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Lean and agile supply chain strategies: the role of mature and emerging information technologies

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Abstract

Purpose – The significant changes that supply chains (SCs) are undergoing and the emergence of disruptive technologies have led to a growing effort to integrate novel and mature technologies into existing SC strategies. Thus, this study investigates the relationships between mature information technologies (ITs), emerging IT and the lean supply chain (LSC) and agile supply chain (ASC) strategies.

Design/methodology/approach – An empirical study based on structural equation modeling of survey data from 256 Spanish focal companies has been conducted to test six hypotheses.

Findings – Drawing on resource orchestration, our results point to mature IT use being an enabler of both LSC and ASC strategy implementation. The results also show an LSC mediating effect on the relationship between mature IT and ASC when SCs follow both strategies. Also, the implementation of emerging IT requires a process of consolidation over time to be genuinely useful as a facilitating mechanism for developing both the lean and agile strategies along the SC. In this sense, a suitable mix needs to be orchestrated between emerging and mature IT.

Originality/value – This study sheds light on the relevance of the mature IT and emerging IT in the context of two SC strategies (lean/agile) and provides practical and theoretical implications.

Keywords Lean supply chain, Agile supply chain, Mature information technology, Emerging information technology

Paper type Research paper

1. Introduction

Lean and agile are two strategies that have evolved from the intra-organizational level to the supply chain (SC) level and have been adopted by SCs to meet challenges such as increasing competition and dynamic customer preferences through the development of lean supply chain (LSC) and agile supply chain (ASC) strategies (Srinivasan *et al.*, 2020). At the same time, the increasing complexity of the business context has led to efforts to integrate lean and agile practices with information technologies (ITs) (Qrunfleh and Tarafdar, 2014).

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Over the years, the growing availability of IT has helped companies to cross corporate boundaries and to extend their SCs internationally (Vanpoucke *et al.*, 2017). IT has a role in supporting and improving customer-supplier relationships through information sharing and supporting key processes, including procurement, sourcing and order fulfillment (Zhang *et al.*, 2016). In this sense, IT is considered an enabler of the deployment of SC strategies (Qrunfleh and Tarafdar, 2014). Indeed, it has been observed that different types of IT classified by their life cycles have influenced SC strategies such as LSC (Núñez-Merino *et al.*, 2020). Nowadays, many lean practices are executed with the support of traditional technologies, for example, e-business web technologies and their use has received considerable academic attention (Núñez-Merino *et al.*, 2020).

However, due to the unprecedented development and adoption of novel IT, SCs are undergoing significant changes (Queiroz *et al.*, 2021). These new types of IT, related to the phenomenon known as Industry 4.0 (Kagermann *et al.*, 2013), are driving the modernization of traditional SCs and transforming them into digital/smart SCs. These IT can support, for example, smart manufacturing and new forms of supplier and customer integration as well as SC strategies (Ghobakhloo, 2018).

Thus, while some IT used in the SC is in the advanced or mature phase of its life cycle, other IT is only just beginning to be adopted in the business environment, which is why it is emerging in nature. In this sense, the role of mature IT might be different from the role that emerging IT would play in the deployment of the lean and agile SC strategies. Emerging IT offers new possibilities for deploying SC capabilities, such as blurring the lines between the physical and digital worlds (Calatayud *et al.*, 2019).

Although the interest in combining IT and lean and agile practices is not new, much of the previous research has a broad-based approach to IT use and does not consider the features of the different types of IT (Oliveira-Dias *et al.*, 2022a). In this regard, given that different bundles of technologies can be positioned at different stages of the life cycle and have very specific features (Frank *et al.*, 2019), it is hard to gain a specific understanding of their impacts with a broad-based approach. In addition, an analysis of the previous research reveals some inconsistencies (Oliveira-Dias *et al.*, 2022b); while some studies suggest that IT can directly facilitate the implementation of lean and/or agile SC strategies, other studies do not find a direct positive association (e.g. Bi *et al.*, 2013; Chiarini and Vagnoni, 2017; Gorane and Kant, 2017). Consequently, there is a need for further research on the impact of specific Industry 4.0 technologies on the implementation of the lean and agile SC strategies (Frederico *et al.*, 2020; Raji *et al.*, 2021). Furthermore, disruptive technologies are becoming more affordable and widespread, which leads to the challenge of combining mature and novel technologies (Kagermann *et al.*, 2013; Maqueira *et al.*, 2019). Nonetheless, theoretical and empirical research on the relationship between both bundles of technologies remains scarce (Maqueira *et al.*, 2019; Oliveira-Dias *et al.*, 2022b). The literature has also highlighted that SCs need to develop both lean and agile strategies (Fadaki *et al.*, 2020). However, how one SC strategy can influence the other also needs further understanding (Calatayud *et al.*, 2019).

Our study aims to fill these gaps by shedding light on the effects that mature IT and emerging IT have on the deployment of LSC and ASC and the relationships between technologies and the two SC strategies. This study is drawn from resource orchestration theory (ROT) (Sirmon *et al.*, 2011) with the aim of understanding how managers identify and deploy mature IT and emerging IT in the context of LSC and ASC strategies. Both of these are critical SC approaches since LSC ensures the optimal productivity of SC processes by eliminating waste, while ASC enables a quick response to changing market requirements by reducing cycle times and increasing delivery capability (Qrunfleh and Tarafdar, 2014; Swafford *et al.*, 2008).

This paper is structured as follows. In the next section, we discuss the theoretical background and hypothesis development. In the third section, we present the research method used in the empirical analysis. Section 4 includes the analysis and results, while Section 5 is dedicated to the discussion and the conclusions of the paper.

2. Theoretical framework and hypothesis development

2.1 Resource orchestration theory (ROT): overview

ROT is an extension of the resource-based view (RBV) (Sirmon *et al.*, 2011). However, while RBV relies on the characteristics (valuable, rare, inimitable and non-substitutable) that resources must have to create a competitive advantage, ROT helps to explain the processes in which competitive advantage is developed (Sirmon *et al.*, 2011).

ROT stresses that the most important factor for building a competitive advantage is the ability of managers to structure a firm's set of resources and bundle them in such a way as to generate synergistic effects (Sirmon *et al.*, 2011). The ROT framework has been used to explain how certain suitably selected and combined resources are shared between organizations to develop capabilities at the firm level, but it can also be extrapolated to the SC level (Ellram *et al.*, 2013; Liu *et al.*, 2016; Rojo *et al.*, 2020a). In this sense, ROT has been used, for example, to develop a theoretical framework to support environmental management in SCs (Wong *et al.*, 2015) and to explain the relationship between IT competence and SC integration (Liu *et al.*, 2016) and the relationship between SC ambidexterity and SC flexibility (Rojo *et al.*, 2020a, b). Accordingly, the focal firm needs to bundle and leverage different resources across the SC to create operational and strategic benefits (Liu *et al.*, 2016).

Based on the above, mature and emerging IT can be seen as enabling resources (Powell and Dent-Micallef, 1997; Yu *et al.*, 2017) and the implementation of LSC and ASC strategies can generate a competitive advantage (Srinivasan *et al.*, 2020; Wamba and Akter, 2019) that stem from the firm's ability to integrate, create and recombine internal and external resources in new ways to improve market responsiveness (Qrunfleh and Tarafdar, 2013).

From this perspective, a ROT background can be useful for understanding how mature IT and emerging IT are related to LSC and ASC implementation.

2.2 Lean and agile supply chain strategies

LSC strategy aims to create a set of organizations that collaborate to reduce cost, inventories and lead time with the implementation of a more effective pull system (Lamming, 1996; Moyano-Fuentes *et al.*, 2019; Reichhart and Holweg, 2007). An LSC strategy is focused on creating a cost-efficient SC by eliminating non-value-adding elements, integrating resources to design well-coordinated processes between SC partners and inculcating continuous improvement throughout the SC (Moyano-Fuentes *et al.*, 2019; Reichhart and Holweg, 2007). However, implementing lean along the SC is a complex and challenging process (Moyano-Fuentes *et al.*, 2021; Tortorella *et al.*, 2017) but when it is correctly deployed, LSC strategy enhances the SC's ability to improve quality, eliminate waste and improve competitiveness (Srinivasan *et al.*, 2020).

For its part, ASC strategy focuses on the ability to respond to uncertain and changing environments (Tarafdar and Qrunfleh, 2017) by dealing with volatile demand by using market knowledge to shorten lead time and exploit opportunities to cope with volatile demand (Christopher, 2000). This strategy employs a "wait-and-see" approach by carrying inventory in a generic form with final assembly only carried out when demand becomes known (Goldsby *et al.*, 2006).

Therefore, LSC and ASC share some common objectives (e.g. to improve SC responsiveness) and there is a common interest in studying and comparing the two strategies (Ghobakhloo and Azar, 2018a; Qrunfleh and Tarafdar, 2013; Raji *et al.*, 2021). Indeed, some previous studies state that lean and agile are reciprocally supportive concepts (Elmoselhy, 2013; Fadaki *et al.*, 2020) and that SCs can pursue both strategies through the adoption of a "Leagile" infrastructure (Fadaki *et al.*, 2020; Mason-Jones *et al.*, 2000; Naim and

Gosling, 2011; Naylor *et al.*, 1999). The article by Mason-Jones *et al.* (2000) discusses whether in some situations the SC should adopt a lean approach before the decoupling point and an agile approach downstream of the decoupling point to enable cost-effectiveness upstream and an agile response in a volatile marketplace downstream. Considering the manufacturing scope, another stream of research states that lean can be considered an antecedent to agile (Ghobakhloo and Azar, 2018b; Narasimhan *et al.*, 2006). Particularly, Inman *et al.* (2011) found that lean practices such as JIT can lead to a higher level of agile manufacturing.

2.3 Mature and emerging information technologies

Different IT sets are available to support firm processes and SC processes. One way to shed light on this diversity and understand the effects of different types of IT is to use a chronological point of view (Núñez-Merino *et al.*, 2020). In this sense, frameworks such as the "Technology Life Cycle" (TLC) (Kim, 2003; Taylor and Taylor, 2012) and the "Gartner Hype Cycle for Emerging Technologies" (Gartner Consulting, 2021) help to explain how technology evolves. The former includes the stages of introduction, growth, maturity and eventual decline of a technology (Taylor and Taylor, 2012), whereas the latter provides an annual forecast of the way that emerging technologies progress through a pattern of overenthusiasm and disillusionment, followed by eventual productivity (Gartner Consulting, 2021).

Mature technologies are those that can be considered to have been widely used and become stabilized in the market (Kim, 2003). Conversely, technologies are recognized as emerging when they first reach the marketplace. Emerging technologies can be defined as technologies that present "radical novelty, relatively fast growth, a certain degree of coherence persisting over time, the potential to exert a considerable impact, and also uncertainty and ambiguity" (Rotolo *et al.*, 2015, p. 1840). In this context, mature IT and emerging IT are resources that play a critical role in competitive advantage when combined with other SC resources and capabilities such as human and management resources (Powell and Dent-Micallef, 1997; Wu *et al.*, 2006).

2.4 Hypotheses

2.4.1 The relationship between mature and emerging information technologies. According to ROT, it is not so much the isolated resources that are important but rather that resources should be aligned with each other, i.e. a good fit (Sirmon *et al.*, 2011). In this sense, the previous research indicates that mature and emerging technologies need to be properly integrated (Maqueira *et al.*, 2019). Research also indicates that the success of an Industry 4.0 transition includes the ability to harmonize and integrate existing (mature) and emerging technologies (Ghobakhloo, 2018; Kagermann *et al.*, 2013).

Furthermore, the implementation and use of mature technologies over several years lead to a superior level of technological maturity and experience (Maqueira *et al.*, 2019). Previous experiences in IT implementation can be embedded into employees' knowledge and skills as well as into organizational routines (Bharadwaj, 2000; Li and Jia, 2018). So, this maturity and technological experience could serve as the basis for implementing newer technologies (Mabad *et al.*, 2021). For example, van Hoek (2019) states that lessons from radio frequency identification (RFID) implementation can benefit blockchain adoption in the SC and also suggests that the two technologies can complement each other, rather than one replacing the other. Following ROT reasoning (Rojo *et al.*, 2020b; Sirmon *et al.*, 2011), managers' prior knowledge of mature IT could make it easier to identify emerging IT that can be jointly deployed with mature IT. In other respects, once the resources represented by mature and emerging IT have been suitably identified and combined, they can be deployed to create new competences. In this sense, the two types of IT are combined; mature IT that is already well-known and whose results have been tested, and the new, not so well-known IT, whose results still have to be determined. This combination generates new competences due to the interrelationship between mature and emerging IT. For example, Tesla Motors, the popular company spearheading electric cars, combines very well-known mature IT in the automotive sector with emerging IT that enables, for example, the vehicle to be self-driving. The outcome of this combination has been the development of new capabilities that have turned the automobile sector on its head with prior knowledge of older technologies enabling the functionalities provided by the new IT to be perceived (Verganti *et al.*, 2020). Therefore, the implementation and use of mature technologies would act as a driver of the adoption of emerging IT. Accordingly, the first hypothesis formulated is

H1. There is a positive relationship between mature IT use and emerging IT use.

2.4.2 Mature and emerging IT and lean supply chain strategy. A fundamental requirement for the implementation of LSC strategy is the efficient coordination and management of physical, information and financial flows along the SC (Vonderembse *et al.*, 2006). The exchange of information needs to be executed efficiently to minimize time spent on routine processes (Núñez-Merino *et al.*, 2020). Therefore, inter-organizational IT plays a significant role in coordination between SC members and reduction of the risk of the bullwhip effect (Zhang *et al.*, 2016). Thus, following ROT, managers already possess accumulated knowledge of the use of mature IT and are aware of its advantages, which enables them to orchestrate these resources (Li and Jia, 2018) to achieve lean capabilities. Many studies have recognized the benefits of using mature IT to support lean practices (Moyano-Fuentes *et al.*, 2012a; Núñez-Merino *et al.*, 2020). Thus, for example, the adoption of Just-in-Time (JIT) principles has been improved with the support of the internet and web-based technologies to improve delivery time and reduce customer waiting time (Missopoulos and Dergiades, 2007). IT has also been used to support the implementation of the electronic Kanban (e-Kanban) to automate production control and inventory flow. These systems enable real-time scheduling and reduce human error rates in the management of physical cards (Ardalan and Diaz, 2012).

So, consistent with this literature and the ROT perspective, the use of mature IT would allow firms to orchestrate both internal and partner resources to support the implementation of the lean strategy along the SC.

Therefore, taking into account the above, we hypothesize,

H2. There is a positive relationship between the use of mature IT and lean supply chain strategy implementation.

The set of emerging technologies generated by the enormous progress in digital technologies is changing the way that products and services are designed and delivered (Ghobakhloo, 2018). In this sense, there are several conceptual studies and some empirical evidence that address the benefits of implementing emerging technologies (Chauhan and Singh, 2020).

More specifically, researchers are beginning to analyze the simultaneous adoption of some emerging technologies and lean practices at both the internal and external levels (Rosin *et al.*, 2020; Tortorella *et al.*, 2019). In this sense, Tortorella *et al.* (2019) found that some emerging manufacturing-related technologies negatively moderate the relationship between specific lean practices and operational performance. This finding could be related to a lack of appropriate integration between these emerging IT and lean practices (Tortorella *et al.*, 2019), which is in line with ROT arguments (Sirmon *et al.*, 2011). Additionally, it is important to bear in mind that due to its nature, emerging IT can create uncertainty and variability (Rotolo *et al.*, 2015) in SC management, which may be not compatible with lean goals, e.g. the reduction of uncertainty and variability (Chavez *et al.*, 2015). In this sense, drawing on ROT, managers have sufficient knowledge of the effect of mature IT on results but the effect of emerging IT is still unknown. So, orchestrating the emerging IT resources will have results that cannot easily be predicted, which creates a major source of variability, whereas, LSC is a practice-based strategy whose tenet is to reduce sources of variability. Therefore, despite the efforts of SC managers to select and deploy emerging IT and bundle them with lean, they could have a damaging effect on lean outcomes until an adjustment occurs and they offer the results sought with their usage. In this sense, emerging technologies at an early stage of adoption would not be able to provide the expected benefits and would, therefore, harm LSC by acting as a new source of variability. Accordingly, we formulate the following hypothesis:

H3. There is a negative relationship between the use of emerging IT and lean supply chain strategy implementation.

2.4.3 Mature and emerging IT and agile supply chain strategy. A prerequisite for the development of ASC strategy is the virtual integration of SC partners (Christopher, 2000) and the use of IT is one of the most important enablers of this (Gligor *et al.*, 2013).

In this sense, according to ROT, supplier and customer resources must be orchestrated by the focal firm to address market changes through information exchange and cooperation (Liu *et al.*, 2016). Competitive advantage based on SC capabilities achieved by companies such as Wal-Mart and Amazon relies on the orchestration of assets and capabilities such as the use of IT to support their ASC strategy (Ellram *et al.*, 2013). For example, with IT support, Wal-Mart was able to work together with its suppliers to be more agile in the replenishment of products, thus reducing out-of-stocks (Vanpoucke *et al.*, 2017). Therefore, the widespread use and consequent greater compatibility of mature technologies can improve the focal firm's capability to share information with its SC partners (Liu *et al.*, 2013). The literature also suggests that IT improves the capability to monitor market changes by facilitating information gathering in real-time (Tarafdar and Qrunfleh, 2017), while simultaneously improving the capability to respond to these changes through faster joint decision-making (DeGroote and Marx, 2013).

Furthermore, mature technologies such as e-business technologies provide a higher degree of automation in the execution of basic SC tasks (Seethamraju, 2014) including sales, distribution and customer order management, thus reducing lead times. In light of the ROT view, it can be argued that using mature IT as a tool can enhance the implementation of the ASC strategy, thus improving the SC's ability to deal with changing markets. In other words, the use of mature IT empowers the strategic coordination of firm and supplier resources to improve agility throughout the SC. So, we posit that mature IT can have a positive impact on the implementation of the ASC strategy.

Therefore, we hypothesize the following:

H4. There is a positive relationship between the use of mature IT and agile supply chain strategy implementation.

As discussed earlier, recent technological advances provide a range of new solutions that can be applied to SCM (Chauhan and Singh, 2020). Since the strategic aim of ASC is to enable a swift response to market changes, studies have highlighted the fact that different types of emerging IT can help achieve agile goals in different ways. For example, additive manufacturing enables rapid prototyping (thus reducing development cycle time) and higher levels of customization (Kurpjuweit *et al.*, 2021). Artificial Intelligence can support systems for agile decision-making and improve demand forecasting and the capacity to accurately predict maintenance (Giannakis and Louis, 2016). Managers who have a good knowledge of these resources and the opportunities that they afford can identify those that are most suitable and orchestrate them to achieve agility in the SC (ROT). There are numerous emerging IT killer applications that provide agility-related capabilities, which means that the most innovative managers can orchestrate these IT to obtain surprising capabilities in the SCs. For example, Deliveroo has disrupted the SCs of many fast-food firms by affording these the capability of immediate delivery through the use of the so-called collaborative economy, with emerging IT such as smartphone apps and GPS tracking enabling riders to make super-fast deliveries.

In general, emerging technologies can trigger the digitization and automatization of SC processes (Queiroz *et al.*, 2021), which will lead to an improvement in mass customization, agility and responsiveness (Chauhan and Singh, 2020). Therefore, due to their greater ability to handle variability and uncertainty, agile SCs are in a better position to take advantage of the benefits that emerging technologies can offer. In this sense, with support from ROT, managers should identify emerging IT that have great potential to support the implementation of the ASC strategy; for example, types of IT that contribute to reducing delivery lead times.

Considering these arguments, the fifth hypothesis is formulated as:

H5. There is a positive relationship between the use of emerging IT and agile supply chain strategy implementation.

2.4.4 The relationship between lean and agile supply chain strategies. LSC and ASC strategies are both needed by a high number of SCs (Moyano-Fuentes *et al.*, 2019) to cope with the challenges of today's highly competitive environment. In reality, purely lean and agile SCs are rarely found in real-world situations (Fadaki *et al.*, 2020; Kisperska-Moron and De Haan, 2011). In this sense, according to ROT, it is important to understand whether one strategy might influence the other and how managers can orchestrate resources in both strategies to create value for customers (Helfat and Winter, 2011; Sirmon *et al.*, 2011).

A conceptual study developed by Carvalho *et al.* (2011) has identified synergies between the two strategies with regard to the increase of information frequency and integration level and the reduction of production and transportation lead times. Recent empirical findings confirm that lean manufacturing and agile manufacturing are complementary paradigms, implying that their joint adoption enhances operational, financial and market business performance (Iqbal *et al.*, 2020). Similar results are found at the SC level, which means that lean and agile approaches are not mutually exclusive (Calatayud *et al.*, 2019). However, while striving for agility may imply leanness, striving for leanness does not necessarily entail agility (Narasimhan *et al.*, 2006). Although it is possible for an SC to adapt its strategy and move from agile to lean (Kisperska-Moron and De Haan, 2011), the opposite (lean to agile) is considered to be the logical path (Hormozi, 2001; Iqbal *et al.*, 2020). In this sense, evidence in the literature points to lean being an antecedent to agile (Abdelilah *et al.*, 2021; Ghobakhloo and Azar, 2018a; Hormozi, 2001; Narasimhan *et al.*, 2006; Sarkis, 2001). More specifically, research has shown that JIT practices have a positive relationship with agile by, for example, promoting a smooth production flow (Abdelilah *et al.*, 2021; Inman *et al.*, 2011). Furthermore, common features of an LSC strategy such as involvement with key suppliers and customers and employee empowerment (Moyano-Fuentes *et al.*, 2021) have been identified as drivers of agility (Ghobakhloo and Azar, 2018a). Additionally, two of the targets of lean operations -delivery speed and reliability-are considered enablers of agility (Soltan and Mostafa, 2015). Research also supports the need for "lean thinking" to achieve agility through the use of minimum manufacturing resources (Vinodh *et al.*, 2009). Indeed, since lean seeks to eliminate different forms of waste, the time saved by eliminating inefficiencies directly increases the agility of SCs (Soltan and Mostafa, 2015). Once an SC has achieved high-level quality systems and eliminated waste, the next step would be to develop new capabilities to master market turbulence. So, previous studies have demonstrated that lean practices can provide a vital basis for building an ASC strategy.

Thus, LSC implementation would facilitate the development of agile practices along the SC through supplier-customer integration and the development of continuous improvement systems.

Based on these arguments, the final hypothesis is formulated:

H6. Lean supply chain strategy implementation is positively associated with agile supply chain strategy implementation.

Figure 1 visually represents the research model based on the theoretical background.

3. Method

3.1 Sample and data collection

To test the proposed research hypotheses, a population of 2,650 Spanish manufacturing firms with ≥50 employees in intermediate positions in their SCs was set as the object of study. The population framework was taken from the Iberian Balance Sheet Analysis System (SABI) database.

A questionnaire with items drawn from the literature was used to gather the data. The initial questionnaire version was pretested by a panel of five international researchers in supply chain management (SCM) (3) and IT (2). As a result, several questions were adapted following the experts' feedback. Furthermore, the pilot research was initially carried out with 5 SC managers to confirm that the survey items were clear and unambiguous. Questionnaires were split into two parts, one for each of the two different functions/respondents (head of IT and head of SCM).

Data collection was carried out by telephone survey using a computer-aided telephone interviewing (CATI) method. This methodology is often employed in studies in the field of SCM (Fredendall *et al.*, 2016; Novais *et al.*, 2020; Rojo *et al.*, 2020a). The CATI method gives interviewers access to an information system that randomly displays the contact details of potential respondents and allows the computerized management of the entire process. CATI enables appointments to be made with respondents to make it easier for interviewees to respond. Responses are saved in real-time (Novais *et al.*, 2020). The interviewers received specific training for the purpose of this research. In addition, a supervisor is always on hand to control the quality of the interviews by randomly listening to surveys conducted by the interviewers. The supervisor can, thus, give more precise instructions to the interviewers if any problems are detected in the interviewees' understanding of any of the questions. Furthermore, during the first day of work, the authors personally supervised the work of the interviewers. The respondents were asked to give responses on behalf of their organization/SC, rather than on a personal level and the anonymity and confidentiality of their responses were guaranteed to reduce social desirability bias (Nath and Agrawal, 2020; Podsakoff *et al.*, 2003). In addition, a web-based version of the questionnaire was sent to the companies that had not

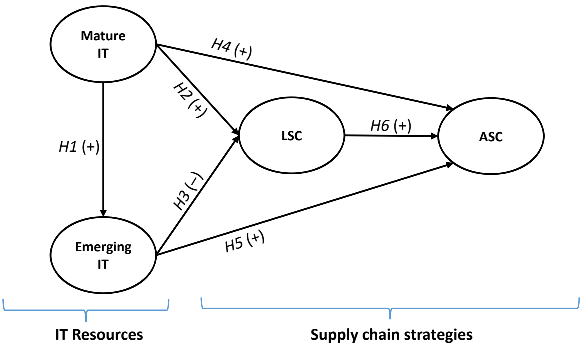


Figure 1.
Research model

completed the whole questionnaire or had not had time to attend to the interviewers to enable the outstanding respondents to answer.

The fieldwork commenced on 30 January 2018 and ended on 20 July 2018. The final sample was 256 companies (9.7% response rate), all of which returned valid questionnaires (total = 256). This figure is similar to the response rates reported in several recent studies in the SCM and IT literature (Qrunfleh and Tarafdar, 2013; Rojo *et al.*, 2016). The sample error was 5.7% (95% CL for $p = q = 0.5$). Table 1 presents details of the population and sample distributions of companies in major categories of Spanish industries (Spanish Standard Industrial Classification–CNAE). Firm distribution across the various sectors was observed to be similar.

No significant differences in distribution by yearly sales were found in the population and the sample. Non-responding companies were also randomly followed up by telephone, which did not identify any specific differences between the characteristics of non-respondents and the main sample. A comparison of respondents and non-respondents established that no evidence of response bias existed.

A comparison of the first 40 and last 40 responses (Armstrong and Overton, 1977) determined that no significant differences ($\alpha = 0.05$) existed for the questionnaire variables, thus ruling out any late response bias. This comparison also allowed us to check and discard the possibility of response bias related to the data collection method since the first 40 responses were obtained by CATI, while the last 40 responses were gathered by web questionnaire. Furthermore, using two managers from each firm as informants reduced the common bias associated with having a single informant. Lastly, we checked for any possible common method bias with Harman's single-factor test (Podsakoff *et al.*, 2003). The test results showed that no single factor explained the majority of the variance in our model (a single factor explained 17.64% of the total variance). This result indicates that the common method bias was not a major issue in this study.

3.2 Variables

LSC strategy is a second-order construct derived from the scale validated by Moyano-Fuentes *et al.* (2019) and Moyano-Fuentes *et al.* (2021). The variables that measure

Sector	Firms in population	%	Firms in sample	%	Response rate
Food products and tobacco	543	20.49%	46	17.97%	8.5%
Chemical and pharmaceutical products	422	15.92%	46	17.97%	10.9%
Manufacture of metal products	322	12.15%	42	16.41%	13.0%
Manufacture of machinery and equipment	275	10.38%	29	11.33%	10.5%
Motor vehicles	273	10.30%	21	8.20%	7.7%
Meat industry	158	5.96%	6	2.34%	3.8%
Electrical machinery and materials	141	5.32%	11	4.30%	7.8%
Manufacture of beverages	106	4.00%	6	2.34%	5.7%
Furniture industry	82	3.09%	7	2.73%	8.5%
Informatics, electronics and optics products	81	3.06%	12	4.69%	14.8%
Manufacture of other transport material	77	2.91%	10	3.91%	13.0%
Shoes and leather	63	2.38%	5	1.95%	7.9%
Other manufacturing industries	60	2.26%	9	3.52%	15.0%
Fabrics and textile	47	1.77%	6	2.34%	12.8%
Total	*2,650*	*100%*	*256*	*100%*	*9.7%*

Table 1. Population and sample distributions

LSC strategy are grouped in three dimensions: (1) tools to eliminate waste in the SC; (2) LSC operationalization and (3) LSC planning (Moyano-Fuentes *et al.*, 2021). ASC strategy is measured using items adapted from previous studies (Gligor *et al.*, 2013; Qi *et al.*, 2011; Tachizawa and Gimenez, 2010). ASC is a first-order construct composed of five items. For LSC and ASC measures, respondents were required to rate their level of agreement with the proposed items on a five-point Likert scale from 1 (totally disagree) to 5 (totally agree).

Mature IT is a second-order construct adapted from the literature (Bruque *et al.*, 2015; Maqueira *et al.*, 2019) and composed of two dimensions: e-business technology and web 2.0 technologies. E-business technology focuses on IT resources adopted by firms to exchange information with suppliers and customers online and measured using items adapted from previous studies (Maqueira *et al.*, 2019; Moyano-Fuentes *et al.*, 2012b). The scale used by Bruque *et al.* (2015) was adopted to measure the use of Web 2.0 technologies. This scale contains a subset of technologies such as blogs, mashups and the use of wikis. Emerging IT use is measured using a first-order construct adapted from the previous literature (Tortorella and Fettermann, 2018). The construct is composed of a set of smart technologies: virtual reality (VR), augmented reality (AR), artificial intelligence (AI) and 3D printing (or additive manufacturing). Informants were requested to indicate the extent of mature IT use on a five-point scale from 1 (never used) to 5 (always used) and the degree of adoption of emerging IT from 1 (not adopted) to 5 (fully adopted).

Appendix presents the items used in the study to measure the aforementioned variables.

4. Analysis and results

4.1 Measurement model

Content validity was ensured by using measures already validated in the previous research and the above-mentioned expert review and pretest of the questionnaire. Unidimensionality of components was verified by applying exploratory factor analysis for each factor (Qrunfleh and Tarafdar, 2013; Srinivasan *et al.*, 2020) (eigenvalues above 1; standardized factor loadings above 0.5; average variance extracted (AVE) above 0.5 for all the extracted factors; high χ^2/df values in the Bartlett sphericity test, which were also considered significant ($p < 0.05$)). Three dimensions were used to measure the LSC construct and two dimensions to measure the mature IT use construct. Reliability assessment was tested using Cronbach's coefficient (Hair *et al.*, 2010). Constructs have Cronbach's alpha values between 0.7 and 0.8 (see Table 2). Table 2 presents the results of the exploratory factor analysis. As observed in Table 2, two items were removed from LSC due to low factor loadings (<0.50). However, since the factor loadings of the retained items were above 0.60 and the Cronbach's alpha values for the research constructs were satisfactory ($\alpha \geq 0.7$) (Nunnally and Bernstein, 1994), the results confirm the consistency and reliability of the constructs (Ahire and Devaraj, 2001).

Divergent or discriminatory validity was tested in accordance with Fornell and Larcker (1981), which involves comparing the square root of the AVE with the correlations between constructs. As Table 3 shows, the square root of the AVE (on the main diagonal) for each construct was greater than the correlations between constructs, which confirmed the discriminant validity of the measurement model. In addition, divergent validity was also assessed through the heterotrait–monotrait (HTMT) ratio of the correlations (Henseler *et al.*, 2015; Voorhees *et al.*, 2016). HTMT was originally established for variance-based structural equation modeling, but it has also been applied in covariance-based structural equation modeling (CB-SEM) studies (Lucianetti *et al.*, 2018; Rojo *et al.*, 2020a). The ratios, displayed in the upper part of Table 3, take values below 0.85, suggesting that adequate discriminant validity exists for all the constructs.

Factor		Variable	Standardized factor loading	AVE		Cronbach's alpha	Bartlett test
Mature IT	Web 2.0	WE1	0.888	0.7	0.7	0.8	χ^2 = 469,575
		WE2	0.845				gl = 15
		WE3	0.686				Sig. = 0.000
	E-business technologies	EB1	0.705	0.6			
		EB2	0.818				
		EB3	0.874				
Emerging IT		ET1	0.904	0.7		0.8	χ^2 = 465.670
		ET2	0.884				gl = 6
		ET3	0.817				Sig. = 0.000
		ET4	0.658				
LSC	Tooling	LS1	0.886	0.7	0.7	0.7	χ^2 = 270.415
		LS2	0.839				gl = 15
	Operationalization	LS3	0.821	0.6			Sig. = 0.000
		LS4	0.768				
		LS5*					
	Planning	LS6	0.684	0.6			
		LS7	0.881				
		LS8*					
ASC		AS1	0.629	0.5		0.8	χ^2 = 369.964
		AS2	0.744				gl = 10
		AS3	0.728				Sig. = 0.000
		AS4	0.792				
		AS5	0.780				

Note(s): Asterisks (*) indicate items discarded after the first exploratory factor and reliability analysis

Table 2. Exploratory factor analysis

Research constructs	Mature IT	Emerging IT	LSC	ASC
Mature IT	*0.8211*	(0.448)	(0.281)	(0.125)
Emerging IT	0.448**	*0.8215*	(0.057)	(0.016)
LSC	0.281**	0.057	*0.8513*	(0.208)
ASC	0.125*	−0.016	0.208**	*0.7368*

Note(s): The square root of the AVE appears on the main diagonal in italics, correlations between constructs on the lower triangular part and HTMT on the upper triangular part. **Significant at 0.01; *Significant at 0.05

Table 3. Correlation matrix and HTMT ratio

Further, EQS 6.4 software was used to carry out a CFA (confirmatory factor analysis). Mardia's multivariate normality test had previously been applied to the data and had demonstrated non-normality. This indicated that the most suitable method to apply was robust maximum likelihood. Finally, a factor model was designed with the 21 observed variables. Table 4 shows the standardized factor loads and R^2 for the variables in the CFA. The measurement model fits the data reasonably well with an RMSEA value of 0.06, a CFI value of 0.86 and an NNFI value of 0.84.

4.2 Structural equation model

The CB-SEM method was used to analyze the data and the proposed relationships. The estimation method applied was robust maximum likelihood, as it is considered the most suitable for non-standard environments (Satorra, 1993). The baseline structural model was developed and the proposed hypotheses were tested with EQS 6.4 software. Key indices of the

Table 4.
Confirmatory factor analysis

Factor	Variable/Factor	Standardized factor loading	R^2
Mature IT	Web 2.0	0.610	0.372
	E-business technologies	0.596	0.355
Web 2.0	WE1	0.855	0.731
	WE2	0.768	0.590
	WE3	0.557	0.310
E-business technologies	EB1	0.523	0.274
	EB2	0.691	0.478
	EB3	0.944	0.891
Emerging IT	ET1	0.866	0.749
	ET2	0.906	0.821
	ET3	0.718	0.515
	ET4	0.516	0.266
LSC	Tooling	0.547	0.299
	Operationalization	0.860	0.740
	Planning	0.859	0.738
Tooling	LS1	0.606	0.368
	LS2	0.877	0.768
Operationalization	LS3	0.592	0.351
	LS4	0.642	0.412
Planning	LS6	0.657	0.431
	LS7	0.526	0.277
ASC	AS1	0.500	0.244
	AS2	0.644	0.414
	AS3	0.677	0.459
	AS4	0.762	0.581
	AS5	0.784	0.468

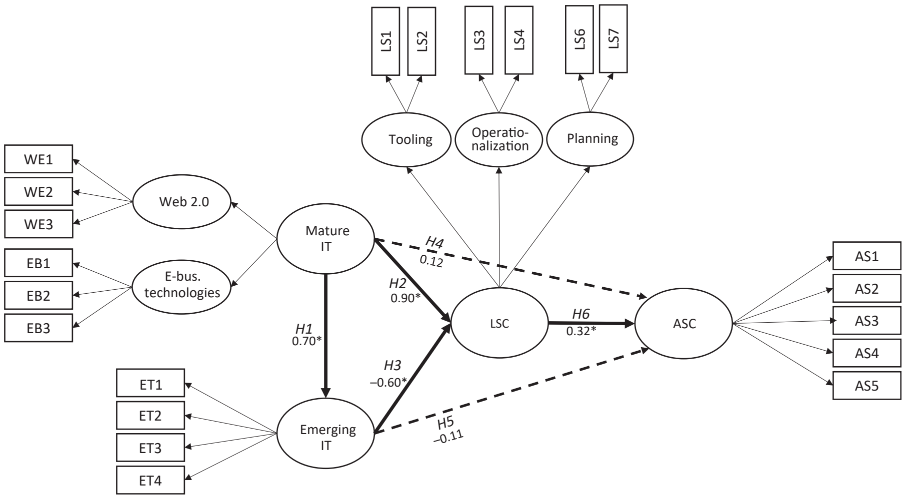
structural model show that the model yields a good overall fit (Satorra, 1993): scaled, Satorra-Bentler, $\chi^2 = 275.1725$, df = 178, χ^2/df = 1.55; RMSEA = 0.046; MFI = 0.827; NFI = 0.815; NNFI = 0.91; CFI = 0.924; IFI = 0.926. Significant relationships were found in H1, H2, H3 and H6 ($p < 0.05$). The strongest support was given to H2 (loading of 0.90), followed by H1 (0.70) and H3 (−0.60). Significant support was also given to H6 (0.32). However, the relationships in H4 and H5 were not supported (see Figure 2 – *baseline structural model*). This result was unexpected as it is not in line with the previous literature, which finds a positive relationship between IT and ASC (e.g. DeGroote and Marx, 2013).

A new model that omitted LSC (Model 1, see Figure 3) was tested to further investigate this unexpected result. The results of the new model (Model 1) showed satisfactory values of goodness of fit (Satorra, 1993): scaled, Satorra-Bentler, $\chi^2 = 135.6163$, df = 85, χ^2/df = 1.595; RMSEA = 0.048; MFI = 0.906; NFI = 0.864; NNFI = 0.930; CFI = 0.943; IFI = 0.944.

The results for Model 1 confirmed that H1 and H4 are supported with significant factor loadings of 0.70 and 0.41, respectively. However, H5 was still not significant. Consequently, according to Model 1, after removing LSC, the mature IT–ASC relationship receives empirical support, while the relationship between emerging IT and ASC remains non-significant.

4.3 Mediation analysis

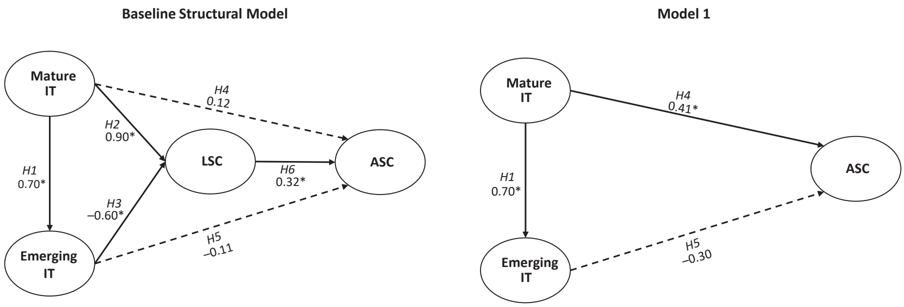
We used a bootstrap method with the SPSS PROCESS macro (v. 4.0) to further investigate whether the LSC strategy mediates the relationship between mature IT and ASC strategy (Hayes, 2013; Preacher and Hayes, 2008). Specifically, to conduct the mediation analysis (model 4 of PROCESS), we used the bootstrapping method based on 5,000 bootstrap samples and computed 95% bias-corrected confidence intervals (Zhao *et al.*, 2010). The analysis



Note(s): *p < 0.05 Model

Source(s): Goodness of fit (Robust statistics)
χ^2: 275.1725 df: 178 S-B χ^2/df: 1.547 CFI: 0.924 IFI: 0.926 MFI: 0.827 RMSEA: 0.046

Figure 2. Baseline structural model and measurement model: results



Note(s): ——→ Supported hypothesis
- - - - → Unsupported hypothesis

Figure 3. Baseline structural model and model 1

results are presented in Table 5. The bootstrapping analysis shows that the indirect effect of mature IT on ASC is significantly positive ($p < 0.05$). In addition, the direct effect of mature IT on ASC is non-significant ($p > 0.05$). According to the results, the mediating effect of LSC in the relationship between mature IT and ASC was statistically significant at $p < 0.05$ with

IV	MV	DV	Effect of IV on MV	Effect of MV on DV	Direct effect	Indirect effect	Total effects	95% CI for mean indirect effect
Mature IT	LSC	ASC	0.2410**	0.0605**	0.0199	0.0146**	0.0345**	0.0041–0.0282

Note(s): IV, independent variable; MV, mediating variable; DV, dependent variable. **Significant at 0.05

Table 5. Mediation effect

95% CI = 0.0041–0.0282, which indicates indirect-only mediation (Zhao *et al.*, 2010), i.e. LSC had a full mediation effect.

5. Discussion and conclusions

Several studies have highlighted the importance of IT for SCM. However, there are many different types of IT and they are positioned at different stages of the life cycle, which makes it hard to gain a general understanding of their impacts. This study sheds some light on the role that mature IT and emerging IT play in the context of two SC strategies (lean/agile). Furthermore, this study follows the Danese *et al.* (2018) recommendation to use promising managerial theories to develop lean research. Accordingly, by adopting a relevant management theory, ROT, our findings help to understand that mature IT and emerging IT have substantially different effects on LSC and ASC implementation. As the previous literature has focused on other issues such as internal vs. external IT (Moyano-Fuentes *et al.*, 2012a; Zhang *et al.*, 2016), our results expand the knowledge of IT's impact on SC strategies.

Our results have shown that there is a relationship between mature IT and emerging IT (H1), which is in line with previous studies (Maqueira *et al.*, 2019). Our findings have also demonstrated that LSC implementation is facilitated by the use of mature IT (H2). This finding supports the mature IT-LSC association (e.g. Núñez-Merino *et al.*, 2020). Conversely, we have found that, rather than aiding LSC implementation, emerging IT could have an adverse effect (H3). This finding confirms our hypothesis that due to its nature, emerging IT acts as a source of variability, which leads to a negative effect on LSC (Chavez *et al.*, 2015; Rotolo *et al.*, 2015). Our results shed light on the importance of managing the inflated expectations for emerging IT. A process of adaptation and adjustment will be necessary for the foreseen results to be obtained. Furthermore, the results show that when both SC strategies are present in the model, the use of mature and emerging IT has no significant effect on ASC (H4, H5). This is contrary to the common belief that IT is one of the main drivers of ASC (e.g. DeGroote and Marx, 2013). On the other hand, in line with previous studies (Ghobakhloo and Azar, 2018b; Vinodh *et al.*, 2009), some support exists for H6, denoting that LSC can be considered an enabler of ASC.

Additionally, when Model 1 is analyzed with LSC omitted due to the unexpected results for H4 and H5, mature IT is verified to have a positive effect on ASC (H4, model 1). This leads us to conclude that LSC (in the baseline structural model) exerts a full mediating effect between mature IT and ASC. In other words, LSC eclipses the impact of mature IT on ASC. Our findings have also demonstrated that LSC is an antecedent of ASC and that the mature IT-LSC relationship (baseline model) is stronger than the mature IT-ASC relationship (model 1). One explanation for these findings could be that mature technologies play a more important role in the deployment of the LSC strategy than the ASC strategy by significantly reducing inventory levels (So and Sun, 2010) and operating costs (Núñez-Merino *et al.*, 2020). In this sense, previous studies on the relationship between mature IT and LSC (Núñez-Merino *et al.*, 2020) and the relationship between LSC and ASC strategies found in our study could explain the fact that an indirect IT-LSC-ASC effect could be more robust than the direct impact of IT on ASC.

Regarding the relationship between emerging IT and ASC strategy implementation (H5), this has continued to be unsupported in Model 1. Even though this is unexpected, given that the previous literature finds a positive relationship between IT and ASC this result is in line with other studies (Swafford *et al.*, 2008) that did not find a direct relationship between IT and SC agility. One interpretation of this result might be that there are many types of emerging IT and the potential that is often attributed to them is not corroborated by their initial use. According to the Gartner Hype Cycle (Gartner Consulting, 2021) much emerging IT goes through a phase of inflated expectations and slides into the trough of disillusionment when these expectations are not met. Numerous types of emerging IT sink without trace in this trough, while others cross it and enter the productivity plateau. In this sense, it might be necessary to individually analyze the behavior of each emerging IT, given their great variability.

5.1 Theoretical implications

At least four major contributions to the literature can be highlighted based on the findings discussed above.

First, studying the relationship between mature IT and emerging IT provides additional evidence for the importance of integrating these different bundles of resources, which could help advance the challenge of the SC digital transition (Ghobakhloo, 2018).

Second, the significant support for the relationship between mature IT and LSC and ASC implementation reinforces IT's role as a resource that enables the deployment of SC strategies. The prior research on the antecedents of LSC and ASC has confirmed the effect of collaboration (Srinivasan *et al.*, 2020) and SC integration (Gorane and Kant, 2017) but the previous results on the direct effect of IT were varied (Sharma *et al.*, 2017). In addition, our study's findings further the understanding of the impact of emerging IT on the deployment of the LSC and ASC strategies. In this line, the findings for H3 corroborate a basic premise of ROT that establishes that the misalignment of resources can lead to negative results (Sirmon *et al.*, 2011). Therefore, an optimal mix has to be found between mature IT and emerging IT to support the LSC strategy. Mature IT should predominate in this mix, otherwise, the adverse effect of emerging IT on LSC management would prevail and cause a loss of leanness.

Third, our work expands the existing knowledge on the association between lean and agile (Ghobakhloo and Azar, 2018b; Srinivasan *et al.*, 2020) by confirming LSC as an antecedent of ASC. Therefore, an appropriate orchestration of resources related to mature IT and the LSC strategy can build the foundations for ASC strategy implementation.

Lastly, our findings underscore the fact that despite the rise in emerging technologies and strong growth in the number of publications on the subject, SCs still need to learn how to leverage and align the use of these emerging technologies with lean and agile SC strategies. In other respects, our results also confirm that the use of mature technologies remains essential for the deployment of the LSC and ASC strategies.

Therefore, the main theoretical contributions of this paper can be summarized as follows:

(1) According to the ROT theory, this paper shows that a suitable mix needs to be orchestrated between mature and emerging IT (with special emphasis on mature IT) to support both the LSC and ASC strategies.

(2) Mature IT and emerging IT play different roles in LSC and ASC implementation.

(3) Previously implementing LSC facilitates the implementation of the ASC strategy.

(4) LSC mediates the relationship between mature IT and ASC.

5.2 Practical implications

The aforementioned theoretical conclusions can also have implications for SC managers. First, SC managers should take into account the company's experience in mature IT use for the adoption of emerging IT. SC managers should also be aware that mature IT enhances LSC implementation and that leanness is a precursor to agility. Notwithstanding, companies that do not apply lean in their SCs can also achieve agility through mature IT. However, neither leanness nor agility is achieved directly with emerging IT and, in the case of SCs where LSC strategy is deployed, the effect of emerging IT on lean goals is negative. This can be explained by the fact that, as brand new technologies, emerging ITs are a further source of variability and so require SC managers to make adjustments during their implementation and follow-up. At the same time, this leads us to conclude that, provided that emerging ITs are correctly monitored and have progressed in line with the maturity process, with the passage of time companies will perceive their expected benefits, which will be compatible with lean/agile management. Therefore, our results indicate that managers should play an active role in orchestrating their IT resources to support the deployment of the LSC and ASC strategies, and mature IT must predominate over emerging IT. Managers should be aware that giving predominance to emerging IT would result in adverse effects and a simultaneous loss of leanness and agility in the first instance.

5.3 Limitations and future studies

These results have been obtained from Spanish companies only. Therefore, further research could be conducted in other countries to confirm these findings. Another limitation is the measures of mature IT and emerging IT. In our study, we measure only a specific range of technologies, while emerging ITs are grouped into one factor. Thus, given the great variability of emerging technologies, to complement our study, further studies could group emerging IT into different dimensions, for example, those considered Industry 4.0 emerging base technologies, those more related to the automation of manufacturing processes, or more oriented toward logistics and analyze their effects on the LSC and ASC strategies. Finally, new studies could shed light on how the relationship and integration of specific mature and emerging technologies could be used to boost the SC digital transformation.

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Appendix
Survey items used in this study

Lean supply chain strategy–Moyano-Fuentes *et al.* (2019)

To what extent do you agree with the following aspects related to LSC? (5-point Likert scale; 1 = totally disagree, 5 = totally agree).

Tools to eliminate waste in the SC:
LS1–Value stream mapping is used to identify and eliminate waste throughout our supply chain.
LS2–Our supply chain uses lean manufacturing techniques (such as pull flow, Kanban systems and setup time reduction).

LSC operationalization:
LS3–Our supply chain generates high stock turnover and minimizes inventory.
LS4–Process and product standardization is a common practice in our supply chain.

LSC planning:
LS6–Our supply chain does long-term forecasting of customer demands serving only the current market segments.
LS7–In our supply chain, the strategy for handling uncertainty consists of using queues and buffers to protect sub-processes.

Agile supply chain strategy–adapted from Gligor *et al.* (2013), Qi *et al.* (2011) and Tachizawa and Gimenez (2010)

To what extent do you agree with the following aspects related to ASC? (5-point Likert scale; 1 = totally disagree, 5 = totally agree).

AS1–Our supply chain can make adjustments to order specifications requested by our customers.
AS2–Production planning has the ability to respond quickly to varying customer needs.
AS3–Our supply chain can increase short-term capacity as needed.
AS4–Our supply chain can adjust/expedite its delivery lead times.
AS5–Our supply chain responds to customer demand.

Mature IT

Web 2.0 technologies–adapted from Bruque et al. *(2015)*
Please indicate the extent to which you use each of the following WEB 2.0 technologies in the supply chain (5-point scale; 1 = never used, 5 = always used).

WE1–Blogs.

WE2–Mashups
WE3–Easily editable collaboration pages (Wikis).

E-business technologies–adapted from Maqueira et al. *(2019) and Moyano-Fuentes* et al. *(2012b)*
Please indicate the extent to which you use each of the following e-business technologies in the supply chain (5-point scale; 1 = never used, 5 = always used).
EB1–We allow customers to check the status of their orders online.
EB2–Access to electronic collaboration (online) with our suppliers on production scheduling and inventory restocking.
EB3–Access to electronic collaboration (online) with our customers on sales forecasting and inventory replenishment.

Emerging IT–adapted from Tortorella and Fettermann (2018)
Please indicate the extent to which each of the following technologies is implemented in the supply chain (5-point scale; 1 = not adopted, 5 = fully adopted).
ET 1–Virtual reality.
ET2–Augmented reality.
ET3–Artificial intelligence.
ET4–3D printing (or additive manufacturing).

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