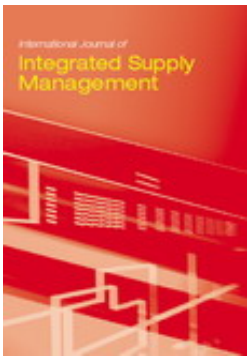

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A deeper understanding of the relationships between 'firm size' and supply chain digitalisation: an empirical investigation

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A deeper understanding of the relationships between 'firm size' and supply chain digitalisation: an empirical investigation

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Abstract: In a context of unprecedented crises and uncertainties, digital tools appear to bring more visibility to decision-takers along the supply chain (SC). They enhance information sharing and collaboration between SC entities. This research contributes to providing a more complete understanding of the relationships between the size of the firm and its adoption of SC digital tools and the challenges encountered. For this purpose, we mobilise the resource-based view (RBV) and analyse 311 surveys collected from SC professionals using the Kruskal-Wallis and Mann-Whitney tests. Our results clarify the role of firm size in SC digitalisation. More precisely, groups of different firm sizes show a significant difference of SC digital tools adoption level and our study enables researchers and practitioners to understand that this difference depends on the type of tools (either operational or support tools). In addition, this study brings a counter-intuitive result that is not consistent with previous research: there is no difference between the groups of different firm sizes with regards to SC digitalisation challenges encountered.

Keywords: digitalisation; supply chain; challenges; digital tools; firm size; resource-based view; RBV.

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1 Introduction

Our modern business world presents numerous challenges for supply chains (SCs). Financial, economic, social, ecological but also sanitary crises remind firms on a daily basis how uncertain their environments are and that disruptions may occur (Dwivedi et al., 2020; Ivanov and Das, 2020; Ruel and El Baz, 2021). In this context, digital tools appear to be solutions (Ivanov and Dolgui, 2019; Ivanov, 2021a): they bring more visibility to decision-takers along with the SC due to the collection of data in real-time, enhance information sharing and collaboration between SC entities, and automatically analyse more data (Kache and Seuring, 2017; Min, 2019). Therefore, many studies show, by examining certain specific SC digital tools at a time, (e.g., Min, 2019; Dubey et al., 2021), the various advantages of adopting SC digital tools.

However, researchers have indicated that the implementation of digital tools is a complex process, and firms face numerous difficulties (Frank et al., 2019; Kamble et al., 2018). The main reasons for the complexity lie in the high investment levels and the unclear return on investment of digital tools (Kamble et al., 2018). Indeed, the literature provides many studies concerning the barriers and obstacles that inhibit the implementation of new technologies. For instance, front liner barriers for SC digitalisation are those challenges relating infrastructural issues, absence of adequately skilled workforce and lack of standards (Frank et al., 2019; Kamble et al., 2018).

Previous studies agree that investigations of challenges faced by firms in digitalisation have not been sufficiently explored (Frank et al., 2019; Horváth and Szabó, 2019) and that more research is required to achieve a general consensus.

On the one hand, most research states, based on the resource-based view (RBV) (Barney, 1991) that firm size is one of the determining factors in SC digitalisation (Yang et al., 2021) along with SC maturity (Zouari et al., 2021) which requires competences

(Colli et al., 2019), an organisational structure (Schuh et al., 2017) and the capability to capture value (Schumacher et al., 2016). Our literature review reveals the heterogeneity of the corpus concerning the link between firm size and digital transformation. The adoption of digital tools may require significant investment and expertise (Williams et al., 2015; Pan et al., 2019), and smaller firms have limited resources available for such investments (Elia et al., 2021). However, some research points out that SMEs are more flexible as the decision-making and information are decentralised, which facilitates the digital transformation (Müller et al., 2018b; Gupta et al., 2020).

On the other hand, Lin et al. (2018) show that firm size and nature[1] do not have any significant impact on firms' digitalisation. This means that, regardless of their size, firms highlight their difficulties in digitalising their SCs (Deloitte, 2017). Thus, firm size is a factor that has an unclear and ambiguous position in the SC digitalisation process.

The contribution of this study is to shed new light on the role of firm size on the SC digitalisation. Indeed, if the firm size is a usual control variable in this line of research, the focus is never on this variable and the way it directly impacts the SC digitalisation and its challenges.

Therefore, to bridge this gap, we attempt to answer the following research question: Is there any relationship between the size of the firm and

1 its SC digital tools adoption level

2 the challenges to SC digitalisation?

Addressing this gap is an essential contribution for research to consider SC digitalisation more realistically: although SC digitalisation may bring advantages for some firms, most of them, whatever their size, struggle with it and many SC professionals do not know where to begin in the process (Whysall et al., 2019).

From a theoretical standpoint, we mobilise RBV related to the availability of resources for supply chain management (SCM) (Elia et al., 2021; El Baz and Ruel, 2021). Indeed, RBV is a relevant framework because research shows that large firms have greater access to resources (Asamoah et al., 2021).

From a practical standpoint, our study offers several managerial contributions by better embracing the reality of firms trying to digitalise their SC and theoretical contributions by exploring the aspects of SC digitalisation that are impacted or not by firm size, which makes it possible to clear up ideas about firm size and SC digitalisation that are sometimes preconceived for several academics and practitioners.

To reach our research goal, 311 surveys from SCM professionals were statistically analysed. Three steps were necessary:

1 defining each of the challenges faced by firms in the digitalisation context (as per Türkeș et al., 2019; Raj et al., 2020)

2 measuring the SC digital tools adoption level

3 evaluating the impact of firm size from an RBV perspective, on those SC digitalisation variables (Li et al., 2020).

The paper is structured as follows: after having laid the theoretical foundations of our analysis, we review the relevant literature on SC digitalisation and SC digital tools adoption and describe the challenges faced by firms when digitalising their SCs. We then discuss the methodological approach and subsequently present and discuss the results.

Finally, our conclusion provides the contributions, limitations, and future research perspectives.

2 Theoretical background and hypotheses development

2.1 Firm size and supply chain digitalisation from RBV perspective

The need for SC digitalisation in our current time of recurrent crises can be analysed through the lenses of the RBV (Wamba and Queiroz, 2020). RBV is a well-established theoretical approach that highlights that firm may achieve long-term competitive advantages if they possess valuable, inimitable, and non-substitutable resources (Barney, 1991). According to Barney (1991, p.114), 'computers or other types of machines, are part of the physical technology of a firm and usually can be purchased across markets'. Thus, the links between RBV and digitalisation have been highlighted since the origin of this theoretical framework.

The contribution of technologies to the development of competitive advantages is widely emphasised in academic research (Wamba and Queiroz, 2020; Ivanov et al., 2021) and RBV is a popular theoretical framework for studying this (Seyedghorban et al., 2020). At the same time, studies highlight difficulties for small firms in identifying, acquiring, and developing their resources, including those related to digitalisation (Elia et al., 2021). Indeed, firm size reflects the amount of available resources that can be leveraged to build a competitive advantage (Ramon-Jeronimo et al., 2019); the smaller the firm, the fewer resources it has.

However, the few research studies that mobilise the 'firm size' variable in the context of SC digitalisation find results that are sometimes contradictory, (e.g., Lin et al., 2018) stating that firm size does not have any significant impact on digitalisation whereas Yang et al. (2021) show a positive impact), suggesting that resources to achieve this digitalisation are certainly lacking in smaller firms but may also be lacking in larger firms. In the next section, we develop these aspects more thoroughly.

2.2 Supply chain digitalisation

As a new industrial revolution, digitalisation is one of the most popular topics among international institutions and professionals; thus, it is a burgeoning research area (Raj et al., 2020). Due to this revolution, numerous business models and organisations are changing and will continue to change profoundly (Büyüközkan and Göçer, 2018). Lately, the rise in the use of interactive and mobile communication tools has accelerated this revolution (Schniederjans et al., 2020; Ivanov, 2021b). In this context, which frequently highlights the expected benefits of digitalisation, other perspectives are being examined. For instance, a recent literature review (Ain et al., 2019) indicates that researchers and practitioners are also interested in better understanding the challenges faced when implementing digital tools. Ivanov (2021b) mentions the important challenges to create end-to-end visibility in the SC thanks to digital tools.

Examining SC digitalisation specifically, SCM is considered to be a very suitable application domain for digital tools (Park et al., 2016). Indeed, such tools enhance the decision-making processes of SC managers. In this context, Büyüközkan and Göçer (2018, p.165) define digital SC as:

> "An intelligent best-fit technological system that is based on the capability of massive data disposal and excellent cooperation and communication for digital hardware, software, and networks to support and synchronise interaction between organisations by making services more valuable, accessible and affordable with consistent, agile and effective outcomes."

2.3 Digital tools for SCM and their adoption level

Digital tools are needed to enhance the decision-making processes of SC managers (Park et al., 2016) and disrupt traditional SCs. These new technologies are directed to distributed systems in order to improve physical and communication systems. They work with different methods like auto-optimisation, simulation, intelligent worker support, self-diagnosis, machine perception and self-configuring in order to achieve multiple goals. For example, tools such as the internet of things (IoT) play a key role in the design, operations, and performance of global SCs (Gunasekaran et al., 2016). Zouari et al. (2021) study 15 digital tools which are the most useful in the field of SCM and list their definitions. Based on this research, in Table 1 we consider the same tools and explain their main purpose in SCM.

Digital tools are essential to the success of global SC networks (Gunasekaran et al., 2016) and are desired by most firms, even smaller ones, because they recognise the benefits over the costs and organisational challenges (Buer et al., 2020). Future SC will converge people, businesses, and things in a digital value network thanks to the incorporation of fast-emerging digital tools. In the context of SCM, the adoption of digital tools seeks to achieve not only coordination inside the firm but also inter-organisational coordination by means of electronic links between information systems, enabling automated and digitalised processes which involve different partners from suppliers to customers (Büyüközkan and Göçer, 2018).

Several models for digital tools adoption exist and these may help to understand the various adoption stages (e.g., Hameed et al., 2012), from the pre-adoption phase and its antecedents to the implementation phase, including users' practices and habits, and then to the post-adoption phase. However, these models, which focus on the adoption phases of digital tools, do not provide information about their adoption level. Nevertheless, this is of key importance: the emergence of Industry 4.0 has brought an important number of challenges and opportunities for organisations and with these, the need to evaluate the digitalisation process.

2.4 Challenges to supply chain digital tools adoption

A number of scholars underline the need for further investigation of the challenges to achieving digital adoption (Raj et al., 2020). Indeed, SC digitalisation is still in its nascent stage; the transformation into an effective digital SC requires specific capabilities and firms need to develop a deep understanding of their current situation. Numerous studies agree that the lack of skilled workflow and training to fit the change is one of the major challenges in digital tools implementation (Büyüközkan and Göçer, 2018; Raj et al., 2020). Türkes et al. (2019) highlight the organisational resistance from employees and middle management levels, and also the lack of expertise.

Table 1 Digital tools and their purpose within SCM

Tool	*Abbreviation*	*Purpose within SCM*	*Authors*
Big data analytics	BD	Have multiple advantages in SCM: reduced operational costs, improved SC agility, and increased customer satisfaction	Ramanathan et al. (2017)
Artificial intelligence (AI)	AI	Consists of technological platforms used to collect, analyse, store and present business data. Supports decision-making by converting raw business data to meaningful and valuable information and insights.	Russell and Norvig (1995)
Machine learning (ML)	ML	Makes it easier to discover patterns in SC data by relying on algorithms that quickly identify the most important factors for the SCM success, while constantly learning and updating the process.	Min (2010)
Augmented/ virtual reality	AR/VR	Could be used to design a layout in a warehouse or a production line and communicate repair instructions through mobile or other remote-control devices.	Merlino and Sproge (2017)
Mobile devices/ wearables	MDW	Wrist bands, smart watches, wearable cameras or smart eye-wears. Offer huge potential for increased SC collaboration. Enable workers to access information and identify tasks, so improve operational efficiencies. Are often used in warehouses (order picking, tracking, and inventory management).	De Assis Dornelles et al. (2022)
Robotic process automation	ROBOT	Is intended to replace a manual process with an automated one and minimise human errors such as amounts, contracts information.	Viale and Zouari (2020)
IoT platforms	IoT	Increase cost-saving, inventory accuracy, product tracking, flexibility. IoT integrates technologies like RFID tags, actuators.	Gunasekaran et al. (2016)
Cloud computing	Cloud	Provides benefits such as on demand access to inventory information, as well as massive scalability in service, payment and privatisation. Companies can use it to share real-time overviews of inventory and sales information resulting in closer integration between channels and more efficient SC and customer analytics.	Salkin et al. (2018) and Ivanov et al. (2022)

Table 1 Digital tools and their purpose within SCM (continued)

Tool	*Abbreviation*	*Purpose within SCM*	*Authors*
Blockchain technology	BCT	BCT contains a single record of the data which is stored by every participant in the SC, so it enforces transparency. BCT enables cutting timeframes in SC financing.	Hughes et al. (2019)
Advanced human-technology interfaces (AHTIs)	AHTI	AHTI serve as gateways between humans and digital tools in several fields including SCM. They are interfaces easily usable by humans that collect and show data collected from other digital tools in real-time.	Zouari et al. (2021)
Advanced smart manufacturing technologies, e.g., 3D printing	SMT	3D printing reduces the steps and materials needed to manufacture small parts, reduces lead time and transportation costs throughout the SC.	Schniederjans (2017)
Location detection technologies, e.g., RFID	LDT	RFID provides real-time information to track the movement of materials. Can be used for product forecasting, inventory and order management, tracking, shipping. Improves SC visibility, customer satisfaction, the timeliness of SC information. Increases profitability by reducing lead-time variability, decreasing labour costs.	Kim et al. (2008)
Collaborative technologies (e.g., ERP, APS, EDI and workflow)	COLLAB	They support information exchanges within business functions and across SC actors.	Romero and Vernadat (2016)
Smart sensor technology	SS	Can be used in manufacturing environments, freight containers to detect miles, miles per gallon, fuel, location, speed, etc.	Schniederjans et al. (2020)
Self-driving vehicles	SDV	Fully automated transportation systems used within the industry and warehouses. It raises productivity by reducing the resources needed for daily tasks.	Büyüközkan and Göçer (2018)

It is also important to highlight that the integration of systems, tools, and methods requires the development of a flexible interface for the synchronisation of different languages, technologies, and such methods can lead to significant challenges in SC digital tools adoption (Büyüközkan and Göçer, 2018; Müller et al., 2018b).

In Table 2, we highlight the various challenges identified from the literature.

2.5 The ambiguous influence of firm size on digitalisation

Prior research on digital tools adoption reveals that 'firm size' is a potential determinant of the adoption process (Frank et al., 2019; Gupta et al., 2020; Li et al., 2020) because firm size influences the quantity of resources available to succeed with digitalisation, e.g.,

technological and financial resources, organisational skills and knowledge and expertise (Ramon-Jeromino et al., 2019; Pan et al., 2019; Buer et al., 2020; Elia et al., 2021). The size may be measured by the number of employees, turnover, total assets, or even market shares.

Table 2 Description of challenges to SC digital tools adoption

	Challenge type	*Definition/impact*	*References*
C1	Lack of planning	Internal capability is a central issue with regard to digitalisation. In order to enhance this, management should focus on building roadmaps and planning strategically to invest in suitable resources.	Raj et al. (2020)
C2	Lack of collaboration	In order to support the adoption of digital tools in the SC, it is necessary that there is collaboration between the players. Some partners in SC work in their own silos, without sufficiently communicating and with significant organisational barriers, digital transformation in these situations can be a struggle. Subsequently, the ability to establish high-quality collaboration and communications on digital platforms brings organisations increased reliability, agility, and efficiency.	Büyüközkan and Göçer (2018) and Zouari et al. (2021)
C3	Lack of knowledge – training and digital skills	Under-qualified employees are considered the second major obstacle to achieving SC digitalisation. With the importance of data, companies need a specific and more qualified workforce. Some companies admit that they do not have the necessary expertise. Thus, improving employee skills is essential to realise the full potential of SC digital tools.	Oesterreich and Teuteberg (2016), Büyüközkan and Göçer (2018) and Raj et al. (2020)
C4	Lack of required flexible and agile SCM	The next generation of SCs must be stronger and more agile. As the implementation of SC digitalisation is a complex process, sometimes, conflicts between workers arise due to rapid changing working environments. This has resulted in rigid organisational configurations, inaccessible data and fragmented relationships with partners.	Müller et al. (2018a)
C5	Lack of integration	The integration of SC digital tools can provide various benefits to SCM, such as a unified and whole view of inventory across the firm, the integration of customer purchase data to offer better and personalised sales and customer services. Lack of integration may hinder SC digital tools' better adoption.	Büyüközkan and Göçer (2018)
C6	A tendency to overestimate the potential gains	The value and productivity gains from digital SC are unclear. The economic benefits of spending on digital tools have always been questioned, particularly for firms which lack financial resources.	Rutaganda et al. (2017) and Raj et al. (2020)

Table 2 Description of challenges to SC digital tools adoption (continued)

	Challenge type	*Definition/impact*	*References*
C7	Lack of organisation and skills in implementing this new information technology tool	The adoption of new digital tools is a complex process. Moreover, it is necessary to adopt several tools simultaneously. As a result, employees and managers may resist the use of new technologies and associated practices. With a strong organisational resistance, there is a need to consider management as an essential function in the digital transformation process.	Rutaganda et al. (2017), Türkeş et al. (2019) and Raj et al. (2020)
C8	Poor quality of data	SC professionals are inundated with data. However, in order to make appropriate management decisions, SC managers should be assured that they have access to accurate or 'good' data. The number of various tools used also makes it difficult to get aggregated and useful data, which in turn may hinder any attempt to go further with SC digital tools adoption.	Chen et al. (2014)
C9	Lack of financial capacities	The lack and shortage of financial resources is a significant challenge. Some companies do not have enough resources to access and effectively use digital tools. Other ones fear not receiving a return on investment, that this investment is not profitable. Observing short-term financial returns after implementation is needed for them.	Kiel et al. (2017), Müller et al. (2018b) and Raj et al. (2020)

The smallest firms lag behind larger ones regarding digital transformation (Mittal et al., 2018) and are ill-prepared for the new technologies' changes (Basl, 2017). Indeed, large firms have more resources to invest in digital tools and are more capable of bearing the high risk associated with this investment. Furthermore, small and medium-sized firms tend to underestimate the time, skills, and effort required to adopt digital technologies (Basl, 2017). Some researchers note that the shortage of financial resources could be a significant obstacle to digitalisation for SMEs (Müller et al., 2018b; Basl, 2017). Lee et al. (2017) highlight that SMEs lack financial resources when implementing radio frequency identification (RFID) as well as for using data from this technology. The authors also remark that a lack of human competency is an obstacle when attempting to implement data mining technologies. In addition, some governments provide financial support for firms wanting to digitalise their processes, but many small firms do not meet the size requirements to benefit from those programs (Gessner and Snodgrass, 2015).

Nevertheless, it should be stressed that SMEs possess certain strengths that are harder for larger firms to reproduce. They usually innovate much faster than established large firms since they have flexible organisational structures (Bouncken et al., 2019). Furthermore, SMEs are recognised as being more open to IT than larger firms and are ready to form alliances when size does not permit the use of technology advancements (Narula, 2001). In addition, depending on the industry, SMEs do not always lag behind: for example, in export activities that require important investment in digital tools for SCM, they show no less adoption of digital tools despite their limited resources (Elia et al., 2021). Another example comes from Buer et al. (2020), who show that 'firm size' does not always have an impact on SC digitalisation. More specifically, in this study, on the one hand, firm size influences the digitalisation of warehouses, but on the other hand,

the size has no impact on the adoption of digital tools that support the SC integration. Buer et al. (2020, p.635) suggest that this result could mean that 'such solutions [for SC integration] have started to become mainstream'. Finally, in their study on the strategic response to digitalisation, Lin et al. (2018) show that firm size and nature do not have any significant impact on the digitalisation of firms, which may sound like a surprising result.

Therefore, we can conclude that both small and large firms have different opportunities (Horváth and Szabó, 2019) and the success or failure of their SC digitalisation is determined by several factors. Overall, the relationships between firm size and digital adoption have been explored in relatively little detail, and the results appear contradictory, because firm size may have various effects on the different aspects of SC digitalisation. Furthermore, few authors have made an empirical examination of the challenges to digital transformation and the effect of firm size remains unclear.

To answer the research questions, we propose two hypotheses:

H1 There is a significant difference between groups of firms of different sizes regarding the adoption of supply chain digital tools.

H2 There is a significant difference between groups of firms of different sizes regarding the challenges to supply chain digitalisation.

3 Research objectives and methodology

3.1 Research objectives

We aim to better understand and analyse which digital tools firms adopt for their supply chain and what the level of adoption is for each of those tools, along with what the various challenges are that firms must face in their digitalisation program and, more importantly, what the impact is of firm size on SC digital tools adoption and challenges to SC digitalisation. Overall, these three steps contribute to answering the research question.

3.2 Data collection and sampling method

We carried out a quantitative study to measure the phenomenon of SC digitalisation through digital tools adoption, challenges to this digitalisation, and the impact of firm size on those two variables. For this purpose, we created an online survey after reviewing the relevant academic literature. We chose Google Forms as a platform as it allowed us to retrieve all the answers on a spreadsheet in chronological order, together with descriptive statistics of the collected data. Prior to any diffusion of the survey, we followed a validity process by pre-testing it on 10 people: two senior SC Managers and eight researchers. This pre-test led us to eliminate one item: AHTI. Indeed, several respondents indicated that they were unsure of identifying which interfaces we were referring to.

The survey is divided into three parts: digital tools adoption (14 tools after the exclusion of AHTI – see Table 1), challenges to digitalisation (nine items – see Table 2), and some general questions such as firm size. All items and tools were chosen following the literature review. In this survey, we are interested in managers' perceptions and representations concerning SC digitalisation within their company.

We collected the data in November 2020. To collect 311 complete and valid questionnaires, 2320 personal emails were sent to various qualified SC managers in

different firms in Europe. No technicians were included in the sample. The set of respondents was selected according to the 'convenience sample' principle which is frequently used in SCM research (De Beuckelaer and Wagner, 2012) despite the potential lack of generalisability. Indeed, all the professionals mobilised are linked to the education programs provided by the university institutions to which the members of our research team belong. The advantages of using a convenience sample are the possibility:

1 to control the quality of the profiles of the potential respondents

2 to ensure there is only one respondent per company.

In addition, this type of survey for collecting data is relevant when there are small firms in the sample (Flynn et al., 2018). The response rate is 13.41%, which is acceptable (Dillman, 2000). We analysed the dataset using IBM SPSS statistics 27.

3.3 Response and common method bias

To achieve a high response rate and avoid non-response bias, we included in the emails the personalised assurance that the results would be sent as soon as they are available (Frohlich, 2002). Furthermore, we assessed non-response bias using the protocol proposed by Rogelberg and Stanton (2007). We evaluated and compared the early 25% of respondents with the last 25% ones. This technique enabled us to detect if any difference existed between their responses. A t-test comparison between these two groups regarding two descriptive variables – the number of employees and company turnover – indicated no significant difference in the responses of early and late participants ($p < 0.05$). These results indicate that common method bias is not an issue for this study.

4 Empirical results

4.1 Brief description of our sample

Regarding firm size, 46.2% of the respondents work in firms of more than 5,000 employees with an international dimension. We should note that, for a study about the impact of firm size, many of the respondents are from large firms. This is because we sought responses from SC vice presidents, directors and managers, profiles mostly found in large firms, as the SCM function is still under the process of development in small firms (Kilpi et al., 2018) and with a low level of SC maturity (Zouari et al., 2021). Nevertheless, our study also includes respondents working for SMEs in their local market (20% of respondents).

More than half of the sample (67.2%) works in the manufacturing industry, the rest mainly working in retail or services (e.g., transportation). In addition, 69.5% of respondents have at least nine-years' experience in an SCM-related field. The respondents work mainly at the managerial level (83.28%), with positions such as vice-president, directors, and managers. Given the extensive corporate experience in SCM, our sample has abundant knowledge of SCM and is in a position to take decisions regarding SC digitalisation projects.

4.2 SC digital tools adoption

In this section, we first depict the means and standard deviation for each item related to digital tools adoption in an SCM context in order to better embrace the current reality of firms; subsequently, we investigate the impact of firm size on adoption.

4.2.1 Digital tools adoption in SCM

This study measures the adoption of 14 digital tools used in the SCM field. Recent studies have frequently focused on several of those digital tools in order to perceive what advantages they could bring to SCM. The overall impression is that digital tools are widely adopted through SCs.

Very recently, some researchers have offered scales to evaluate the adoption degree of digital tools in SCM (Li et al., 2020; Zouari et al., 2021). More precisely, Li et al. (2020) study the implementation of four SC digital tools and evaluate the extent to which firms have implemented digital technologies in their operation by using a seven-point Likert scale. However, they do not explicitly state the meaning of each of the seven points. In contrast, Zouari et al. (2021) propose a measurement scale for digital tools adoption in the field of SCM which includes five levels and the definition of each (see Table 3). We, therefore, adopt this scale for our study. The question we asked is 'please indicate your level of adoption of the following digital technologies/tools to help improve your SCM'. For each tool, respondents scored the adoption level within their firm:

1 not started

2 basic

3 developing

4 intermediate

5 advanced.

Table 3 Measurement scale of digital tools adoption

Adoption level		*Explanation*
1	Not started	We have not considered any use cases yet
2	Basic	We are considering some use cases now, but limited work has been delivered
3	Developing	We are focusing on incremental development and are piloting select use cases and point solutions.
4	Intermediate	We are currently implementing a scale solution and piloting some select others in areas where we see the biggest opportunities.
5	Advanced	We have already tested and scaled a few technologies and are continually piloting use cases spanning all SC functions.

Table 4 shows the adoption levels and ranks the digital tools, from the most adopted to the lowest.

Unsurprisingly, collaborative tools are the most adopted (3.61): they are part of the oldest and best-known tools developed in SCM. Nevertheless, on average participants score them only between (3) and (4), when we might expect a stronger adoption. All the other digital tools are scored lower than (3) and half are even lower than (2). For the less

adopted tools, the standard deviation is also low (around 1), which reflects the strong unanimity of the responses. A surprising answer emerges concerning the low adoption level of AI and ML: 38.9% affirm the development stage of AI is at level (1), 34.1% report the same about ML at a time when academic literature on this topic is strongly increasing (Sharma et al., 2020). Finally, it appears that, overall, the adoption level of almost every digital tool is weak in SCM.

Table 4 Digital tools adoption levels and ranking

Digital tools	*N*	*Mean*	*Standard deviation*	*RANK*
COLLAB	311	3.61	1.252	1
MDW	311	2.85	1.369	2
CLOUD	311	2.75	1.415	3
ROBOT	311	2.52	1.348	4
LDT	311	2.30	1.282	5
BDA	311	2.26	1.175	6
IoT	311	2.14	1.237	7
SS	311	2.02	1.280	8
SMT	311	1.85	1.214	9
ML	311	1.83	1.155	10
BLOCK	311	1.73	1.019	11
AI	311	1.67	1.021	12
SDV	311	1.62	1.100	13
VR	311	1.59	1.018	14

4.2.2 Relationship between firm size and SC digital tools adoption

'Firm size' is frequently considered a variable with an influence over topics related to digitalisation. In this section, we explore in detail the potential link between digital tools adoption and firm size. We separated respondents into three groups depending on their firms' employee numbers. We used the firm size categories defined by the National Institute of Statistics and Economic Studies (INSEE), which collects, analyses, and disseminates information on the French economy and society and is an internationally recognised Institute (Stekelorum et al., 2020). According to this institute, firms that employ fewer than 249 people are defined as small enterprises, those with 250–4,999 employees as medium-sized enterprises, and those with 5000 or more employees as large enterprises. Firm size is a categorical variable, and respondents answered the question 'what is the approximate number of employees in your company?'.

In this study, group 1 (G1) is composed of the largest firms (more than 5,000 employees; 46.2% of the total sample), group 2 (G2) is the average range (250 to 5,000; 33.8%) and group 3 (G3) has the smallest firms (less than 250; 20%).

To test the link between firm size and digital tools adoption, we first ran a factorial analysis (EFA) with all 14 items using maximum-likelihood extraction with varimax rotation (Corner, 2009) in order to avoid the type I errors implied by running a large series of tests (Field, 2017). Consequently, all items were retained with two dimensions.

Every dimension contains elements homogeneously grouped (see Table 5): construct (1) includes operational digital tools and construct (2) modern decision support digital tools.

The EFA explained 55.88% of the variance for a Kaiser-Meyer-Olkin (KMO) of 0.930, which is excellent according to Hutcheson and Sofroniou (1999). We then assessed the reliability of the scale by Cronbach's alpha; Cronbach's α values were above the lower limit of 0.60 (Hair et al., 2017).

Table 5 EFA and reliability analysis for SC digital tools adoption

Digital tools	*Loadings*	*Loadings*	*Cronbach's alpha (α)*
Construct 1: operational tools			0.868
SDV	0.713		
ROBOT	0.704		
SS	0.684		
COLLAB	0.662		
MDW	0.651		
LDT	0.630		
SMT	0.591		
CLOUD	0.587		
Construct 2: modern decision support tools			0.861
AI		0.821	
ML		0.763	
BDA		0.762	
BLOCK		0.673	
VR		0.616	
IoT		0.551	

We then ran Kruskal-Wallis tests as not all our data follow a normal distribution (Landau and Everitt, 2004), which we established after running the Shapiro-Wilk test (Shapiro and Wilk, 1965). The Kruskal-Wallis test is not sensitive to the normal distribution (Landau and Everitt, 2004); this test is a widely used non-parametric technique for testing different samples from the same population (Daniel, 1990). It does not show how the groups differ; it only tells us that they are different in some manner (Chan and Walmsley, 1997). The Kruskal-Wallis tests results are presented in Table 6. They show that firm size influences both constructs of SC digital tools. Thus, H1 is validated.

Table 6 Influence of firm size on digital tools adoption – Kruskall Wallis tests

Independent variable	*Dependant variable*	*Kruskal Wallis H*	*Df*	*Sig.*	*Status*
Firm_size	Construct 1: Operational	26.571	2	0.001	H1 validated
	Construct 2: Decision support	19.455	2	0.000	

As the Kruskal-Wallis tests show a statistically significant difference, we perform a post hoc analysis (Mann-Whitney U tests) to check between which groups there are actually statistically significant differences. At this stage, the Bonferroni correction should be calculated (Field, 2017) to determine the new alpha level. As there are three groups in our

study, the calculation is as follows (Field, 2017): 0.05/ (3*(3 – 1)/ 2) = 0.017. Table 7 provides the results and shows that, regarding the first set of SC digital tools, those that are more operations-oriented, differences between groups exist between G1 vs. G2 and G1 vs. G3. This means that the largest firms are significantly more advanced in their operational digital tool adoption than the medium and small firms. Examining the means of the adoption levels enables us to understand better the differences between groups. Therefore, the operational digital tool adoption means score for G1 is 2.38, G2 = 2.02, and G3 = 1.69. With regards to SC digital tools which are decision support-oriented, here differences between groups exist between G1 vs. G3 and G2 vs. G3. This means that the smallest firms are significantly less advanced in their decision support digital tool adoption than the large and medium firms (decision-support digital tool adoption mean score for G1 = 1.76, G2 = 1.53, G3 = 1.22).

Table 7 Difference between groups regarding firm size influence on digital tools adoption – Mann Whitney tests

Mann Whitney U tests				
Groups	*Construct 1: Operational tools*		*Construct 2: Modern decision support tools*	
	U test	*Sig.*	*U test*	*Sig.*
G1 vs. G2	5,364.500	0.002*	6,000.500	0.063
G1 vs. G3	2,302.000	0.000*	2,573.500	0.000*
G2 vs. G3	2,381.000	0.023	2,231.5000	0.004*

Note: *The value is significant.

4.3 Challenges to digitalisation

In this section, we first detail the means and standard deviation for each item related to challenges to SC digitalisation in order to better understand them, and subsequently investigate the impact of firm size on these.

Table 8 Challenges to SC digitalisation and ranking

Label	*Challenges*	*N*	*Mean*	*Standard deviation*	*Rank*
C5	Lack of integration	311	3.50	1.141	1
C7	Lack of organisation and skills in implementing this new information technology tool	311	3.44	1.173	2
C3	Lack of knowledge – training and skills	311	3.36	1.231	3
C1	Lack of planning	311	3.34	1.252	4
C4	Lack of required flexible and agile SCM	311	3.33	1.219	5
C2	Lack of collaboration between SC partners	311	3.26	1.156	6
C8	Poor quality of data	311	3.24	1.246	7
C6	Tendency to overestimate the potential gains	311	3.16	1.146	8
C9	Lack of financial capacities	311	2.57	1.626	9

4.3.1 Challenges to supply chain digitalisation

We also explore the challenges faced by the respondents and their firms in improving the digitalisation of their SCs. Respondents answered the question 'What factors are limiting your organisation's ability to capture value from existing digital opportunities in the supply chain?' for each item (each of the 9 challenges). They had to score on a Likert scale between (1) totally disagree and (5) total agree. Table 8 shows the scores for each challenge.

Focusing on the TOP 3 challenges to SC digitalisation, it appears that the first is mainly linked to technology and human-technology interplay whereas the two others are more human-process interplay-related.

4.3.2 Relationship between firm size and challenges to supply chain digitalisation

Following the same procedure as the previous one (see Section 4.2.2.), to test the link between firm size and the challenges to supply chain digitalisation, we first ran the factorial analysis (EFA) with all 9 items using maximum-likelihood extraction with varimax rotation. The results show that 8 items were retained within the same dimension (see Table 9) and that C9 shows a very high loading (above 0.9, more precisely 0.925), which justifies its exclusion (Field, 2017). The EFA explained 53.44% of the variance for a KMO of 0.901. The reliability analysis shows Cronbach's α value of 0.871.

Table 9 EFA for challenges to SC digitalisation

Challenges	*Loadings*
C5	0.820
C7	0.790
C3	0.787
C1	0.765
C2	0.764
C4	0.736
C8	0.597
C6	0.541

Then, considering that the Shapiro-Wilk test showed again that the data does not follow a normal distribution, we ran a Kruskal Wallis test. The results are presented in Table 10 and the correlation between firm size and the challenges to SC digitalisation were not statistically significant, which indicates the hypothesis H2 was not supported. Thus, H2 is rejected and there was no need to further investigate by running Mann-Whitney tests. This implies that, regardless of firm size, there is no significant difference in the manner firms experiences the challenges of SC digitalisation.

Table 10 Influence of firm size on challenges to digitalisation – Kruskall Wallis test

Independent variable	*Dependent variable*	*Kruskal Wallis H*	*Df*	*Sig.*	*Status*
Firm_size	*Challenges*	3.434	2	*0.180*	*H2 rejected*

5 Discussion

In this article, we aim to better understand the relationships between firm size and SC digitalisation by examining the adoption level of SC digital tools and the challenges linked to SC digitalisation. The first step in answering the research question concerned the current adoption levels of SC digital tools; results are shown in Table 4. The findings regarding AI and blockchain technology require further discussion, as the descriptive statistics show that these are among the least-adopted SC digital tools. However, Wang et al. (2019) conducted a systematic literature review on blockchain technology applications in SCs and offer a research agenda indicating an ever-growing interest from researchers in this tool. Similarly, Toorajipour et al. (2021) conducted a systematic review of the literature on AI in SCM and show the increasing number of studies on those tools, which are considered the most promising for SCM in the future. Therefore, there appears to be a dissonance with firms' reality and it is necessary to question the validity of these studies if the research does not accompany the experience of firms (Stentoft and Rajkumar, 2018) in the adoption of these digital tools. Beyond operational research highlighting the possible advantages of AI or blockchain technology, (e.g., Liu and Li, 2020) for SCs, qualitative research to better explore the obstacles and remove them in an action research dynamic is also desirable.

Another interesting result related to the adoption level of SC digital tools is based on the factorial analysis of the 14 SC digital tools considered in this study. The statistical analysis shows that two categories emerge based on the level of adoption: the first category contains digital operational tools (i.e., SDV, ROBOT, SS, COLLAB, MDW, LDT, SMT, and CLOUD) and the second the modern decision support digital tools (i.e., AI, ML, BDA, BLOCK, VR, and IoT). An interesting outcome of this research is the discovery of a new form of categorisation of tools, based on the level of adoption, at a time when some researchers aim to propose such typologies (e.g., Ivanov et al., 2019). Examining the two categories, it is clear that in terms of operational digital tools, the largest firms (G1) are significantly more advanced than the others (G2 and G3). However, for the so-called decision-oriented modern digital tools, G1 and G2 show no difference between them, whereas they both differ significantly from G3. However, it is not possible to conclude that G1 and G2 firms are significantly more 'advanced' in their adoption than G3, because referring to them as advanced is not realistic. Whereas G1 and G2 firms show a more advanced adoption of these digital tools than those in G3, the average adoption levels remain very low, and lower than for the category of operational tools. This is an important finding at a time when consultants and researchers are focusing a great deal on tools such as AI, big data analytics, or blockchain: on the ground, the level of adoption remains very low (Brinch et al., 2018) and the need to support firms, regardless of their size, is very important.

In respect of the challenges to SC digitalisation, which is the second step in our research, the findings regarding 'collaboration' (C2) for the whole sample are particularly interesting. Collaboration is always a paradoxical theme for SCM research. Whereas so-called 'collaborative' tools are the most developed (TOP 1), the statistical results indicate that 'lack of collaboration with SC partners' ranked 6th among the nine challenges to digitalisation. This finding is to be considered in the light of pre-existing research. Collaboration in the SCM field is still a common topic. Over the last two decades, thousands of articles have been published, reflecting the considerable interest in

a concept that is difficult to assess empirically (Fawcett et al., 2015). Therefore, research on SC collaboration is still being conducted and frequently with a focus on technology (e.g., Chi et al., 2020). This finding shows the difficulty of simultaneously relying on SC partners when a firm lacks competencies and resources for SC digitalisation and of collaborating with the above-mentioned partners.

Finally, with regard to 'firm size', research has widely highlighted the influence of this variable on digitalisation issues, (e.g., Frank et al., 2019; Gupta et al., 2020; Li et al., 2020), whereas fewer studies have shown that smaller firms also have advantages in the digitalisation race (Narula, 2001; Bouncken et al., 2019). Our research finds results that contradict the mainstream concept that firm size is a key variable to consider when addressing SC digitalisation. The existence, on the one hand, of a dominant research stream that strongly suggests the significant influence of firm size on SC digitalisation in general and, on the other, scientific publications valuing the innovativeness in this field among SMEs or managerial publications showing the difficulties for all kinds of firms faced with digitalisation (Deloitte, 2017), implies a great deal of ambiguity concerning the real influence of firm size. Our results highlight two main findings about the relationships between firm size and the two variables: the adoption level of digital tools and challenges to SC digitalisation. Our results show that firm size has a significant correlation with the level of adoption of digital tools. On the other hand, our findings confirm that there is no significant correlation between firm size and the challenges to SC digitalisation, as indicated by the results of the Kruskal-Wallis test. Therefore, almost all firms, whatever their size, face identical challenges when trying to adopt SC digital tools. This means that the findings do not fully corroborate suggestions in the RBV regarding the importance of resources in succeeding with SC digitalisation (Ramon-Jeronimo et al., 2019; Elia et al., 2021); even the largest firms face challenges and have as much difficulty as smaller ones in meeting them. This result suggests that all kinds of firms currently need to acquire new resources, certainly in the form of knowledge and skills, seek to gain digital maturity, and succeed in their SC digitalisation projects beyond the simple adoption of digital tools (Zouari et al., 2021). Of course, it is natural to anticipate that larger firms will have an easier time acquiring these necessary resources first, just as they were the first to be capable of adopting SC digital tools.

6 Conclusions

The findings discussed above provide several insights for research and practice and open various research avenues.

6.1 Theoretical implications and contributions

In this study, in order to contribute to the line of research on SC digitalisation, we aimed to understand and analyse the relationships between firm size and SC digitalisation, more precisely on the adoption level of SC digital tools and the challenges linked to SC digitalisation. This enabled us to develop a realistic picture of the adoption of SC digital tools and the main challenges faced by firms when they consider digitalising their SC. More importantly, we contribute to the scientific literature by identifying in which respects firm size matters, in order to address the ambiguity stemming from earlier research studies. To do so, we referred to the RBV as a theoretical lens, which enabled us

to understand how firm size and related resources have an ambivalent role in SC digitalisation, which we develop hereafter for a deeper understanding.

The findings show, first, that SC digital tools can be divided into two categories (operational and modern decision-support digital tools) and that the adoption level of SC digital tools is mostly at the 'basic' stage for firms. Notably, AI and blockchain are very commonly studied in SCM research (Wang et al., 2019; Toorajipour et al., 2021), although this does not reflect the reality of all firms. This suggests that researchers should consider how to better address the different realities of firms regarding digitalisation, and, in particular, those of SMEs, which constitute a large part of the global business environment.[2] Second, the findings indicate that almost all the challenges to SC digitalisation were higher than average for the respondents. Having established this, we then provided multivariate analyses to assess the link between firm size and the aforementioned variables. The key finding from this is as follows: firm size does not have a link to every aspect of SC digitalisation, which makes it possible to clarify and provide nuance for some of the previous research statements. If different groups of firms categorised by size show significant differences in their adoption level of SC digital tools, it appears that such variation does not exist for the challenges to SC digitalisation. These contributions provide a better understanding that firm size does not always have the same types of relationships with different aspects of SC digitalisation. This is the main theoretical contribution of this study. Therefore, SC managers and researchers may consider firm size, as a key aspect of the RBV, and which has a direct effect on the resources available, as having an ambivalent role in SC digitalisation.

6.2 Practical implications and contributions

As a first managerial contribution, practitioners should find out more about the opportunities offered by advanced technologies. New digital tools appear every day and companies have an interest in following this progress and taking advantage of it. We believe that digital tools boost firms' creativity and help them capture new market opportunities. Regardless of firm size, digital transformation provides more available data and enhances the efficiency of the process, as well as communication. Barriers to digitalisation are the same for all kinds of firms and may significantly inhibit the level of adoption of SC digital tools. Therefore, managers should understand and mitigate these challenges for successful adoption, which is not possible without the development of a digital culture, greater digital maturity, and more expertise. Given the pressure placed on SC managers by the COVID-19 outbreak, the adoption rate of digital tools is accelerating (Modgil et al., 2022); without enhanced skills, training, and support with working in a digital SC, employees are unlikely to adopt new technologies. As a final contribution, we also urge practitioners to explore further the methods by which they can collaborate with their SC partners to improve their digitalisation and together remove the barriers to it.

6.3 Limitations and further research directions

All research contains limitations that are often opportunities for future research. The limitations of our paper include methodological concerns. First, the sample was composed of 311 qualified respondents from firms with differing characteristics from several industries, but exclusively from European countries. Second, we did not test a

conceptual model requiring the use of more advanced statistical methods. Nevertheless, this was not necessary to examine both the reality of the level of adoption of SC digital tools and the challenges to SC digitalisation faced by firms.

The type of statistical analysis conducted in this study has been proposed due to the descriptive nature of this study. With regard to further research, we are confident that future hypothetical models combining several variables from the SC digitalisation research field through PLS-SEM techniques will consider the potential influence of 'firm size' in a more precise manner. Future research could consider other key factors that may influence the implementation of digital tools in the SC, such as the level of engagement of the organisation in SC digitalisation and its digital maturity, which will make it possible to ascertain whether the companies involved have better control of the barriers encountered.

In addition, in an SC context, it would also be interesting for future research to examine users' perspective on SC tools adoption and acceptance by mobilising the technology acceptance model (Davis et al., 1989) or the unified theory of acceptance and use of technology (Venkatesh et al., 2003).

Despite the limitations presented here, the authors believe that this study provides valuable insights and reveals implications that serve both researchers and practitioners in better understanding relevant issues linked to SC digitalisation.

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Notes

1 For Lin et al. (2018) 'the nature of the company refers to the way how the company is organised'. This variable was measured by the following items: state-owned joint venture, private joint venture, foreign companies, domestic companies, others.

2 See statistics: https://ec.europa.eu/growth/smes/sme-definition_en (accessed 5 November 2021).