted with a severe lack of skilled labor. Digital transformation exacerbates this issue by widening the gap between SMEs' demand and supply for skilled workers.	

4. Data and methodology

Digital transformation is a multidimensional phenomenon and, as such, the exact metrics to measure its dynamics and changes are still missing. Our study examines the empirical link between digital transformation and SMEs and not the development of new metrics for measuring digital transformation. Since we research the connection between digital transformation and European SMEs, we use the official European database for both digital transformation and SMEs indicators to ensure the empirical robustness of our results.

We use DESI as a proxy for digital transformation in Europe. Table 3 shows the structure of DESI.

DESI country profiles provide member states the analysis needed to identify areas that require priority action. At the same time, the thematic chapters offer a European-level analysis across key digital areas for details and methodological explanations, such as human capital, connectivity, integration of digital technology, and digital public services (Commission, 2021).

We use data on DESI from 2016 to 2021 as a proxy for digital transformation in Europe—the weighted average of the four main DESI dimensions with the selected weights. This study does not discuss each component or dimension: sample selection and aggregation methodology.

Table 4 presents the data on European SMEs. We use observations in SAFE from 2016 to 2021 (https://ec.europa.eu/growth/access-finance/data-and-surveys-safe_en). Moreover, we do not discuss each of the following indicators or surveys: country selection, sample selection, aggregation methodology, survey questionnaires, weighting, and calibration. Instead, we focus on the data from the survey (e.g. How important have the following problems been for your enterprise in the past six months? Please answer on a scale of 1–10, where 1 means not it is not at all important, and 10 means it is crucial.) Microdata from the survey, which are scaled as above, answers the following issues: finding customers, competition, access to finance, availability of skilled staff or experienced managers, and regulation. Based on the data from SAFE, we set up an econometric panel model to estimate the relationship between digital transformation (DESI data) and SMEs' related issues that impact their performance (SAFE data). The countries included in the sample are Austria, Belgium, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

Data availability is constrained by the available DESI data for 2016–2021. The same data availability limitations account for the selection of sample and countries with available data. We intend to study the bi-directional link between DESI and SMEs' performance indicators,

Table 3 (DESI) Index structure.

Dimension	Sub-dimension	Indicator
1 Human capital	1a Internet user skills	1a1 At least basic digital skills 1a2 Above basic digital skills 1a3 At least basic software skills
	1b Advanced skills and development	1b1 ICT specialists 1b2 Female ICT specialists 1b3 Enterprises providing ICT training 1b4 ICT graduates
2 Connectivity	2a Fixed broadband take-up	2a1 Overall fixed broadband take-up 2a2 At least 100 Mbps fixed broadband take-up 2a3 At least 1 Gbps take-up
	2b Fixed broadband coverage	2b1 Fast broadband (NGA) coverage 2b2 Fixed Very High Capacity Network (VHCN) coverage
	2c Mobile broadband	2c1 4 G coverage 2c2 5 G readiness 2c3 5 G coverage 2c4 Mobile broadband take-up 2d1 Broadband price index
3 Integration of digital technology	3a Digital intensity	3a1 SMEs with at least a basic level of digital intensity
	3b Digital technologies for businesses	3b1 Electronic information sharing 3b2 Social media 3b3 Big data 3b4 Cloud 3b5 AI 3b6 ICT for environmental sustainability 3b7 e-Invoices
	3c e-Commerce	3c1 SMEs selling online 3c2 e-Commerce turnover 3c3 Selling online cross-border
4 Digital public services	4a e-Government	4a1 e-Government users 4a2 Pre-filled forms 4a3 Digital public services for citizens 4a4 Digital public services for businesses 4a5 Open data

Source: Digital Economy and Society Index (DESI) 2021 DESI methodological note

and how a change in business environment and SMEs' performance affects digital transformation proxies. Our sample characteristics dictate the best method selection before estimation (Saura et al., 2021a). We check for the possibility of using partial least squares modeling on our sample. Following (Goodhue, Lewis, & Thompson, 2012) and Henseler et al. (2016), we find that using partial least squares as a primary research technique on the sample data results in statistical bias due to data stationarity and heterogeneity issues of random and fixed panel modeling. Panel (second generation) stationarity tests (Bai & Ng, 2004, 2005; Chang, 2002; Moon & Perron, 2004; Pesaran, 2007; Harris et al., 2005) show variables are stationary, and Wald test for nonlinearity find the hypothesis of linearity in the data to hold. Preliminary test results, which are not published here, show that panel data modeling is preferred over partial least squares in this study, so we proceed with panel data techniques to capture the omitted variable effect.

Our model takes the form (Baltagi, 2021)

$$y_{it} = \beta' x_{it} + \alpha_i + u_{it} \tag{1}$$

assuming no correlation u_{it} and (x_{i1}, \dots, x_{iT}) under $E[u_{it}|x_{i1}, \dots, x_{iT}] = 0$.

Here, α_i is the specific intercept that captures the fixed effect (heterogeneity across countries/firms) or unobserved individual effect. The error term u_{it} captures the effect of unobservable omitted variables, y_{it} is a dependent variable, and x_{it} is a k-dimensional vector (inde-

Table 4
(SAFE) Q0 – Questionnaire Structure.

Q0	Countries	Scaling
1 Finding customers	Austria	How important have the following problems been for your enterprise in the past six months? Please answer on a scale of 1–10, where 1 means not it is not at all critical and 10 means it is extremely important
2 Competition	Belgium	
3 Access to finance	Bulgaria	
4 Costs of production or labour	Croatia	
5 Availability of skilled staff or experienced managers	Cyprus	
6 Regulation	Czechia	
7 Other	Denmark	
	Estonia	
	Finland	
	France	
	Germany	
	Greece	
	Hungary	
	Ireland	
	Italy	
	Latvia	
	Lithuania	
	Luxembourg	
	Malta	
	Netherlands	
	Poland	
	Portugal	
	Romania	
	Slovakia	
	Slovenia	
	Spain	
	Sweden	

Source: European Central Bank, Survey on the Access to Finance of Enterprises. Methodological Information on the Survey and User Guide for the Anonymised Micro Dataset 2022, https://www.ecb.europa.eu/stats/pdf/surveys/sme/methodological_information_survey_and_user_guide.pdf

pendent variables). The regression model takes the following form:

$$SAFE_{it} = \beta_0 + \beta_1 DESI_{it} + \beta_2 X_{it} + \beta_3 X2_{it} + X3_{it} + \alpha_i + u_{it} \quad (2)$$

where.

- SAFE = indicators from the survey on access to finance of enterprises - finding customers (CUST), competition (COMP), access to finance (FINAN), cost of production or labor (COST), availability of skilled staff or experienced managers (LABOR), regulation (REGUL), and others (OTHER), (European Central Bank, 2022a; European Central Bank, 2022b; Enterprise Surveys Indicators Data - World Bank Group, 2022),
- DESI = Digital Economy and Society Index (Commission, 2021),
- TFP = Total factor productivity index,
- CPI = Harmonized Consumer Price Index (ZCPIH), 2015 = 100,
- LRATE = Interest rates, Long-term real, deflator, in %,
- NAWRU = Non-accelerating wage rate of unemployment, in %,
- COVID-19 = COVID-19 pandemic (dummy variable equal to one in 2020 and zero otherwise).

We have a strongly-balanced panel data from 2016 to 2021 on SMEs in the European Union across member countries and macroeconomic indicators affecting each member state and others, such as business and financial cycle synchronization. Furthermore, we assume the existence of a cross-sectional dependence of the observations and test for its existence using the Breusch-Pagan LM statistic for no cross-section dependence, Pesaran’s scaled LM version, and the bias-corrected scaled LM (Baltagi & Liu, 2016; Pesaran, 2021). As expected, the cross-sectional dependence results, which are not presented here, reject the null hypothesis of no cross-sectional dependence. Therefore, we do not use pooled OLS regression. Our panel only has a six-year period sample; hence, standard panel unit root tests are not adequate to capture unit root dynamics. In addition, having just six years from 2016 and with

2020–2021 having pandemic effects, running a dynamic panel model only captures part of the actual relationship between digital transformation and European SMEs. A panel with the same data but for another time, say 2000–2010, gives significantly different results compared to this study’s panel.

For this reason, we do not use dynamic panel modeling because our T is small and we are missing longer time series data to capture the dynamic effects in the variables. A panel fixed effect model provides consistent and unbiased data estimates. However, because we have a cross-sectional dependent observation, which violates basic model assumptions, we rely on robust standard error estimation, as proposed by (Driscoll & Kraay, 1998). We run the model using the STATA 17 package (Hoechle, 2007). Before proceeding with the one-way fixed effect modeling, we estimate both one-way fixed and random effects to test whether the effects are fixed or random (Breusch & Pagan, 1980; Hausman, 1978; Honda, 1985). Test results are conditional upon modeling to set up the best-fit econometric model.

5. Results

Here, we present empirical results from econometric model estimation for a different testing hypothesis developed in Section three.

5.1. Digital transformation and SMEs’ access to customers

We explore the link between digital technology (DESI) and SMEs’ ability to reach customers in the market. We run cross-sectional and random fixed effect tests to establish the model. Both cross-section and random fixed effects select the random effect model as appropriate. Omitted variables, in this case, are more likely to be time-dependent than time-invariant, so we use the random effect model. Random effect model for digital technology and customer takes the form

$$y_{it} = x_{it}\beta + (\alpha_i + u_{it}), t = 1, 2, \dots, T; i = 1, 2, \dots, N \quad (3)$$

$$CUST_{it} = \beta_0 + \beta_1 DESI_{it} + \beta_2 COST_{it} + \beta_3 COVID_{it} + \beta_4 TFP_{it} + \alpha_i + u_{it} \quad (4)$$

assuming strict homogeneity and no correlation between the time-invariant residual part and explanatory variables. Table 4 presents the results of Eq. (4).

Table 5 shows the impact of the variables of interest on SMEs’ access to customers. All the variables have the expected signs, and the overall model fit (adjusted R2) is 0.5769. DESI, as a proxy for digital transformation, has a statistically significant impact on SMEs’ access to customers at – 0.030. An increase in DESI by one unit on the index scale results in SMEs’ better customer access. The resulting coefficient (–0.030) indicates that SMEs have fewer issues finding new customers

Table 5
SMEs’ access to customers.

Regression with Driscoll-Kraay standard errors Method: Random-effects GLS regression Group variable (i): id maximum lag: 2 corr (u, i, Xb) = 0 (assumed)				Number of obs = 162 Number of groups = 27 Wald chi2 (4) = 4859.01 Prob > chi2 = 0.0000 overall R-squared = 0.5769		
CUST	Coefficient	Std error	t	P > t	[95 % conf interval]	
DESI	-0.030	0.005	-6.420	0.001	-0.043	-0.018
COVID19	0.340	0.029	11.810	0.000	0.266	0.414
COST	0.843	0.024	35.000	0.000	0.781	0.904
TFP	-0.030	0.009	-3.400	0.019	-0.053	-0.007
CONS	5.238	0.914	5.730	0.002	2.889	7.587
Sigma_u	0.536					
Sigma_e	0.252					
Rho	0.819		(fraction of variance due to u _i)			

Source: Authors’ research

Notes: in bold, statistically significant coefficients

for their products and services due to digital transformation. On the SAFE indicator scale, the ranking of finding new customers decrease by -0.030 owing to digital transformation in SMEs.

COVID-19 expectedly hurt SMEs' ability to reach new customers (on the SAFE scale, 1 means access to customers is not critical, and 10 means it is crucial). Therefore, when the SAFE index on the scale increases and scales to 10 as a result of COVID-19, it means that SMEs have issues finding new customers. On the other hand, if the SAFE indicator drops on scale, it indicates an improvement in SMEs' position in the market and performance. The impact of COVID-19 on SMEs' ability to attract new customers and overall performance is negative (0.340).

Furthermore, the higher production cost or lack of labor force and labor market worsens SMEs' ability to reach new customers by lowering their performance and reach on the market (0.843). We see that the impact is significant as an increase in COST increases CUST by 0.843, moving close to 10 on the SAFE scale. This means that the SMEs' conditions and performance are worsening. On the other hand, an increase in the country's TFP improves SMEs' position and performance (-0.030) by decreasing CUST on the scale, which translates to having more to less issues in finding new customers. The impact of TFP on SMEs' access to customers is equal to DESI. Moreover, in European SMEs, digital transformation has at least the same impact on SMEs' performance (access to new customers) as a rise in TFP (Solow's residual-technological advancement).

Rho denotes the ratio of the individual specific error variance to total error variance. A high ratio indicates that individual-specific errors account for a considerable proportion of error variance. For example, in our random effect model, individual-specific errors explain 82% of the error variation (goodness-of-fit for the random-effect model). Moreover, the Wald test shows that the coefficients are statistically significant (Wald $\chi^2(4) = 4859.01$).

We accept the hypothesis that digital transformation strengthens European SMEs' ability to attract and find new customers for their products and services.

5.2. Digital transformation and SME competition

Here, we study the impact of digital transformation on SMEs' competitiveness. Specifically, we study if competition is a significant constraint for European SMEs. We execute the same testing procedure to select the best-fit model. Cross-sectional and random fixed effects tests show that the best-fit model takes the form

Table 6
SMEs' concerns about competition.

Regression with Driscoll-Kraay standard errors				Number of obs = 162		
Method: Random-effects GLS regression				Number of groups = 27		
Group variable (i): id				Wald $\chi^2(4) = 2731.60$		
maximum lag: 2				Prob > $\chi^2 = 0.0000$		
corr (u_i, Xb) = 0 (assumed)				overall R-squared = 0.3118		
COMP	Coefficient	Std error	t	P > t	[95% conf interval]	
DESI	-0.040	0.002	-16.910	0.000	-0.047	-0.034
COVID19	-0.154	0.035	-4.390	0.007	-0.244	-0.064
COST	0.463	0.037	12.680	0.000	0.369	0.557
TFP	-0.003	0.004	-0.750	0.489	-0.012	0.007
CONS	5.109	0.510	10.020	0.000	3.798	6.420
Sigma_u	0.436					
Sigma_e	0.182					
Rho	0.852	(fraction of variance due to u_i)				

Source: Authors' research

Notes: in bold, statistically significant coefficients

$$COMP_{it} = \beta_0 + \beta_1 DESI_{it} + \beta_2 COST_{it} + \beta_3 COVID19_{it} + \beta_4 TFP_{it} + \alpha_i + u_{it} \tag{5}$$

Table 6 presents the results of Eq. (5) testing.

Table 6 shows that SME competition practices significantly constrain SMEs' performance and development. Based on the results, COVID-19, as a constraint, decreases competition. Before the COVID-19 pandemic, European SMEs rate concerns about competition practice as a limiting factor. Owing to the pandemic, we observe a sharp decline in SMEs' concerns about competition in their business activities. For this reason, we see that COVID-19 decreases SMEs' concerns about competition, with a coefficient of -0.1542 . The pandemic has lowered the SMEs' concern about competition by 0.1542 index points. Therefore, we conclude that during pandemics, SME competition decreases as they operate in uncertain and broken supply chains that equally affect all SME business activities.

The impact of digital transformation on SMEs' concerns about competition is expected at -0.040 . An increase in the country's DESI allows SMEs' adaptability and capabilities to hold against market competition. Therefore, SMEs view digital transformation as an efficient policy to address the competition problem, thereby influencing their performance and profitability.

As expected, an increase in production or labor costs due to low labor supply and higher wages raise SMEs' concerns about competition. With increasing production or labor costs, SME competition becomes a constraining factor in the market (0.4632). An increase in COST significantly increases COMP by 0.4632 index points, signaling deterioration in SMEs' position in the market against competition.

TFP also has an expected sign (-0.0027), but the coefficient is not statistically significant in this model; hence, we do not discuss it. A country's increase in TFP is vital to SME performance. TFP's positive impact on SMEs' competition concerns is offset by the adverse effects of the COVID-19 pandemic. A high ratio suggests that the significant deviations are due to specific errors. In our random effect model, 85% of the error variance is attributed to Rho. The Wald test shows that the coefficients are statistically significant (Wald $\chi^2(4) = 2731.60$).

We corroborate the hypothesis that digital transformation improves European SMEs' ability to address market competition by enhancing their business activities and performance.

5.3. Digital transformation and SMEs' access to finance

According to SAFE, access to finance, including public financial support, credit lines, bank loans, trade credit, leasing, and hire-purchases, in the era of historically low interest rates is a minor SME concern in Europe. We study the impact of digital transformation on SMEs' access to finance, including the fact that access to finance has never been more accessible in the past. We perform the same testing procedure to select the best-fit model. Cross-sectional and random fixed effects tests show that the best-fit model takes the following form:

$$FINAN_{it} = \beta_0 + \beta_1 DESI_{it} + \beta_2 COST_{it} + \beta_3 COVID_{it} + \beta_4 TFP_{it} + \alpha_i + u_{it} \tag{6}$$

Table 7 presents the results of estimating Eq. (6).

The estimated model has the expected signs and provides an overall good fit to the data ($R^2 = 0.61$).

Digital transformation improves SMEs' access to finance, which means that it is a minor constraint on SMEs' business activities (-0.024). Digital transformation enables SMEs to increase productivity, innovate, find new customers, and compete in the market. This in turn improves the European SME's overall market position and performance, enhancing the availability of external financing. An increase in DESI decreases SMEs' concerns about the availability of external funding by -0.024 index points. The impact is less significant than the effects on customers and competition, but is consistent.

Table 7
SMEs' access to external funds.

Regression with Driscoll-Kraay standard errors		Number of obs = 162				
Method: Random-effects GLS regression		Number of groups = 27				
Group variable (i): id		Wald chi2 (4) = 28,338.47				
maximum lag: 2		Prob > chi2 = 0.0000				
corr (u _i , Xb) = 0 (assumed)		overall R-squared = 0.6111				
FINAN	Coefficient	Std error	t	P > t	[95% conf interval]	
DESI	-0.024	0.007	-3.680	0.014	-0.041	-0.007
COVID19	0.441	0.041	10.860	0.000	0.336	0.545
COST	0.459	0.088	5.220	0.003	0.233	0.686
TFP	-0.010	0.006	-1.720	0.145	-0.025	0.005
CONS	3.710	0.546	6.800	0.001	2.307	5.113
Sigma_u 0.438						
Sigma_e 0.271						
Rho 0.723 (fraction of variance due to u _i)						

Source: Authors' research
Notes: in bold, statistically significant coefficients

COVID-19 harms SMEs' access to finance. Global supply chain disruption due to pandemics results to uncertainty and risk. Even under low interest rates in 2020, SMEs' access to finance has worsened. Pandemics, through distributional channel disruptions and deteriorated risk levels, adversely affect SMEs' access to finance. Moreover, for a pandemic episode such as COVID-19, SMEs' concerns about access to finance increase by 0.4407 index points.

Production or labor costs also adversely affect European SMEs' access to finance due to higher financing needs. Rising input costs due to pandemics and global supply chain disruptions result in SMEs' deteriorated access to external funds (0.4594). The adverse effect of increasing input costs is equal to the harmful effects of COVID-19 on SMEs' access to finance. Therefore, the negative impact of rising input costs is comparable to the harmful effects of COVID-19 and disrupted supply chains on European SMEs.

The impact of TFP has an expected sign, with the country's rising TFP improving SMEs' access to external funds. However, the effect is not statistically significant; therefore, we do not discuss it. Moreover, the effect of TFP's increase on SMEs' access to finance is offset by the impact of the COVID-19 pandemic (-0.101).

Rho explains 72% of the error variation. The Wald test shows that the coefficients are statistically significant (Wald chi2(4) = 28338.47).

Thus, we accept the hypothesis that digital transformation alleviates European SMEs' access to external funding and compensates for SMEs' soaring financial needs.

5.4. Digital transformation and SMEs input costs

We study the impact of digital transformation on SMEs' ability to address rising input costs, whether production or labor. Since TFP includes inputs COST involved in the production, we omit TFP from the model as COST is an endogenous variable. Our random model is as follows:

$$COST_{it} = \beta_0 + \beta_1 DESI_{it} + \beta_2 COVID-19_{it} + \beta_3 LABOR_{it} + \beta_4 CPI_{it} + \alpha_i + u_{it} \tag{7}$$

Table 8 presents the results of running Eq. (7). We see that all coefficients have the expected signs and are statistically significant.

Digital transformation significantly impacts SMEs' input costs. As a result of digital transformation, input costs, as a dominant concern for SMEs' business activities, decline (-0.026). The impact is less than that for finding new customers or increasing competitiveness, but is similar to that of SMEs' access to finance. The rising DESI helps European SMEs engage in digital transformation, allowing them to adapt to higher input costs. Therefore, the concern about rising input costs is lower in SMEs undergoing digital transformation.

The impact of COVID-19 is both adverse and significant. During the

Table 8
SMEs and input costs.

Regression with Driscoll-Kraay standard errors		Number of obs = 162				
Method: Random-effects GLS regression		Number of groups = 27				
Group variable (i): id		Wald chi2 (4) = 1877.02				
maximum lag: 2		Prob > chi2 = 0.0000				
corr (u _i , Xb) = 0 (assumed)		overall R-squared = 0.4550				
COST	Coefficient	Std error	t	P > t	[95% conf interval]	
DESI	-0.026	0.003	-8.060	0.000	-0.034	-0.018
COVID19	0.261	0.075	3.470	0.018	0.068	0.455
LABOR	0.597	0.105	5.700	0.002	0.328	0.867
CPI	0.025	0.008	3.360	0.020	0.006	0.045
CONS	0.794	0.198	4.020	0.010	0.286	1.302
Sigma_u 0.487						
Sigma_e 0.258						
Rho 0.781		(fraction of variance due to u _i)				

Source: Authors' research
Notes: in bold, statistically significant coefficients

pandemic, SMEs' concerns with rising input costs increase due to supply shocks. As a result, SMEs' problems with rising input costs, which affect their business activities, increase by 0.261 index points.

Instead of TFP, we use LABOR to represent SMEs' concern about the lack of skilled labor. We see that the impact of the labor market mismatch is significant and sizable (0.597). This is more pronounced than the adverse effects of the pandemic shocks on SMEs' input costs. For a unit change in the lack of skilled labor, SMEs' adverse effects, which includes concerns about finding skilled labor, increase by 0.597 index points. Hence, the lack of skilled labor has a considerable negative effect on the business activities of European SMEs.

It is also essential to check for potential adverse effects of rising inflation on SMEs' input costs. As expected, a rise in the consumer price index increases SMEs' input costs, raising concerns about their impact on business activities. Moreover, an increase in inflation by one percentage point raises SMEs' concerns about input costs (inflation expectations) by 0.025 index points. Such adverse effects are comparable in size to the positive impact of SMEs' digital transformation, showing the trade-off between digital transformation and inflation.

RHO explains 78% of the error variation. The Wald test shows that the coefficients are statistically significant (Wald chi2(4) = 1877.02).

Therefore, we accept the hypothesis that digital transformation advances the ability of European SMEs to manage input costs through increased efficiency and resource allocation.

5.5. Digital transformation and SMEs' regulatory burden

Here, we study the impact of regulatory burden changes on the business activities of European SMEs. After running cross-sectional and random fixed effects tests, we set up the following best-fit model in the form of a random effect model:

$$REGUL_{it} = \beta_0 + \beta_1 DESI_{it} + \beta_2 COVID-19_{it} + \beta_3 COST_{it} + \alpha_i + u_{it} \tag{8}$$

Table 9 shows the results running Eq. (8). The impact of TFP on the regulatory burden for SMEs is not statistically significant; therefore, we leave it out of the model.

Digital transformation helps decrease SMEs' concerns about regulatory burdens. Countries successfully undergoing digital transformation help SMEs adapt quickly to changing regulatory structures by promoting cloud public services, making quality digital infrastructure easily accessible, and addressing digital security and privacy issues. In economies introducing iCloud digital services and transforming public services through digital infrastructure and the fintech industry, SMEs face lower regulator burden concerns (-0.020). The effect of digital

Table 9
SMEs and regulatory burden.

Regression with Driscoll-Kraay standard errors				Number of obs = 162		
Method: Random-effects GLS regression				Number of groups = 27		
Group variable (i): id				Wald chi2 (4) = 261.27		
maximum lag: 2				Prob > chi2 = 0.0000		
corr (u_i, Xb) = 0 (assumed)				overall R-squared = 0.5312		
REGUL	Coefficient	Std error	t	P > t	[95% conf interval]	
DESI	-0.020	0.001	-14.690	0.000	-0.024	-0.017
COVID19	0.064	0.025	2.530	0.053	-0.001	0.129
COST	0.553	0.090	6.170	0.002	0.323	0.784
CONS	2.951	0.589	5.010	0.004	1.437	4.465
Sigma_u	0.453					
Sigma_e	0.239					
Rho	0.783	(fraction of variance due to u_i)				

Source: Authors' research

Notes: in bold, statistically significant coefficients

transformation on SMEs is statistically significant and consistent with competition and other business issues.

COVID-19 has adverse effects on SMEs' concerns about administrative burdens. In addition, the lockdown and other pandemic measures increase the regulatory burden for European SMEs (0.0638). Although the adverse impact is not as pronounced as that for previously explored SMEs, business concerns remain essential.

Rising input costs adversely affect SMEs' regulatory burden concerns. With rising production costs, SMEs have less time on changing regulatory frameworks because rising input costs have become a top priority for their business activities. Therefore, increasing input costs by an index point results in a 0.553 increase in SMEs' concerns about the regulatory burden, as dealing with efficiency and production concerns is prioritized over changing regulations.

Rho explains 78% of the error variation. The Wald test shows that the coefficients are statistically significant (Wald chi2(4) = 261.27).

Thus, we accept the hypothesis that digital transformation improves European SMEs' ability to adapt to changing regulatory frameworks.

5.6. Digital transformation and SMEs' exogenous shocks

Table 10 shows the results of our study on the impact of digital transformation on SMEs' other business concerns or exogenous shocks. We run standard cross-sectional and random fixed effect tests and set up

Table 10
SMEs and other business issues.

Regression with Driscoll-Kraay standard errors				Number of obs = 162		
Method: Random-effects GLS regression				Number of groups = 27		
Group variable (i): id				Wald chi2 (4) = 67.97		
maximum lag: 2				Prob > chi2 = 0.0000		
corr (u_i, Xb) = 0 (assumed)				overall R-squared = 0.2051		
OTHER	Coefficient	Std error	t	P > t	[95% conf interval]	
DESI	-0.001	0.015	-0.080	0.939	-0.039	0.037
COVID19	0.393	0.148	2.660	0.045	0.013	0.773
COST	0.430	0.083	5.150	0.004	0.215	0.644
TFP	-0.025	0.007	-3.540	0.017	-0.044	-0.007
CONS	7.792	1.034	7.530	0.001	5.132	10.451
Sigma_u	0.103					
Sigma_e	0.647					
Rho	0.025	(fraction of variance due to u_i)				

Source: Authors' research

Notes: in bold, statistically significant coefficients

the following random effect model.

$$OTHER_{it} = \beta_0 + \beta_1 DESI_{it} + \beta_2 COVID-19_{it} + \beta_3 COST_{it} + \beta_4 TFP_{it} + \alpha_i + u_{it} \tag{9}$$

We see that the variable OTHER captures more exogenous factors that are not influenced by European SMEs. Therefore, the impact of DESI is limited for SMEs, resulting in the expected coefficient of -0.001. However, the coefficient is not statistically significant, and even if it is significant, it only has a minor impact on SMEs; therefore, we do not discuss it in this model. This is because the exogenous variables form OTHER.

COVID-19's impact on other business concerns of European SMEs is expected to be pronounced with a value of 0.430. The effect of pandemics on the exogenous variables in OTHER is statistically significant. A pandemic shock increases SMEs' concerns about taxes, cash flow/liquidity, bureaucracy, exchange rate fluctuations, political instability/economic crisis, and Brexit by 0.430 index points.

An increase in SMEs' input costs adversely affects OTHER, resulting to an increase of 0.430 index points in OTHER and worsening the conditions of SMEs as COST rises. On the other hand, TFP decreases the adverse effects of OTHER business concerns on SMEs by -0.025. In times of increased uncertainty and exogenous risks, SMEs that become more efficient when TFP rises are more flexible to adapt to these exogenous shocks. Similarly, economies with increasing TFP are more robust to exogenous shocks, which, in turn, help SMEs maintain their market position.

Rho explains 3% of the error variation. The Wald test shows that the coefficients are statistically significant (Wald chi2(4) = 67.97). The constant term is important and sizable, meaning that the model can be improved by adding the variables that are omitted from the sample.

Therefore, we reject the hypothesis that digital transformation helps European SMEs' manage exogenous shocks because the coefficient is not statistically significant.

5.7. Digital transformation and skilled labor shortage

Here, we study the impact of digital transformation on SMEs' demand for skilled labor. the lack of skilled labor is a significant constraint for European SMEs. We execute the same testing procedure to select the best-fit model.

$$LABOR_{it} = \beta_0 + \beta_1 DESI_{it} + \beta_2 REGUL_{it} + \beta_3 COVID-19_{it} + \beta_4 TFP_{it} + \alpha_i + u_{it} \tag{10}$$

In Table 11, cross-sectional and random fixed effect tests show that

Table 11
SMEs and availability of skilled staff or experienced managers.

Regression with Driscoll-Kraay standard errors				Number of obs = 162		
Method: Random-effects GLS regression				Number of groups = 27		
Group variable (i): id				Wald chi2 (4) = 27,349.52		
maximum lag: 2				Prob > chi2 = 0.0000		
corr (u_i, Xb) = 0 (assumed)				overall R-squared = 0.4223		
LABOR	Coefficient	Std error	t	P > t	[95% conf interval]	
DESI	0.025	0.005	4.850	0.005	0.012	0.039
COVID19	-0.601	0.011	-52.670	0.000	-0.630	-0.572
REGULAR	0.655	0.097	6.720	0.001	0.405	0.906
TFP	0.027	0.010	2.810	0.037	0.002	0.052
CONS	-0.956	0.703	-1.360	0.232	-2.764	0.852
Sigma_u	0.538					
Sigma_e	0.306					
Rho	0.755	(fraction of variance due to u_i)				

Source: Authors' research

Notes: in bold, statistically significant coefficients

the best-fit model takes the form of variables of importance for SME access to customers.

The overall model fit (adjusted R2) is 0.4423 and each variable has a predicted sign. We see that DESI has a statistically significant effect on SME customer access (0.0253). On the index scale, a one-unit rise in DESI increases the demand for skilled labor by SMEs. As a result of digital transformation in SMEs, the resultant coefficient (0.0253) indicates that SMEs have more issues in acquiring new high-skilled labor. In addition, the difficulty in obtaining new skilled labor increases by 0.0253 index points on the SAFE scale.

As anticipated, COVID-19 adversely affects the ability of SMEs to attract new, skilled workers. This is corroborated by the [European Central Bank \(2022a\)](#), which reports a significant decline in SMEs' concern with the lack of high-skilled labor and managers (−0.6008). During COVID-19, European SMEs face more pressing issues, such as access to capital, finding customers, and competition, pushing concerns about the availability of skilled staff or experienced managers down by 20%. Therefore, employing more skilled labor and experienced managers is not a critical issue for SMEs during pandemics.

We observe a significant impact for a unit rise in REGUL. Due to the strict regulatory burden, rigid labor markets increase SMEs' concern about the lack of skilled staff by 0.6551 index points. Regulatory obligations make SMEs more vulnerable to skilled labor demand/supply mismatches. An increase in a country's TFP worsens the position of SMEs (0.2729) in the labor market as it increases LABOR on the scale due to more issues in finding skilled staff. The impact of TFP on SMEs' shortage for skilled labor is similar to the impact of digital transformation.

Rho explains 76% of the error variation.

Thus, we accept the hypothesis that digital transformation exposes European SMEs to the lack of skilled staff and associated risks.

5.8. Robustness testing

To test the robustness of our results, considering the effect of omitted variables and heterogeneity or stationarity issues in the data, we proceed in several ways. We use variables, such as long-term interest rate, inflation rate, and the long-run non-accelerating wage rate of unemployment. We also change the ordering of the variables in the model and use various lags of the variables. In addition, we use lagged dependent variable observations to test for a possible autoregressive effect that could result in estimation bias. None of the tests discussed above have a significant impact on the estimation results. Thus, we safely conclude that the estimation results are robust, and that no exogenous inference or bias could invalidate the study results.

6. Discussion

Our research aims to understand the impact of digital technologies on the business activities of European SMEs. Despite the growing interest in digital technologies for companies, most studies focus on a single type of company, whereas SMEs receive less systemic attention and few empirical insights. Our study examines the impact of digital technology on company performance by size, focusing on SMEs. It provides new insights into the effects of digital transformation-related metrics from the perspective of competition capacity, customer/demand capacity, access to financial capacity, development capacity, and capacity to deal with exogenous shocks. We show that digital technologies have a noticeable impact on European SMEs' performance and confirms the relationship and degree of effects for European SMEs. This study examines the impact of digital transformation on the performance of European SMEs in seven different business activity concerns. This study fills the gap in the literature and policy implications.

Digital transformation improves the ability of European SMEs to address market competition by enhancing business activities and performance. Digital transformation is reshaping corporate strategies,

business models, and marketing strategies that drive the digital humanities in the wave of information technology. We examine the link between digital technology and the SME's ability to adapt to changing business and social environments. Digital transformation enables SMEs to increase productivity, innovate, find new customers in the market ([Ogunjimi et al., 2021](#)), and compete. Furthermore, digital transformation helps European SMEs better manage exogenous shocks. However, the results of this study are limited.

We corroborate the hypothesis that digital transformation improves European SMEs' ability to address market competition by enhancing business activities and performance.

We accept the hypothesis that digital transformation statistically impacts SMEs' access to external funding; thus, compensating for SMEs' financial needs. As expected, COVID-19 has adverse effects on SMEs' business concerns and activities ([Bai et al., 2021](#)). On the other hand, digital transformation has a significant positive impact on SME business activities. Moreover, we see digital transformation as a suitable policy to improve SMEs' ability to adapt to changing business activity conditions, including access to customers, access to finance, access to skills, improved adaptability and flexibility, and enhanced efficiency and internationalization.

Our study yields several significant results. First, digital transformation is important for creating new markets and connecting digital platforms to new customers for European SMEs. We use SAFE and DESI to investigate the interaction effect of digital transformation. This finding expands the literature on digital transformation and its impact on European SMEs' customer relationships and market creation.

Digital transformation in Europe offers SMEs the opportunity to better meet customers' expectations and enter new markets ([Matarazzo et al., 2021](#); [Nichifor et al., 2021](#)). As a result, SMEs face fewer issues connecting to new customers and have less difficulty finding customers for their products and services. Nevertheless, digital transformation is a necessary but insufficient condition for European SMEs to meet customers' needs ([Castagna et al., 2020](#); [Ramírez-Durán et al., 2021](#)).

Second, the impact of digital transformation on SMEs' concerns about competition is expected. Our study shows that an increase in the country's DESI increases SMEs' adaptability and capabilities to compete in the market. Therefore, European SMEs view digital transformation as an efficient policy to address the problem of facing market shares/competitors' prices, influencing their performance and profitability. Digital transformation improves SMEs' ability to adapt to market share/competitors' prices through innovation, new business model adoption, efficient resource allocation, and smart manufacturing ([Ku et al., 2020](#)), making competition less pressing for their business activities ([von Joerg & Carlos, 2022](#)). Our results corroborate the findings that digital transformation drives SMEs to adapt to changes in business models, business strategies, ([Cozzolino et al., 2018](#)), and B2B exchanges ([Pagani & Pardo, 2017](#)), advancing their competition policy. The findings align with existing research ([Marx et al., 2021](#)). Digital transformation is a strategic imperative for companies to remain competitive in a digitally disrupted and constantly changing business environment. Previous research shows a link between a company's response to external changes, dynamic capabilities, and digital maturity, which increases its competitive advantage.

We investigate the link between digital transformation and SMEs' access to finance. Before the COVID-19 pandemic, interest rates are historically the lowest because of inflation, Federal Exchange Reserve intervention, and European Central Bank intervention, European firms in the last five to ten years have no external financing issues. However, COVID-19 has significantly increased the financing needs of businesses worldwide, and government and central bank interventions have supported this business need. Moreover, the increasing demand for funds from businesses is met through improvements in companies' access to external funds. However, European companies expect tighter financial conditions in the future, limiting their access to finance.

Third, digital transformation improves SMEs' access to finance,

making it a lower constraint (Hasan & Cheung, 2018) on SMEs' business activities. Digital transformation enables European SMEs to increase productivity, innovate, find new customers, and face competition by adopting new business models. This, in turn, improves their market position, performance, and availability of external financing (Wang et al., 2019). An increase in DESI reduces concerns regarding the availability of external funding. The impact is less significant than that on customers and competition, but it is consistent. Our findings support the importance of financial inclusion in SMEs' (Arner et al., 2020) business activities and performance. Furthermore, digital finance improves the business market position through servitization (Chen S, 2021).

The results corroborate that digital transformation boosts supply chain finance, improving the SMEs' position and access to finance (Chen L, 2021).

Fourth, digital transformation significantly impacts input costs for SMEs. Digital transformation enables SMEs to manage input costs to effectively ensure and promote business activities. The rising DESI helps European SMEs take on digital transformation, allowing them to adapt to rising input costs. As a result, concerns about rising input costs in SMEs undergoing digital transformation are lower. However, SMEs report higher material and energy costs that adversely affect their profits (European Central Bank, 2022a).

On the other hand, digital transformation increases production and lowers input costs of companies that use the latest technology to develop and provide innovative goods and services (Bagale et al., 2021). Consequently, the government urgently needs to build a digital sharing platform based on large manufacturing companies and a digital enabling platform for SMEs (Zhang et al., 2021). Among the benefits of digital transformation on SMEs are product and process innovations, which increase productivity and lower production costs (Zhu et al., 2021).

Fifth, digital transformation helps reduce the concerns of SMEs regarding regulatory burdens, making public sector organizations leaner, more efficient, and more responsive to citizens and private sector needs (Newman et al., 2022). Countries successfully undergoing digital transformation help SMEs quickly adapt to changing regulatory structures by promoting cloud public services, providing easy access to high-quality digital infrastructure, and addressing digital security and privacy issues. In economies that introduce digital cloud services and transform public services through private/public service digital infrastructure (Faro et al., 2021; Sobotovičová & Blechová, 2021) and the Fintech industry (Milian et al., 2019), SMEs face lower regulatory burdens. In line with previous studies, SMEs leveraging current and near-future digital technologies use the benefits of platform governance (Fenwick et al., 2019).

Sixth, SMEs undergoing digital transformation are more adaptable to exogenous shocks, such as tax policy changes, cash flow/liquidity-monetary policies, bureaucracy, exchange rate fluctuations, political instability/economic crisis, and Brexit. Moreover, previous research shows that digital technologies help firms adapt more quickly to COVID-19 (Jiang & Stylos, 2021) by developing new products or services, investing in marketing and communication, or introducing new collaborations (Corvello et al., 2022). However, our study shows that the so-called anti-fragility impact of digital technology on European SMEs is still in the development phase and has no significant effect.

Lastly, the shortage of skilled labor is a critical concern for European SMEs (European Central Bank, 2022a). Human resources in SMEs must be able to design, implement, and integrate new and current IT systems and have expertise in business, finance, project management, contract negotiation, and data integration. In addition to skill requirements, the human resources must be well-versed in technology, mechatronics, and information technology (Nguyen et al., 2015). However, low managerial quality, lack of ICT skills, and policies curbing market access are associated with lower digital transformation dynamics in firms (Nicoletti et al., 2020). Moreover, digital transformation in SMEs is trapped in a vicious cycle of constraints on digital technology adoption and human

capital requirements. Our study reveals that digital transformation is impossible without high-skilled human capital stock, and SMEs adopting digital technology face a sizable skilled labor shortage.

6.1. Theoretical contributions and implications

This study makes four critical contributions to the literature. First, this study contributes to the current research on the impact of digital transformation on European SMEs, and the main issues linked to the inherent business environment and business activities. The results of this study show the essential role of digital technologies in SMEs, and suggest the necessity of considering advanced technologies to improve SME performance and adaptability (Saura et al., 2021a; PricewaterhouseCoopers, 2018).

Second, using DESI and SAFE databases, we extend current research involving DESI and SAFE in Europe. Third, using data from both databases, we contribute to the research on digital transformation and SMEs in Europe. Digital transformation of SMEs require a deeper investigation of the interaction between business activities/concerns of SMEs and digital technology adoption.

Fourth, our research complements the literature on the benefits and disadvantages of European SMEs' digital transformation; thus, supporting empirical knowledge. Additional research is needed to demonstrate how management understanding and commitment can be better aligned with the potential for business model innovation for new value creation (Akpan & Ibadunni, 2021; Hai, 2021; Ko et al., 2022; Nguyen et al., 2015; Verhoef et al., 2021; Garzella et al., 2021; Kraus et al., 2022; Xie et al., 2022).

Our study encourages the assessment of SMEs' implementation tools and constraints in digital technologies. We focus on managerial and operational understanding of the impact relationships between digital technologies and SMEs' performance.

6.2. Practical implications

Our research provides practical advice to managers and entrepreneurs of SMEs regarding the application of digital technologies and the resulting new business models. We reveal the connections between digital transformation and the factors shaping the business environment and SMEs' activities. Policymakers perceive these conditions as incentives for companies to innovate and increase productivity for sustainable growth. A more productive private sector generates tax revenue that can be used for public investment in health, education, and other services. However, a poor business climate raises barriers to SME business activities and reduces the chances of full employment, production, and welfare frontiers (World Bank, 2022). SME managers focusing on digital technologies are interested in the impact of these advanced tools on SME business performance (Saura et al., 2021b; Saura et al., 2022). In addition, entrepreneurs and managers consider whether digital technologies boost the success or revenue of SMEs. Therefore, we address the impact of digital transformation on SMEs' performance linked to the more critical growth-constraining factors.

SMEs' access to new and traditional customers significantly improves with CRM software adoption. Digital technologies related to customer management enable European SMEs to connect, communicate, create, and exchange content online. Therefore, SMEs using digital technologies report fewer issues in accessing customers. The impact is significant, as the difficulty in finding customers decline by 15–20% for SMEs adopting CRM software. SME managers and owners should invest in CRM software to manage vendors, channel partners, and groups of individuals with specific needs (Bose, 2002). SMEs adopting CRM increase productivity and competitiveness and improve adaptability to market conditions.

SMEs significantly improve competitiveness upon the introduction of CC, enterprise resource planning (ERP), and CRM. Firms operating in economies with high digital economy and DESI report a pro-competition

environment, which enhances high-quality managerial practice, workers' skills, adaptability, flexibility, and market discipline. Our results show that a firm-market incentive policy set, which includes easy entry and competition, product market regulation, digital trade restrictiveness, high-speed broadband access, employment protection, open digital markets, external financing availability, tax incentives, and e-government, is critical to SMEs' digital transformation (Nicoletti et al., 2020). European SMEs require a strong market incentive to increase the adoption of digital technologies, which improves their competitiveness. Economies promoting significant market incentives for digital transformation have a higher share of SMEs and report less concern about competition.

External financing and access to finance are critical factors for SMEs, which traditionally have limited internal capital and are more dependent on external financing. Firms operating in an environment with a developed fintech industry report more accessible external funding. Additionally, SMEs with a higher rate of digital technology adoption have easier access to finance, attract investments in R&D, are less risk averse, have lower financing costs, and have access to venture capital. SMEs that adopt CC, ERP, and CRM report fewer constraints in accessing external financing. Because digital transformation enables SMEs to have a more efficient debt policy that lowers risk aversion and associated business risks, SMEs with a higher digital adoption rate have easier access to finance. As a result, deep risk capital markets increase the entry of new companies and the capacity for successful new entrants to expand. Previous research show that the availability of risk capital is significantly and positively correlated with technological diffusion rate (Andrews et al., 2015; Saia et al., 2015).

Digital transformation significantly impacts SMEs' input or labor costs. Economies with advanced digital adoption or high DESI allow SMEs to reduce the costs of business activities. Business costs in SMEs adopting digital technology enable better cost management, including lower energy and personnel costs, unproductive task elimination, higher customer satisfaction, efficient supply/demand chain management, and fewer operational errors in machine/employee downtime. The digital economy influences labour share through three counter-vailing forces: the effect of productivity improvement, the factor-biased effect, and the effect of scale return change (Chen et al., 2022).

A business environment with a high digital technology adoption rate allows SMEs to operate with low regulatory burden. When competitive pressure, employment protection, and product market legislation are transparent and flexible, the link between better managerial quality and a higher digital adoption rate is emphasized. This is a direct market incentive for SMEs to increase their digital adoption, leading to better executive quality. With the support of market incentives, digital transformation motivates stakeholders to develop high-quality management and increases the availability of skilled staff and experienced managers. On the other hand, SMEs that delay digital adoption are more exposed to the divergence between changing market conditions and the speed of digital adoption. Such a situation exposes SMEs to changing regulatory burdens, resulting in skill mismatch, lower managerial quality, low-efficiency business activity, and poor market performance (Nicoletti et al., 2020).

Compared to larger firms, SMEs are more exposed to exogenous shocks. Exogenous shocks pushes firms to digitally transform and adopt digital technologies (Jesse & Jannach, 2021). Moreover, this leads to SMEs building intangible assets through improved managerial quality, skilled labor, vocational training, and minimization of job mismatches. SMEs introducing digital technologies increase their capabilities in managing entry and exit barriers, labor market shortages, access to capital, increased competitiveness, and decreased production costs. There is a strong positive link between digital technology adoption and SMEs' capabilities to address exogenous shocks; thus, providing external incentives to invest in digital technologies.

Digital technology adoption in SMEs requires skilled labor to increase firms' concerns about skilled labor shortages (Eller et al., 2020).

Digital transformation demands leadership skills, managerial practices, innovative business models, working environments, and investment in organizational capital. A prerequisite is ensuring continuous access to a high-skilled labor force and continuing vocational training. European SMEs face a significant skilled labor shortage, in addition to business concerns. In the short run, digital technology adoption increases SMEs' concerns about attracting high-skilled labor, professionals, and experienced managers necessary for digital transformation. In the long run, benefits resulting in improved competition, easy access to finance, lower input costs, better interaction with customers, and lower vulnerability to exogenous shocks level out the initial concerns and issues related to attracting high-skilled labor.

6.3. Limitations and future research directions

This study has several limitations. First, there is a lack of performance information from a subset of countries owing to the lack of relevant records in the database on European SMEs. We define DESI as a digital transformation proxy because a generally accepted indicator for digital transformation is not available. Second, we use total market economy indicators to represent the main business constraints to SMEs' business activities. Based on this study's quantitative knowledge, future studies should consider firm- and industry-level SME indicators.

Third, firms' and industry-level data using SMEs' financial and operational data should be used to evaluate the impact of digital technology adoption on SMEs. This study explains the impact of digital technologies on the business activities and concerns of European SMEs.

Thus, there is an opportunity to conduct additional research using more complete data from the Orbis database and a more advanced scientific methodology, such as the dynamic panel with time-series data, to examine how digital technology influences SMEs.

Future research should focus on specific digital technology instruments, such as CC, ERP, CRM, big data, and advanced cloud computing, and their impact on companies across sectors and sizes. In addition, developing a global cross-country digital transformation model to investigate the effects of digital technology on SMEs worldwide can be explored in future studies.

7. Conclusion

The results of this study reveal that digital transformation has an important effect on European SME business activities. These results broaden our understanding of the mechanism by which digital transformation helps SMEs overcome performance constraints and exogenous shocks. This study presents a novel approach to the field of digital transformation by linking two comprehensive European databases: DESI and SAFE. The Joint European Commission/European Central Bank Survey on enterprises' access to finance provides significant insight into SMEs' performance. The strength of our work lies in using panel data modeling on data from both databases to demonstrate the impact of digital transformation on SME business activities. This technique can be applied to study the impact of digital transformation on a particular SME business segment. Our results can help European policymakers set up relevant and efficient digital transformation strategies and policies by providing empirical knowledge on the impact of digital transformation. The present findings might help explain why SMEs need to invest in digital transformation by discussing its advantages and limitations. This study only focuses on European SMEs. Additional insights can be obtained by checking the robustness and implications of the results using partial least squares. Future studies should focus on the link between digital transformation and various segments of SMEs' business activities using industry- and firm-level data for SMEs outside Europe. Our results are encouraging and should be validated with a larger sample size.

Our study underlines the importance of digital transformation in European SMEs. Digital transformation continuously changes business processes and models, customer experiences, supply chains, and value

delivery. These results indicate that digitally transformed SMEs significantly benefit from digital technology adoption. European SMEs with high digital adoption rates take advantage of being more flexible and adaptable to endogenous or exogenous shocks. SMEs that use digital technologies have fewer issues with customer relations, increasing competition, access to finance, input costs, regulatory burdens, exogenous shocks, and public crises. Simultaneously, SMEs face additional uncertainties and risks related to the availability of skilled labor and experienced managers, which could result in losing a competitive edge in the market. Government support in building digital infrastructure and support for skilled labor force markets is necessary, but insufficient for many European SMEs undergoing digital transformation. Significant support from the fintech and banking sectors is critical for digital transformation financing. This study contributes to the field of digital transformation and its impact on European SMEs by expanding the current quantitative knowledge on the topic.

CRedit authorship contribution statement

Marinko Skare: Conceptualization, Methodology, Software, Writing – original draft. **Samuel Riberio-Navarrete:** Data curation, Writing – original draft. **Maria de Las Mercedes de Obesso:** Supervision, Validation, Writing – review & editing.

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