The data sharing conundrum: revisiting established theory in the age of digital transformation

Giovanna Culot
Polytechnic Department of Engineering and Architecture, University of Udine, Udine, Italy
Guido Orzes
Faculty of Engineering, Free University of Bozen-Bolzano, Bolzano, Italy, and
Marco Sartor and Guido Nassimbeni
Polytechnic Department of Engineering and Architecture, University of Udine, Udine, Italy

Abstract

Purpose – This study aims to analyze the factors that drive or prevent interorganizational data sharing in the context of digital transformation (DT). Data sharing appears as a precondition for companies to capture emerging opportunities in supply chain management and for product-related servitization; however, there are ongoing concerns, and data are often perceived as the "new oil." It is thus important to gain a better understanding of the determinants of firms' decisions.

Design/methodology/approach – The authors develop an embedded case study analysis involving 16 firms within an extended supply network in the automotive industry. The authors focus on the peculiarities of the new context, as opposed to elements highlighted by research prior to the advent of the latest technologies. Abductive reasoning is applied to the theoretical foundations of the resource-based view, resource dependence theory and the complex adaptive systems perspective.

Findings – Data sharing is largely underpinned by factors identified prior to DT, such as data specificity, dependence dynamics and protection mechanisms and the dynamism of the business context. DT, however, can influence the extent of data sharing. New factors concern complementarities whenever data are pooled from different sources and digital platforms, as well as different forms of data ownership protection.

Originality/value – This study stresses that data sharing in the context of DT can be explained through established theoretical lenses, providing the integration of elements accounting for new technological opportunities.

Keywords Case study analysis, Data sharing, Digital transformation, Extended supply network

Paper type Research paper

1. Introduction

When considering the impact of digital transformation (DT), supply chain management (SCM) researchers and industry experts consider end-to-end real-time visibility and autonomous process integration as likely trajectories (Hendriksen, 2023; McKinsey & Company, 2021). The last decade has been characterized by rapid developments in technologies that facilitate interorganizational communication, advanced analytics and automation (Culot *et al.*, 2020a; Frank *et al.*, 2019). Electronic component miniaturization, wireless technologies and direct networking are now allowing the interconnection of processes, machines and products. These trends have spurred ideas of "hyper-connected," "smart" and "self-thinking" supply chains (SCs), which integrate data and decisions across multiple tiers and extend to technology and service providers (e.g. Calatayud *et al.*, 2018; Dolgui and Ivanov, 2022; Hartley and Sawaya, 2019; Pessot *et al.*, 2022).

Amid the excitement for emerging opportunities, some studies have contested the immediate materialization of major disruptions (Klöckner *et al.*, 2022; Sodhi *et al.*, 2022). Expectations may have been inflated by technological breakthroughs that overlook the intricate interplay of technologies with the processes, communication channels and operational principles that characterize SC relationships. Alongside technological advancements, new interorganizational interactions and governance structures are needed (Kache and Seuring, 2017). However, early implementation cases rarely reported substantial changes in ongoing practices (e.g. Cannas *et al.*, 2023; Franzè *et al.*, 2024; Sauer *et al.*, 2022). Moreover, technology adoption has been slower than anticipated, as companies face implementation challenges against existing SC

The current issue and full text archive of this journal is available on Emerald Insight at: **https://www.emerald.com/insight/1359-8546.htm**

Supply Chain Management: An International Journal
29/7 (2024) 1–27
Emerald Publishing Limited [ISSN 1359-8546]
[DOI 10.1108/SCM-07-2023-0362]

Received 25 July 2023
Revised 26 January 2024
15 March 2024
Accepted 16 March 2024

structures and routines (e.g. Cecere, 2022; Hasija and Esper, 2022; McKinsey & Company, 2021). This raises the key question of whether DT is fundamentally altering the functioning of SCs as previously theorized.

Interorganizational data sharing is a central aspect that is crucial for advanced analytics and autonomous decision-making in SCs (e.g. Calatayud *et al.*, 2018; Hendriksen, 2023; Zhou *et al.*, 2022). Although technological opportunities exist (Müller *et al.*, 2020; 2018; Münch *et al.*, 2022), concerns persist about confidentiality, opportunistic behavior and value appropriation dynamics (de Prieëlle *et al.*, 2020; Legenvre and Hameri, 2023; Mathivathanan *et al.*, 2021). These echo past concerns about technologies such as electronic data interchange (EDI) and Web-based solutions (e.g. Fawcett *et al.*, 2007; 2011; Harland *et al.*, 2007; Kembro and Näslund, 2014). To fully understand the impact of DT on SCM, it is thus important to investigate whether previously theorized dynamics still hold true.

The aim of this study is to address the following main research question (RQ): *How are the determinants of interorganizational data sharing changing in the age of DT?* Although the literature has begun exposing the issue as problematic, the factors that drive or prevent firms from sharing data have not been properly clarified. This knowledge gap hinders both researchers and managers from framing challenges and opportunities accurately. Against prospects that are essentially based on the potential of new technologies, it is important to return to the core of SCM. By assessing the fit between established theoretical models and a changing empirical reality, extant knowledge can be leveraged against fashion waves and managerial hypes (Culot *et al.*, 2020a; Hanelt *et al.*, 2021).

As we investigate a long-lived topic, our approach is based on abductive reasoning (Dubois and Gibbert, 2010; Ketokivi, 2006; Ketokivi and Choi, 2014). Unlike the deductive theory-testing approach, this choice prevents us from being bound by pre-formulated hypotheses and allows us to capture novel elements. Further, abductive reasoning is more appropriate than a purely inductive study, as we could leverage prior knowledge to make sense of emerging dynamics without presenting "old wine in new bottles." A review of research prior to DT led to a preliminary framework based on three theoretical lenses: the resource-based view (RBV) (Barney, 1991; Wernerfelt, 1984), resource dependence theory (RDT) (Pfeffer and Salancik, 1978) and the complex adaptive systems (CAS) perspective (Choi *et al.*, 2001). A case study analysis of data sharing practices within an extended supply network allowed us to confront the factors existing before DT with emerging evidence and formulate plausible explanations.

We contribute to the literature by showing that although DT affects the mode and extent of data sharing, extant knowledge can still explain emerging dynamics. Alongside established factors motivating firms' decisions, we also find new elements that refer, for example, to pooling data from different sources for joint analyses, digital platforms and legal setups. We discuss how these elements relate to RBV, RDT and CAS. These findings deepen our understanding of SCs' future beyond speculations on the potential of new digital technologies, aiding managerial decision-making by more clearly highlighting roadblocks and enablers.

2. Literature background

2.1 Factors behind data sharing: established perspectives

Interorganizational relationships always entail some sharing of data, information and knowledge (here, data describe the properties of objects and events, information results from data analysis provide descriptions and explanations, and knowledge refers to the use of information for specific purposes; Ackoff, 1989). The topic has been amply investigated across different research traditions with some kind of ambiguity (e.g. inventory and customer data have been examined in "information sharing" and "knowledge sharing" studies; Colicchia *et al.*, 2019; Fawcett *et al.*, 2007; Gast *et al.*, 2019). For the sake of simplicity, in this overview, we refer only to data as the basic building block of any kind of interorganizational exchange.

In SCM, although buyers and suppliers share data for various purposes – from operational coordination to long-term strategy formulation (Wiengarten *et al.*, 2010) – most of the interest has focused on material flow alignment, following the work of Forrester (1958) (e.g. Fawcett and Magnan, 2002; Kembro and Näslund, 2014). We thus complemented concepts germane to SCM with others originally elaborated on in strategic (e.g. Gulati *et al.*, 2000; Grant, 1996; Grant and Baden-Fuller, 2004) and innovation (e.g. Gast *et al.*, 2019; Lawson *et al.*, 2009) management. It would be beyond the scope of this study to go into these different research streams in detail. The scientific landscape is diverse in terms of the foci and disciplines involved; however, there is a common interest in the factors that motivate firms (not) to share data. To frame the issue in more general terms, we cluster the factors into three overarching dimensions. Three theoretical lenses are used to derive a logical explanation (Kembro *et al.*, 2014).

The first dimension concerns the characteristics of the data. As firms regard data as a resource, the RBV provides a useful anchor. The RBV suggests that firms develop a sustainable competitive advantage if they possess resources that are valuable, rare, inimitable and/or non-substitutable, which should be protected (Barney, 1991; Peteraf, 1993; Wernerfelt, 1984). Since firms do not operate in isolation, resources may originate from interorganizational interactions (Dyer and Singh, 1998; Lavie, 2006). In general, RBV predicts that firms retain data that generate private benefits, whereas they share those that enable superior interorganizational processes (Bergh *et al.*, 2019; Fawcett *et al.*, 2011; Hernández-Espallardo *et al.*, 2010). Based on the literature, two main characteristics motivate sharing decisions:

1. *core-relatedness*, namely, whether the data reveal a firm's competitive advantage in its core business (Barthélemy and Quélin, 2006). Sharing is less likely with respect to customer details, production and innovation processes, sales and operational costs (Ritala *et al.*, 2015; Soekijad and Andriessen, 2003); and
2. *fungibility*, which describes possible different use occasions (Choudhury and Sampler, 1997; Sampler, 1998). Business partners' self-interest can lead to opportunistic behaviors on shared data (e.g. buyers might lose volume discounts after disclosing their demand patterns – Klein and Rai, 2009; business partners might improperly take advantage of shared data for private innovation – Estrada *et al.*, 2016; Yigitbasioglu, 2010).

The second dimension describes the characteristics of the dyadic relationship between business partners. Relevant factors are examined through the RDT (Aldrich and Pfeffer, 1976; Mindlin and Aldrich, 1975; Pfeffer and Salancik, 1978). The basic idea is that patterns of dependence originate as organizations engage in exchanges to obtain resources (Davis and Cobb, 2010; Hillman *et al.*, 2009; Wry *et al.*, 2013). The level of dependence depends on the criticality of the resource and the availability of alternatives. Based on the RDT, partners' motivations can be grouped into five factors:

1 the *need for complementary resources*, as data might not represent a resource *per se* but only in conjunction with other assets and capabilities that reside within firms and other organizations (Im and Rai, 2008; Lawson *et al.*, 2009);
2 *level of dependence,* which is defined as the sum of the dependence between actors. The high stake of maintaining a smooth relationship prompts a stronger relational orientation and joint action (Lu and Shang, 2017; Gulati and Sytch, 2007). Thus, firms are more interested in broadening the scope of data sharing (e.g. Larson, 1992; Zaheer and Trkman, 2017);
3 *dependence asymmetry*, that is, the difference in actors' dependencies on each other (Gulati and Sytch, 2007; Wry *et al.*, 2013). An example is the case of a supplier that generates most of the revenue with a specific customer. More powerful business partners can exert influence (e.g. Bouncken and Kraus, 2013; Goodhue *et al.*, 1992; Yang *et al.*, 2017);
4 *protection mechanisms*, which are part of the tactics that firms use to manage relationships (Pfeffer and Salancik, 1978). These encompass clauses that regulate the ownership, allocation and use of data (e.g. Gast *et al.*, 2019). Formal mechanisms include contracts, intellectual property rights and information security norms; informal mechanisms are routines and processes (Estrada *et al.*, 2016; Ritala and Hurmelinna-Laukkanen, 2013; Salvetat *et al.*, 2013); and
5 *benefit distribution mechanisms*, namely, the upfront definition of the gains from sharing. This factor is relevant for both operational efficiency (Ganesh *et al.*, 2013) and innovation (Ahuja *et al.*, 2013; Sun and Zhai, 2018).

The last dimension concerns network-level dynamics. Interorganizational practices are embedded in the broader network of interfirm relationships and the external environment (Choi and Kim, 2008; Kembro *et al.*, 2017). Factors related to this dimension can be analyzed through the CAS approach (Choi *et al.*, 2001; Holland, 1995). CAS builds on general system theory, defining systems as groups of autonomous agents that are characterized by a common purpose, function as a whole and adapt to external changes (Katz and Kahn, 1978; Mele *et al.*, 2010). CAS allows a simultaneous focus on the network as-is, external influences and coevolutionary trajectories. From the literature, we identified the following factors in this dimension:

- *network governance structure*, which refers to how the firms involved in the network coordinate their actions (Gulati *et al.*, 2012). For example, smaller suppliers that provide complex products to large buyers are typically supported and controlled; thus, exchanges are more intense (Gereffi *et al.*, 2005). The opposite is true for turn-key suppliers (*ibid.*). Overall, multi-tier flows depend on the responsibilities assigned to each party (Mena *et al.*, 2013);
- *environmental complexity and dynamism* describe the business, geopolitical, legal and technological landscape. The more complex and dynamic the environment is, the more firms seek data in support of their decisions (Srinivasan and Swink, 2018); and
- *assimilation of technological/communication standards*, that is, the spread of technical specifications allowing exchanges between information systems (Sodero *et al.*, 2013). The lack of standards has been highlighted as one of the key barriers to systems such as EDI (Frohlich, 2002; Hart and Saunders, 1997; Narasimhan and Kim, 2001). Their origins and diffusion are related to the actions of a few dominant firms that generate coevolutionary patterns (Zhao *et al.*, 2007; Zhu *et al.*, 2006).

Figure 1 summarizes the dimensions and factors outlined above, including key references.

2.2 Digital transformation and data sharing

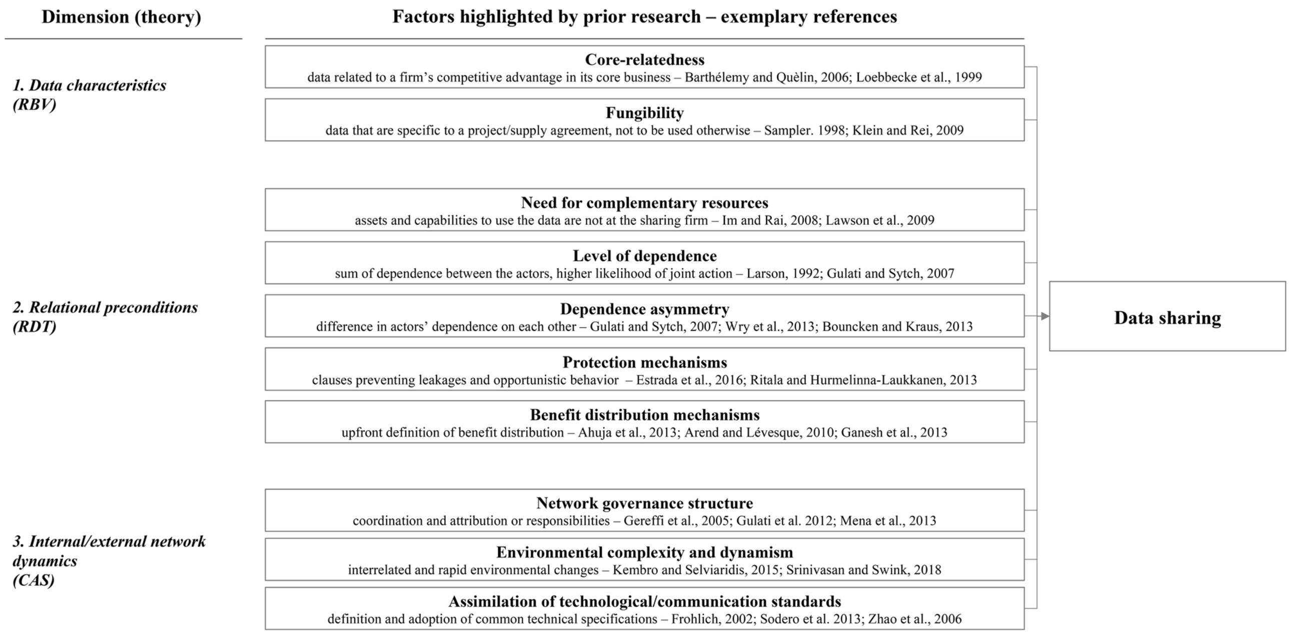
DT is defined as "[...] organizational change that is triggered and shaped by the widespread diffusion of digital technologies" (Hanelt *et al.*, 2021, p. 1160). These include "[...] the combination and connectivity of innumerable, dispersed information, communication and computing technologies" (ibid.). Similar concepts include Industry 4.0 and the idea of a new industrial revolution (Frank *et al.*, 2019). Timewise, there is no clear-cut date marking its beginning. The technologies underpinning the phenomenon have been around for a long time, even though they are not mature for industrial applications (OECD, 2017). Conventionally, the early 2010s are regarded as the start years due to an acceleration in development, falling costs and industrial policies fostering technology adoption (Culot *et al.*, 2020a).

The list of possible front-end applications now available for firms is extensive. On their basis, few enabling technologies are combined for specific purposes (Battaglia *et al.*, 2023; Frank *et al.*, 2019). In SCM, the most relevant ones are those related to connectivity, data-driven decision-making and automation (Calatayud *et al.*, 2018; Dolgui and Ivanov, 2022). These include cloud computing (i.e. hardware and software computing services delivered on-demand through the network; Marston *et al.*, 2011), cyber-physical systems and the Internet of Things (i.e. sensors and connectivity applied to products and machines; Lee and Lee, 2015), blockchain technology (i.e. distributed, immutable and encrypted transactional databases; Babich and Hilary, 2020) and advanced data processing techniques based on artificial intelligence, machine learning and big data analytics (Hendriksen, 2023; Waller and Fawcett, 2013).

These technologies mark a step change in how data can flow and be used across organizational boundaries (Culot *et al.*, 2020a; Paolucci *et al.*, 2021). On the one hand, sensor-generated data can be accessed beyond the ownership of the physical asset (Kiel *et al.*, 2017; Münch *et al.*, 2022). For example, machines can connect with industrial technology providers for smart maintenance and optimization services (Cannas *et al.*, 2023; Cepa, 2021; Dalenogare *et al.*, 2022). Similarly, data from connected products can be analyzed by manufacturers to improve their design (Franzè *et al.*, 2024) and activate services (Chen *et al.*, 2021; Holmström *et al.*, 2019). On the other hand, information systems can be more easily integrated so that data are shared vertically across the different levels and functions of the same firm, as well as horizontally between firms (Müller at al., 2020; 2018). This

Supply Chain Management: An International Journal
Volume 29 · Number 7 · 2024 · 1–27

Figure 1 Conceptual framework: dimensions and factors determining data sharing prior to DT



Source: Author's own creation

potentially allows real-time multi-tier visibility, enabling predictive analyses and autonomous configurations (e.g. Calatayud *et al.*, 2018; Dolgui and Ivanov, 2022).

Although the literature describes some successful implementation cases (e.g. Cannas *et al.*, 2023; Sauer *et al.*, 2022), there is evidence of ongoing challenges connected to interorganizational data sharing (Legenvre and Hameri, 2023; McKinsey & Company, 2021; OECD, 2019; WEF, 2020). These prevent technology diffusion and lead to suboptimal utilization (Kouhizadeh *et al.*, 2021; Sodhi *et al.*, 2022). Some sparse arguments have emerged in the current research, resonating with the dynamics discussed prior to the advent of new digital technologies (e.g. Bechtsis *et al.*, 2021; Kache and Seuring, 2017; Ye *et al.*, 2022). Given the potentially disruptive impact of DT, these factors should be further explored. To this end, we detail the main RQ (i.e. *How are the determinants of interorganizational data sharing changing in the age of DT*) into three specific research questions (sRQs):

sRQ1. What characteristics of the data are (not) shared in the context of DT?

sRQ2. What are the relational preconditions of data sharing in the context of DT?

sRQ3. What network-level dynamics affect data sharing in the context of DT?

3. Methodology

Case research was selected because it offered the opportunity to investigate data sharing within the context of DT in depth and with latitude (Eriksson and Kovalainen, 2008). As our study started from an already theorized landscape, the approach was based on abductive reasoning (Ketokivi and Choi, 2014). Case research is apt for theoretical elaboration in SCM, as it allows the gaining of a comprehensive understanding of complex phenomena in the real world, which is important in investigating *how* questions (Meredith, 1998; Yin, 2018). Moreover, faced with the relative novelty of DT and the hype around emerging technologies (Sodhi *et al.*, 2022), a qualitative empirical approach was appropriate for developing broad and nuanced explanations (Voss *et al.*, 2002).

Under this premise, we investigated data sharing within an extended supply network, defined as the set of multi-tier linkages related to the flow of goods, technology and service provision (Carter *et al.*, 2015). Consistent with this empirical setting, we developed a single embedded case study analysis that involved 16 firm subcases (Yin, 2018). This choice is in line with the methodological recommendations of Dubois and Gadde (2002) and Halinen and Törnroos (2005), as interorganizational practices need a common frame to control for extraneous variables.

3.1 Case selection and sampling

The unit of observation was an extended supply network in the automotive industry. Previous research has broadly investigated the sector (e.g. Iskandar *et al.*, 2001; Lockström *et al.*, 2010); thus, the practices prior to new technologies in the industry remain largely known. Moreover, the extended supply networks in the automotive industry are deeply affected by DT. On the one hand, product connectivity is becoming a standard in the industry (i.e. the "connected car") (Bohnsack *et al.*, 2021). On the other hand, the automotive industry has rapidly adopted new digital technologies in operations and SCM, ranking among the first industries for investment size (Kamble *et al.*, 2020). DT is already considered the norm among original equipment manufacturers (OEMs), whereas suppliers are under pressure to upgrade their capabilities (Arcidiacono *et al.*, 2022; Franzè *et al.*, 2024).

In designing our study, we acknowledged the presence of large first-tier suppliers serving multiple OEMs, usually on a continental basis (Huang *et al.*, 2020; Mohamad and Songthaveephol, 2020). We thus adopted a stratified approach to account for the tiered structure and selected firms headquartered in Europe (Patton, 2002). Europe houses some of the largest and most renowned players (Arcidiacono *et al.*, 2022) while being quite advanced on DT due to policy action (Culot *et al.*, 2020a).

We started with OEMs and their primary interfaces. This led to the identification of an initial sample of 11 subcases. The preliminary analysis highlighted the need to consider other actors (Halinen and Törnroos, 2005). Two industrial technology providers and three digital technology providers were included.

3.2 Data collection

A case study protocol (see the Appendix) including semi-structured interview questions was developed and refined through three pilot interviews. Consistent with the aims of the study, the interviews were meant to gather information about technology-enabled data sharing practices that refer to the last wave of digitalization (i.e. since the early 2010s, which are conventionally assumed as the onset of the phenomenon). The questions specified data sharing practices along the SC (i.e. with buyers and suppliers) as well as with technology providers. To better understand the factors driving or preventing such practices, we asked about the motivations (not) to pursue them as well as relevant enabling factors. Data collection started in autumn 2020 and continued into the first months of 2022. Given the broad scope of data sharing, we looked for executives with expertise in SCM or purchasing; production or logistics; DT or information systems (e.g. information and communication technologies [ICT] director, chief information officer [CIO]); research and development [R&D], innovation or connected vehicles; general management (e.g. chief executive officer [CEO]); project management [PM]; or customer-facing roles. The informants were selected based on their job titles and seniorities. They were identified within the contacts of the researchers and their institutions and by searching the Web and professional social networks (i.e. LinkedIn). Their expertise was verified through preliminary conversations. The informants were asked to share further contacts within their firms. A total of 32 informants were involved. Each interview lasted between 50 and 150 min, and the respondents disclosed specific dashboards on their information systems. All interviews were recorded, fully transcribed and stored in a database, which also included Appendix. Although for some companies, we could not find respondents for all areas, the abundance and variety of material allowed triangulation. Table 1 presents an overview of the subcase companies and informants. The companies are referred to by generic monikers.

3.3 Data analysis

The materials were analyzed through open coding to identify key terms and concepts (Miles and Huberman, 1994). NVivo software was used to simplify the association of categories and text passages, their storage and retrieval. Consistent with the aims of the study, we focused on data sharing enabled by new digital technologies. Pre-existing technologies were considered if complemented by new ones (e.g. supplier portals enhanced by cloud computing).

With respect to the interview protocol, the data were analyzed as follows. The first section concerned the company background, existing interorganizational relationships and the role of the respondent. Together with information from secondary sources, this was used to clarify the contextual conditions surrounding the phenomenon of interest. The second section supported the identification of technology-enabled data sharing practices that were pursued or dismissed by the firm. The data were analyzed inductively to cluster emerging practices based on DT opportunities, area and purpose, flow and assimilation level. Publicly available material was also examined. The results are presented in subsection 4.1. The third and fourth sections of the protocol were meant to gain insights into the motivations (i.e. drivers and barriers) underlying the firm's pursuit or dismissal of such practices. We also asked about the implementation challenges that arose during the process. The arguments were analyzed for consistency with the factors already expounded in prior literature. The results are presented in subsection 4.2. The interview protocol included additional questions on the firm's performance and supply network configuration to better understand the breadth and depth of the data sharing practices.

The results of the coding process were examined by all involved researchers. Any issue was solved through discussion. The presence of multiple companies in each category enabled a pattern-matching logic. Following an abductive approach (Ketokivi, 2006), the factors behind data sharing were compared with those derived from the literature (Figure 1). The plausibility of theoretical explanations was carefully addressed through multiple rounds of discussion.

3.4 Validity and reliability

To ensure rigor in the development of the analysis, we adopted several approaches (Gibbert and Ruigrok, 2010). In terms of construct validity, we triangulated data sources, explicitly indicated the collection and analysis procedures and involved colleagues in reviewing our analysis. Internal validity (i.e. "logical validity"; Yin, 2018) was ensured by deriving the research framework from the literature as well as through pattern matching, both comparing responses of different firms and the outcomes of previous studies (Eisenhardt, 1989b). External validity was pursued by matching empirical observations with theory (Yin, 2018). Finally, reliability was met using a case study protocol, recording and transcribing all interviews, setting up a case study database and involving multiple coders (Silverman, 2005).

4. Findings

4.1 Data sharing practices in the context of digital transformation

Several data sharing practices related to DT were undertaken within the automotive extended supply network. These are summarized in Table 2and illustrated in the following paragraphs to contextualize the findings of the sRQs.Three overarching categories of data sharing practices emerge: **process connectivity**,

Supply Chain Management: An International Journal
Volume 29 · Number 7 · 2024 · 1–27

Table 1 Case companies and informants

Category	Company and description	Informants	Expertise: SC or purchasing	Production or logistics	Digital transf. or information systems	R&D, innovation or connected vehicle	Project management or customer facing
OEMs	**Commercial OEM** Design, production and sale of commercial vehicles (buses, trucks and special vehicles) *Revenue: $25bn–$30bn*	Head of Digital Transformation – global	x	x	x	x	x
		Head of Industry 4.0 – global	x	x	x	x	
		Head of Connected Vehicles – global					
	Premium OEM 1 Design, production and sale of premium motor vehicles (only in the consumer segment) *Revenue: $50bn–$75bn*	Head of Supply Chain – plant	x	x	x	x	x
		Head of Production – plant					
		Project Manager – global					
		Director of Connected Vehicles – global					
	Premium OEM 2 Design, production and sale of premium motor vehicles (both consumer and commercial segments) *Revenue: $150bn–$175bn*	Head of Innovation – global	x	x	x	x	
		Head of Industry 4.0 – plant			x		
	Mass market OEM Design, production and sale of mass market motor vehicles (mostly in the consumer segment) *Revenue: $100bn–$125bn*	Production manager – plant		x			
	Luxury sports OEM Design, production and sale of luxury sports cars *Revenue: $1bn–$2bn*	Head of Connected Vehicles –global			x	x	
First-tier suppliers	**Supplier 1** Design, production and sale of powertrain, climate and lighting and car interiors systems and components *Revenue: $10bn–$15bn*	Supply Chain Manager – global	x	x	x	x	
		ICT Director – global/plant	x		x		
		Head of R&D – business unit					
		Head of Logistics – plant					
		Head of Purchasing – plant					
	Supplier 2 Design, production and sale of powertrain, steering, breaking and battery systems and components; production of sensors for connected vehicles and provision of related digitals services *Revenue: $75bn–$100bn*	Managing Director – plant	x	x	x	x	x
		Head of Production – plant			x		
		ICT Director – plant					
		Head of R&D – business unit					
	Supplier 3 Design, production and sale of powertrain and chassis systems and components. *Revenue: $10bn–$15bn*	Head of Purchasing – global	x		x		
Dealers	**Importer** Import of vehicles from other European country	Marketing Manager					x
	Dealer 1 Multi-brand large regional dealer	Marketing Manager					x
	Dealer 2 Multi-brand large regional dealer	Marketing Manager			x		x
		CIO					
Industrial equipment manufacturers	**Metal equipment** Design, production and sale of equipment and plants for the metal industry; business unit	General Manager – business unit			x		x
		Head of Project Management – business unit			x		x
		CIO – global			x		

(*continued*)

Supply Chain Management: An International Journal
Volume 29 · Number 7 · 2024 · 1–27

Table 1

Category	Company and description	Informants	Expertise: SC or purchasing	Expertise: Production or logistics	Expertise: Digital transf. or information systems	Expertise: R&D, innovation or connected vehicle	Expertise: Project management or customer facing
	dedicated to automation and digitalization *Revenue: $2bn–$3bn*						
	Plastic equipment Design, production and sale of equipment for injection molding of plastic materials *Revenue: $0.5bn*	CIO – global			x		
Digital solution providers	**SC platform** Provision of services for inventory/flow optimization	Founder and CEO	x		x		x
	Software corporation Provision of software systems for various business objectives, including SC, collaborative NPD *Revenue: $4bn–$6bn*	Chief Marketing Officer – country			x		x
	System integrator Digital system integrator specialized in manufacturing	Founder and CEO			x		x

Source: Author's own creation

Table 2 Data sharing practices within the automotive extended supply network in the context of DT

DT-enabled data sharing	Area and main purpose	[Alphanumeric code] Flow	Assimilation level	Illustrative quotes	Sources
[A] Process connectivity	**Production planning** Synchronize production activities along the SC	[A1] Focal firms share production planning, work-in-progress and inventory data with suppliers	Very high – data were shared by all OEMs and first-tier suppliers	*Thanks to the cloud, we open specific portions of our ERP to share with suppliers how much we have in-house* – Supplier 2, Production Manager	Commercial OEM; Premium OEM 1; Premium OEM 2; Mass market OEM; Supplier 1; Supplier 2; Supplier 3
		[A2] Suppliers share production planning, work-in-progress and inventory data with focal firms	Low – Premium OEM 2 and Supplier 3 piloted/completed some projects	*We implemented upstream system integration thanks to a supplier transparency project. We see where our parts are at suppliers* – Premium OEM 2, Head of Industry 4.0	Premium OEM 1; Premium OEM 2; Mass market OEM; Supplier 2; Supplier 3
		[A3] Both focal firms and suppliers share production planning, work-in-progress and inventory data through a digital platform	Very low – Supplier 1 launched a pilot; Commercial OEM, Supplier 2 and Supplier 3 evaluated it	*«he platform acts as a trusted third party accessing the ERPs of multi-tier players. We use artificial intelligence to calculate optimal inventory* – SC platform, Founder and CEO	Commercial OEM; Supplier 1; Supplier 2; Supplier 3; SC platform; Software corporation
	Logistics Reduce errors/delays in deliveries	[A4] Focal firms share detailed delivery request data with suppliers and logistic service providers	Very high – data were shared by all OEMs and first-tier suppliers	*We share to both the supplier and the forwarder the exact quantity that needs to be shipped to minimize errors* – Supplier 3, Head of Purchasing	Commercial OEM; Premium OEM 1; Premium OEM 2; Mass market OEM; Supplier 1; Supplier 2; Supplier 3
	Synchronize production scheduling with inbound flows	[A5] Suppliers and logistic service providers share delivery status data with focal firms	Very high – all OEMs and first-tier suppliers had access to data (often through providers' systems)	*As the material leaves the supplier premises, we know the exact quantity, the license plate of the truck, and the expected time of arrival* – Premium OEM 1, Head of Supply Chain	Commercial OEM; Premium OEM 1; Premium OEM 2; Mass market OEM; Supplier 1; Supplier 2; Supplier 3
	Reduce logistic costs	[A6] Focal firms share bulk data to logistic service providers	Very low – Supplier 1 shared data with one global provider	*They* [service provider] *have tools for logistics optimization, so that by interconnecting our systems we have the best solution* – Diversified supplier, Supply Chain Manager	Supplier 1
	Traceability Enable control and issue resolution along the SC	[A7] Suppliers share product/process traceability data	Very low – Supplier 1 and Premium OEM 1 started a project; some industry-wide initiatives	*We are piloting a blockchain-enabled traceability project with* [OEM name]. *It is basically oriented to facilitate product recalls* – Supplier 1, ICT Director	Commercial OEM; Premium OEM 1; Premium OEM 2; Mass market OEM; Supplier 1
	New product development Enable coordination and monitoring	[A8] Focal firms share data, methods and tools related to new product development with suppliers/external designers	Low – industrial technology providers shared data and methods with external design centers	*We are piloting a blockchain-enabled traceability project with* [OEM name]. *It is basically oriented to facilitate product recalls* – Supplier 1, ICT Director	Plastic equipment
		[A9] Suppliers share simulation parameters, input and results related to new product development with the focal firm	High – all first-tier suppliers shared data with OEMs	*OEMs require to share more about our analyses, such as input data, simulation parameters, and results; they don't trust the results based on our specific expertise* – Supplier 1, Head of R&D	Supplier 1; Supplier 2
[B] Asset/equipment connectivity	**Logistics** Synchronize inbound flows with actual production progress	[B1] Focal firms share data on the progress of individual products along the assembly line	High – data from assembly lines were shared by all companies pursuing just-in-time/just-in-sequence models	*Inbound logistics have long been outsourced, so we have always been sharing the sequence of production within our supplier park. Now this is happening in real time. Over the last few years, we have been integrating information systems* – Mass market OEM, Production Manager	Commercial OEM; Premium OEM 1; Premium OEM 2; Mass market OEM; Supplier 1; Supplier 2; Supplier 3
	Synchronize production scheduling with inbound flows	[B2] Suppliers and logistic service providers share geolocalization data on the location of the truck	Low – Premium OEM 1 and Premium OEM 2 completed pilot projects	*We launched a pilot for the geolocalization of suppliers' trucks. We have real-time visibility on the expected time of arrival* – Premium OEM 1, Head of Supply Chain	Premium OEM 1, Supplier2
	Streamline and reduce errors in data acquisition	[B3] Suppliers and logistic service providers share data through sensors/intelligent labels	Low – Premium OEM 2 and Supplier 3 completed pilot projects	*Thanks to RFID, before the truck enters our plant we know if the delivery, parts and volume are correct. We have connected our information system and the fiscal system* – Premium OEM 2, Head of Industry 4.0	Premium OEM 2, Supplier 3
	Monitor parameters during delivery process	[B4] Suppliers and logistic service providers share sensor-generated data on ambient conditions	Low – Supplier 1 and Supplier 3 completed pilot projects	*Sensors monitor ambient conditions in overseas shipments to assess any impact of temperature on the component* – Supplier 3, Head of Purchasing	Supplier 1, Supplier 3

(*continued*)

Table 2

DT-enabled data sharing	Area and main purpose	[Alphanumeric code] Flow	Assimilation level	Illustrative quotes	Sources
	Traceability Enable control over number of pieces produced	[B5] Suppliers share machine process data with focal firms	Low – Supplier 2 and Commercial OEM completed/ evaluated projects under vendor tooling agreements	*To know exactly how many pieces are produced, we could easily connect machines operating under vendor tooling agreements* – Commercial OEM, Head of Industry 4.0	Commercial OEM; Supplier 2
	Quality Align process parameters along the SC	[B6] Suppliers share machine process data with focal firms	Low – Supplier 2 shared data related to a specific process step	[Name of OEM] *wants to know for every component what bolts are screwed because this impacts their quality. We have connected working stations* – Supplier 2, Production Manager	Premium OEM 2; Supplier 2
	Enable suppliers' autonomous analysis	[B7] Focal firms share quality test data with suppliers for their autonomous analysis and joint quality improvements	Low – Supplier 2 completed a project	*The supplier matches our [test cell] data with their internal process data. Through artificial intelligence, they can reduce scraps and increase the useful life of molds* –Supplier 2, ICT Director	Supplier 2
	Process optimization Adjust process parameters based on advanced analytics	[B8] Focal firms share machine/process data with industrial technology providers	Very low – OEM/first-tier suppliers shared data mainly in case of issues	*We have partnered with some customers to process their data through big data analytics. . . . We are able to optimize their processes for energy consumption and quality* – Metal equipment, Head of Project Management	Commercial OEM; Premium OEM 1; Premium OEM 2; Mass market OEM; Supplier 1; Supplier 2; metal equipment; Plastic equipment
	Maintenance Implement outsourced smart maintenance	[B9] Focal firms share machine data with industrial technology providers for smart maintenance	Low – OEMs and first-tier suppliers shared data depending on the machine	*There is some sharing of real-time machine data for proactive, predictive maintenance. This is still difficult to do in terms of cost-benefit ratio* – Mass market OEM, Production Manager	Commercial OEM; Premium OEM 1; Premium OEM 2; Mass market OEM; Supplier 2; metal equipment; Plastic equipment
[C] Product connectivity	**Service access/ provision** Access product functionalities and services	[C1] Final users share connected vehicle data with OEMs	Very high – owners of connected vehicles mostly share data with OEMs	*Customers sign an agreement directly with the OEM where the authorization clauses are explicit. There are very few customers that opt out* – Importer, Marketing Manager	Commercial OEM; Premium OEM 1; Premium OEM 2; Luxury sports OEM; Supplier 2; importer, Dealer 1, Dealer 2
		[C2] Final users share connected vehicle data with first-tier suppliers and dealers	Very low – owners of connected vehicles mostly do not sign other data sharing agreements	*It would be relatively easy to install a transmitting device on the car and access the vehicle data for maintenance purposes* – Dealer 2, CIO	Premium OEM 2; Luxury sports OEM; Supplier 2; Importer, Dealer 1, Dealer 2
	Enable business partners to provide services	[C3] Focal firms share data with dealers, service centers and other service providers (e.g. insurers, driving schools)	Very high – all OEMs shared data	*We have partnerships for insurance service. This is not something we can offer directly* – Commercial OEM, Head of Digital Transformation	Commercial OEM; Premium OEM 1; Premium OEM 2; Luxury sports OEM
	Develop and provide digital services (e.g. advanced driver-assistance systems – ADAS)	[C4] Focal firms share data with digital service developers/providers	Very high – all OEMs shared data with firms specialized in analytics and digital service development	*This is what we are doing with OEMs. We work for them; they own the data. We provide our know-how, our expertise, place our sensors in the car, and generate algorithms* – Supplier 2, Head of Production	Commercial OEM; Premium OEM 1; Premium OEM 2; Luxury sports OEM; Supplier 2; System integrator
	Enable analytics including vehicles from different brands	[C5] Focal firms share individual-level data through data consolidation platforms	High – most OEMs in the commercial segment were involved	*We partnered up with our competitors to create a data-sharing platform, so that we can more easily access vehicle data* – Commercial OEM, Head of Connected Vehicles	Commercial OEM
		[C6] Focal firms buy/sell anonymized data through data consolidation platforms	Very high – all OEMs bought/sold data through digital platforms	*Data aggregation platforms offer opportunities to share and store data to be processed in large volumes and that are not specific to any OEM* – Premium OEM 1, Director of Connected Vehicles	Premium OEM 1; Premium OEM 2; Luxury sports OEM
	Quality/new product development Enable suppliers' analysis on component use/performance	[C7] Focal firms share product-in-use data with suppliers	Low – no OEM shared data to enable first-tier suppliers' innovation; in case of quality issues, data were shared	*Usually, data from connected vehicles are shared only when there are problems to be solved. We have the simulation models for our components* – Supplier 2, Head of R&D	Commercial OEM; Premium OEM 1; Premium OEM 2; Mass market OEM; Luxury sports OEM; Supplier 1; Supplier 2; Supplier 3

Source: Author's own creation

asset/equipment connectivity and **product connectivity**. In Table 2, each data sharing practice has been attributed an alphanumeric code (e.g. A1, A2). These are consistently used in the text (in bold) to allow the reader to follow our reasoning while confronting more easily exemplary quotes and further details.

4.1.1 Data sharing practices related to process connectivity

In our sample, firms increasingly interconnected and granted external access to their information systems, facilitated by cloud computing and information system integration, minimizing the cybersecurity risks associated with data stored on private servers. Various data sharing practices were identified in production planning. In practice **A1**, firms shared real-time production planning, work-in-progress and inventory data, empowering suppliers to autonomously decide when and how to build stock. Similarly, **A2** involved suppliers integrating their information systems with buyers. Digital platforms interconnected players along the SC in **A3**.

Logistics practices included **A4**, in which timely data access aligned suppliers and operators with inbound material requirements, and **A5**, which leveraged delivery status visibility to enable manufacturers to adjust schedules. Cost reduction in externalized activities was a driver for **A6**, as Supplier 1 integrated information systems with a global logistic service provider to optimize inbound routes. Blockchain technology in **A7** expedited traceability, accelerating the identification of quality issues and recall procedures. In new product development, cloud computing provided external design centers with methods, tools and data while maintaining control over proprietary information (**A8**). Additionally, in **A9**, increased storage space and secure data transfer solutions facilitated OEMs in requesting extensive data from first-tier suppliers, such as simulation parameters and results.

Regarding assimilation levels, OEMs extensively shared production planning data (**A1**) and delivery requests (**A4**). In terms of data sharing from suppliers to buyers, ample sharing occurred in support of inbound logistics (**A5**) and component/system development (**A9**). For other practices, instances were limited, primarily consisting of pilot projects and preliminary conversations.

4.1.2 Data sharing practices related to asset/equipment connectivity

The data sharing practices revealed from the interview data revolved around sensor-generated data from manufacturing plants (e.g. connected machines, gates, working stations, test cells) and logistics operations (e.g. connected trucks, containers, parcels). These were shared either through direct connectivity (i.e. the Internet of Things) or by interconnecting information systems (i.e. through cloud computing, enhanced Web interfaces and secure data transfer). Several of these practices affected interorganizational logistics. Especially in just-in-time or just-in-sequence (JIT/JIS) approaches, suppliers synchronized deliveries based on real-time data from systems of sensors and gates on the assembly line (**B1**). Similarly, truck geo-localization allowed higher accuracy in estimating materials' expected time of arrival so that the production sequence could be adjusted (**B2**). Sensors and intelligent labels were also used to automate data acquisition for inbound materials (**B3**) and to monitor shipments' ambient conditions (**B4**).

Asset/equipment connectivity also influenced traceability. By accessing suppliers' machine data, buyers could verify the number of pieces produced and process parameters (**B5**). With respect to quality, these practices allowed buyers to adjust to what occurred at suppliers (**B6**). Suppliers improved their processes by accessing connected test cells' data (**B7**). All manufacturers collaborated with industrial technology providers, engaging in data sharing practices aimed at process optimization (**B8**) and maintenance (**B9**), both derived from analytics on machine data.

Except for **B1**, we found only pilot projects and a limited number of instances.

4.1.3 Data sharing practices related to product connectivity

Various data sharing practices concerned connected vehicles, using the Internet of Things for data gathering and subsequently sharing data through information system integration, cloud computing, teleservice systems and data transfer solutions. For individual vehicle data, OEMs operated upon owner authorization (**C1)**. Sharing these data was essential for service access/provision, as many vehicle functionalities needed remote data processing (e.g. localization). First-tier suppliers also implemented component/system connectivity, and dealers connected data ports with central control units (**C2**).

Thereafter, sharing individual-level vehicle data enabled external engagement in service provision (e.g. maintenance and insurance) (**C3**). Partially different dynamics emerged for in-vehicle digital services, including infotainment and advanced driver-assistance systems (ADAS), such as automated parking and accident prevention (**C4**). Whenever OEMs leveraged external collaborations (e.g. with first-tier suppliers and digital companies), data sharing occurred in bulk for the development, testing and training of algorithms. Interestingly, connected vehicle data were shared through third-party digital platforms, often backed by OEMs' direct investments. Vehicle-specific data were shared for multi-brand fleet management services (**C5**). Moreover, these data aggregators were used to sell and buy anonymized data in bulk (**C6**). For quality and new product development purposes, data could be shared with suppliers to enable the analysis and evaluation of the performance of their components (**C7**).

In terms of assimilation levels, OEMs were at the center of data governance (**C1**, **C3**), while dealers and first-tier suppliers could not directly access the data (**C2**). Data-driven collaborations (**C4**) and digital platforms were common (**C5**, **C6**). In terms of quality and new product development, data were shared with suppliers only in the case of issues (**C7**).

4.2 Factors driving or preventing data sharing

As described in subsection 4.1, data sharing practices presented different levels of assimilation. The informants' comments were compared with the initial list of factors (Figure 1). Tables 3, 4 and 5 contain illustrative quotes. The main findings are described in the following paragraphs, highlighting the specificities of DT.

4.2.1 Factors related to the characteristics of the data (sRQ1)

Our evidence confirmed that data were shared based on their core-relatedness and fungibility, in line with the RBV (Table 3). In terms of *core-relatedness*, both OEMs and first-tier suppliers hesitated to share data about innovation and core manufacturing processes. Data related to typically outsourced activities were easily shared with greater timeliness and granularity (e.g. logistics and maintenance; **A4**, **A5**, **A6**, **B9**). Regarding connected vehicle

Supply Chain Management: An International Journal
Volume 29 · Number 7 · 2024 · 1–27

Table 3 Factors related to data characteristics in the context of DT

Factor		Illustrative quotes on data sharing practices [A] Data sharing practices related to process connectivity	[B] Data sharing practices related to asset/equipment connectivity	[C] Data sharing practices related to product connectivity
Core-relatedness **Data related to a firm's competitive advantage in its core business**	*High core-relatedness* Data revealing: – product performance – innovation know-how – decisions/expertise in production Data that: – are used for service orchestration and the provision of distinctive services	**Production planning** [**A3**] *Manufacturers are usually interested in keeping in-house the control of planning and related data. It is something they have always done; they do not need to look for external capabilities for that. Most commercial software solutions are designed for this* – Software corporation, Chief Marketing Officer **New product development** [**A8**] [**A9**] *Our data and methods are part of our distinctive know-how* – Plastic equipment, CIO *Some customers have now greater expertise, so they increasingly want to verify our work. Before it was like: "Our suppliers are the experts, they told me it works." Now, they want to verify and keep the data* – Supplier 1, Head of R&D	**Quality** [**B7**] *Product quality is what differentiates us, it is part of our know-how. We don't need or want to share data with our suppliers. It is enough to share the outcomes of our analysis with them* – Supplier 1, Head of R&D **Process optimization** [**B8**] *It is difficult to convince customers that "sharing their secrets" will make them save time and money. . . . Truth is, that the goal of all manufacturers is to increase productivity and quality . . . they obviously hold on to any data or information that constitutes a source of competitive advantage* – Metal equipment, Head of Project Management	**Service access/provision** [**C1**] *Servitization opportunities are out there. We started off saying: my sensors, my data. But OEMs were not seeing it this way* – Supplier 2, General Manager **Quality/new product development** [**C7**] *There are issues that OEMs manage depending on the context, they might avoid recall procedures if the parameters fall within certain limits. These are choices every company makes daily and are confidential. Should we be able to access sensor-generated data, we might also see into these issues . . .* – Supplier 2, Managing Director
	Low core-relatedness Data related to: – already outsourced activities – basic traceability information – services not related to core value proposition	**Logistics** [**A4**] [**A5**] [**A6**] *Inbound logistics of materials have long been outsourced, so we have always been sharing the sequence of production within our supplier park. Now this is happening in real time* – Mass market OEM, Production Manager *We have no issue in sharing data to access a better service not related to our core activities* – Supplier 1, Supply Chain Manager **Traceability** [**A7**] *We share the code of the material, the date of production, the time of production, quantity, and machines used. Our internal traceability system includes machine data, such as control tests, process variables, and machine setting. . . . We would have seen too much risk in giving away data related to decisions we make in our core activities* – Supplier 1, ICT Director	**Logistics** [**B1**] [**B4**] *Again, sensorized assembly lines only increase the accuracy and the timeliness of data we were already sharing to enable our suppliers to work in a JIS environment* – Mass market OEM, Production Manager *The supplier did not see any risk in sharing data on the temperature and humidity in the containers, it is not related to something they are doing* – Supplier 3, Head of Purchasing **Maintenance** [**B9**] *Machine builders access the data: controlling machine failures are their business* – Supplier 2, Production Manager *Machine data are shared for troubleshooting or preventive maintenance, it is not sensitive* – Supplier 1, Head of Purchasing	**Product use** [**C2**] *Should we access connected vehicle data, then we would need to offer a service level that is beyond our capabilities* – Dealer 1, Marketing Manager **Service access/provision** [**C3**] [**C4**] [**C5**] [**C6**] *When it is about services that are commodities, we have no issues* – Premium OEM 2, Head of Innovation *We have partnerships for insurance services* – Commercial OEM, Head of Digital Transformation *Sharing connected vehicle data is hard for those OEMs who have invested in their own services and data infrastructure. If you are a smaller OEM or offer a different class of products, that's not where you are competing. Even if you look at* [Name of OEM]*, they go very deep with the Google experience, having put their money into electromobility. They are sharing more data with Google than is needed* – Premium OEM 1, Director of Connected Vehicles
Fungibility **Data that are specific to a project/supply agreement, not to be used otherwise**	*High fungibility* Data revealing: – efficiency – customer prioritization – machine parameters – product performance	**Production planning** [**A2**] *Suppliers are hesitant . . . They fear that we can calculate their efficiency and leverage this in price negotiations* – Supplier 3, Head of Purchasing *We're still facing some resistance because we will know if our suppliers are not producing for us but for a competitor* – Premium OEM 2, Head of Industry 4.0	**Process optimization** [**B8**] *Once you customize a machine, you can achieve higher efficiency levels and want to keep this advantage for yourself. As you connect the machine for process optimization, the provider can see into your configurations* – Supplier 1, Head of R&D	**Quality/new product development** [**C7**] *If we had access to connected vehicle data, we could improve future design based on the operating conditions and reduce overdesign. This visibility reveals many other engine parameters not related to our systems and components. . . . I understand that the customer doesn't like this* – Supplier 2, Managing Director

(*continued*)

Table 3

Factor		Illustrative quotes on data sharing practices [A] Data sharing practices related to process connectivity	[B] Data sharing practices related to asset/ equipment connectivity	[C] Data sharing practices related to product connectivity
Low fungibility **Data specific to:** **– the interorganizational collaboration activity** **– a limited timeframe**	**Production planning** [A1] *Thanks to the cloud, we can open up specific portions of our ERP to share how much materials we have in–house. Working with* [OEM], *suppliers know when their materials are being assembled* – Supplier 2, Production Manager	**Logistics** [B2] [B3] *The tracking starts as the supplier loads the truck* – Supplier 2, ICT Director *We developed the RFID solution for incoming boxes. It is specific to delivery* – Premium OEM 2, Head of Industry 4.0	**Service provision** [C3] *Dealers have access to data of the vehicles they sold, so that they can plan an intervention and order spare parts* – Commercial OEM, Head of Connected Vehicles	
	Logistics [A5] *We can visualize flows that relate to our business, like when you monitor the status of a parcel that is delivered to you at home* – Premium OEM 1, Head of Production	**Traceability** [B5] *When they produce parts for us, we can see through an app the uptime of the machine* – Supplier 3, Head of Purchasing *Vendor tooling agreements imply that suppliers use their capacity exclusively. We access the data of a machine that is basically operating just for us* – Commercial OEM, Head of Industry 4.0 **Quality** [B6] [Name of OEM] *wants to know for every component what bolts are screwed because this impacts their product quality. We have connected working stations to share these data* – Supplier 2, Production Manager **Process optimization** [B8] *Think of an assembly line with ten production processes in sequence that produce a defective result. It is difficult to identify the root cause. In this case, machine producers can see into our data, for example, the last 12 hours of production* – Supplier 1, Head of Purchasing	**Quality/new product development** [C7] *In case of specific issues, OEMs select the data so that we can analyze them. Similarly, should we need to work with our suppliers, we can select what we want to share—just the relevant parameters—so that we have a lower risk. This is costly, that's why it is not done on a steady basis* – Supplier 2, Head of R&D	

Source: Author's own creation

Table 4 Factors related to relational preconditions in the context of DT

Factor		Illustrative quotes on data sharing practices [A] Data sharing practices related to process connectivity	[B] Data sharing practices related to asset/equipment connectivity	[C] Data sharing practices related to product connectivity
Need for complementary resources **Assets and capabilities to use the data are not at the sharing firm**	*High need for complementary resources* Firms need to look externally for: – Product/process know-how – DT competences (including data management and analytics) – Datasets that complement the ones owned by the firm	**Production planning** [A3] *You can't solve SC issues at a local level, you need multi-tier data. That's what our customers have understood* – SC platform, Founder and CEO **Logistics** [A6] *They* [the logistic service provider] *have developed tools for logistics optimization. We realized that the more they can access the data of different manufacturers, the more they can optimize the service* – Supplier 1, Supply Chain Manager	**Quality** [B6] *The supplier matches our product quality data with their internal process data. Through artificial intelligence, they find patterns* – Supplier 2, ICT Director **Process optimization** [B8] *We access data as clients realize that they haven't achieved anything* – Metal equipment, General Manager *Big data analytics is something a single manufacturer is not able to do leveraging on internal data and expertise* – Metal equipment, Head of Project Management *We looked for external capabilities on how to collect, analyze, and import data* – Commercial OEM, Head of Industry 4.0 *We had partners for this project, one for data analytics, one for the 3 D scan and the digital twin. We shared the data with them* – Premium OEM 2, Head of Industry 4.0 **Maintenance** [B9] *At the beginning, we partnered up with different companies for proofs of concept. We didn't have competence in hard data analytics and machine learning back then* – Premium OEM 2, Head of Industry 4.0 *We wanted to detect compressed air leakages through microphones. We shared data through the cloud with specialized companies* – Supplier 2, ICT Director	**Quality/New product development** [C7] *We have the simulation models for our components, not the OEMs. It is up to us to make sense of quality issues* – Supplier 2, Head of R&D **Service access/provision** [C4] *All the sensors and cameras that* [OEM name] *is using are ours. We know them and develop related algorithms* – Supplier 2, Production Manager *«Sensor-generated data from connected vehicles can be . . . managed by OEMs. Only smaller OEMs have the data on our servers, lacking resources* – Supplier 2, ICT Director **Service access/provision** [C6] *Some data need to be analyzed in large volume to detect patterns, beyond what is under the purview of a single OEM. That's why we leverage data aggregation platforms* – Premium OEM 2, Head of Innovation
	Low need for complementary resources Firms have internal: – Product/ process know-how – Dedicated staff and technologies – DT capabilities	**Production planning** [A3] *Manufacturers are concerned of becoming dependent on an external provider for planning activities. They already have staff and technologies* – SC platform, Founder and CEO	**Quality** [B6] *We recently adopted brushless electric motors. As there were failures, we analyzed the data. The supplier was a small firm without a structured approach to problem solving* – Supplier 2, Head of R&D **Process optimization** [B8] *Advanced customers manage themselves machine data*» – Plastic equipment, CIO *We know the production process. External providers would just look at the wrong variables* – Supplier 2, Managing Director *The algorithms are continuously learning, it is an ongoing process. So, if you only rely on industrial technology providers . . . it is something that increases the cost. . . . No one has 20 years of experience with a proven solution* – Supplier 2, Head of Production **Maintenance** [B9] *We have maintenance capabilities, so we don't see the added value of sharing data* – Commercial OEM, Head of Industry 4.0 *We approach smart maintenance in-house for simpler machines and through external players for more complex ones* – Premium OEM 1, Head of Production	**Product use** [C1] *There are cases where business customers, having developed their own infrastructure and capabilities, manage their data internally* – Premium OEM 1, Head of Connected Vehicles
Level of dependence **Sum of dependence between the actors, higher likelihood of joint action**	*High level of dependence* Firms have: – A high share of common business – Personal relationships – Strongly entwined business processes	**Production planning** [A2] *Whenever we have strong ties and a personal relationship with a supplier it is easier to get the necessary data. . . . We have visibility on suppliers involved in processes that start and get back at our plants* – Supplier 3, Head of Purchasing *«It is easier with mid-sized companies, where we have strong partnerships in place. We discuss this directly with the owners* – Supplier 2, General Manager **Logistics** [A4] [A5] *As we establish partnerships with few logistic service providers, we can have them adopting our systems for data exchange* – Supplier 1, Head of	**Maintenance** [B9] *In an industry that does not carry inventory, it is important to ensure continuity in case of breakdowns. We need to get more data and in real time* – Plastic equipment, CIO	

(***continued***)

Table 4

Factor		Illustrative quotes on data sharing practices [A] Data sharing practices related to process connectivity	[B] Data sharing practices related to asset/equipment connectivity	[C] Data sharing practices related to product connectivity
		Logistics *We have integrated information systems intercompany and with the supplier park* – Mass market OEM, Production Manager **Traceability** [**A7**] *We didn't experience any operational benefit with the blockchain besides strengthening our reputation and the partnership* – Supplier 1, ICT Director		
Dependence asymmetry Difference in actors' dependence on each other	*High dependence asymmetry* Powerful buyers exert pressures	**Logistics** [**A4**] [**A5**] *We have the power to impose on our providers to share the data and adopt our technologies* – Commercial OEM, Head of Industry 4.0 **Traceability** [**A7**] *The blockchain is usually imposed by powerful and large customers, who reap the benefits* – Supplier 1, ICT Director	**Traceability** [**B5**] *Under a vendor tooling agreement, the supplier couldn't refuse to connect the machine* – Commercial OEM, Head of Industry 4.0	
	Low dependence asymmetry Large suppliers oppose resistance	**Production planning** [**A2**] *We are facing resistance from larger suppliers producing for different OEMs* – Premium OEM 1, Head of Industry 4.0 *Large suppliers reject everything. . . . We lack the levers* – Supplier 3, Head of Purchasing **Logistics** [**A4**] [**A5**] *Larger service providers are reluctant. They have their own technology and data formats* – Supplier 3, Head of Purchasing	**Traceability** [**B5**] *Whenever suppliers share their technical capacity with multiple customers, they are not willing to share data. If customers are powerful—depending on the business share—they will be successful at getting the data* – Supplier 2, Head of Production **Logistics** [**A5**] *Even regarding the traceability of trucks. . . only smaller freight forwarders accepted* – Supplier 2, ICT Director	
Protection mechanisms Clauses preventing leakages and opportunistic behavior	*Presence of protection mechanisms* Data protected by: – Legal clauses – Technology – Organizational setups (digital platforms as intermediaries)	**Production planning** [**A1**] [**A2**] [**A3**] *Technology is a big enabler, especially cloud-based applications. Until a few years ago, it was not possible for external users to directly enter the data in our systems* – Supplier 2, Head of Production *If you enable people to share the data—not directly, let's say through a third party platform—then we can optimize the SC* – Supplier 3, Head of Purchasing *By sharing data through a trusted third party like our platform, individual firms can keep the confidentiality of the data* – Supplier 3, Head of Purchasing **New product development** [**A8**] *Thanks to solutions such as VDI, it is hard to "steal" data and know-how whenever you outsource engineering activitie*s – Metal equipment, CIO *The software allows us not only to have control over errors, but also to make sure that our data and methods can't be downloaded* – Plastic equipment, CIO	**Quality** [**B6**] *The project was initiated by our supplier, we signed an NDA* [Not Disclosure Agreement] *as regards to the use made of our data* – Supplier 2, General Manager **Maintenance** [**B8**]/**Process optimization** [**B9**] *We are allowed to use customer data to provide a service, but we can't pool them together with those of other clients. This is most certainly a limitation, but we respect that* – Metal equipment, General Manager	**Service access/provision** [**C1**] [**C3**] [**C4**] [**C5**] [**C6**] *The data contract between the final user and the OEM is very detailed* – Importer, Marketing Manager *Legal mechanisms in place regulate third-party data sharing* – Commercial OEM, Head of Connected Vehicles *Initially we made mistakes. We didn't think that the data would be so important. Now, . . . we are very careful in the contracts* – Commercial OEM, Head of Digital Transformation *The only approach is to work as service provider. We would never be able to go to a competitor with their data* – Premium OEM 1, Head of Connected Vehicles *Data are shared through protected channels. In aggregation platforms, data are anonymized* – Premium OEM 1, Head of Connected Vehicles

(***continued***)

Supply Chain Management: An International Journal
Volume 29 · Number 7 · 2024 · 1–27

Table 4

Factor		Illustrative quotes on data sharing practices [A] Data sharing practices related to process connectivity	[B] Data sharing practices related to asset/equipment connectivity	[C] Data sharing practices related to product connectivity
	Absence of protection mechanisms Protection mechanisms not in line with corporate policies	**Production planning** [**A1**] [**A2**] [**A3**] *Large suppliers are sharing data because of company policy* – Supplier 3, Head of Purchasing *We have so many restrictions when using third-party software because of data and network security* – Supplier 2, General Manager	**Maintenance** [**B8**]/**Process optimization** [**B9**] *We can't connect our internal system with an external network because of information security reasons, it is simply not allowed. This is also why the algorithms are generated in-house* – Supplier 2, Head of Production	
Benefit distribution mechanisms **Upfront definition of benefit distribution**	*Presence of benefit distribution mechanisms* Benefits captured within joint ventures		**Maintenance** [**B8**]/**Process optimization** [**B9**] *To overcome reluctance, we are setting up joint ventures with manufacturers to ensure transparency on data handling and benefit distribution* –Metal equipment, Head of Project Management *Should we just ask for customer data, it would never work. We need to offer something different, basically not the product but service and performance* – Metal equipment, CIO	**Service access/provision** [**C1**] [**C5**] [**C6**] *Usually, our business customers share connected vehicle data. The important thing is that they get benefits from this, such as maintenance, route optimization, and a lower insurance premium* – Commercial OEM, Head of Connected Vehicles *Most OEMs have a stake in data aggregation platforms* – Premium OEM 1, Head of Innovation
	Absence of benefit distribution mechanisms Benefits captured by the sharing firm/not accessible to competitors	**Production planning** [**A1**] *Having visibility into our inventory, suppliers decide when and how to build stock. They become more efficient. We indirectly benefit from this* – Commercial OEM, Head of Digital Transformation **Logistics** [**A4**] *Information systems integration enables our supplier park to adapt in real-time to any change in the sequence. There is a double benefit for us, because the supplier is practically "ours": we carry zero inventory both at our premises and at theirs* – Mass market OEM, Production Manager	**Quality** [**B7**] *Data sharing allows our supplier to reduce scraps and increase the useful life of molds. The benefits for us are a better control of the porosity of our products* – Supplier 2, ICT Director **Maintenance** [**B8**]/**Process optimization** [**B9**] *We have to consider the benefits we can get. The machinery and equipment we use are rather standard. If the industrial technology provider implements innovations that are improving our efficiency, we have no issue sharing our data. When the technology is customized . . ., we do not want to share data and improvements with our competitors for free* – Supplier 1, Head of R&D *The data are shared with the machine provider. . . . The provider will know the algorithm, but we don't have many competitors in our country* – Supplier 2, ICT Director	**Quality/New product development** [**C7**] *Sharing connected vehicle data with first-tier suppliers comes at a cost. But what is the benefit? They won't develop new products just for us* – Luxury sports OEM, Head of Connected Vehicles

Source: Author's own creation

Table 5 Factors related to network-level dynamics in the context of DT

Factor and analysis		Illustrative quotes on data sharing practices **[A] Data sharing practices related to process connectivity**	**[B] Data sharing practices related to asset/ equipment connectivity**	**[C] Data sharing practices related to product connectivity**
Network governance structure **Coordination and attribution or responsibilities**	*Consistency with current network governance structure* Data from connected process and asset/ equipment shared consistently with the tiered structure of automotive Connected product data flows orchestrated by OEMs	**Planning** [**A1**] [**A2**] [**A3**] *Especially in the premium segment, the margins are high, and OEMs don't need to work with suppliers. Instead, when I was working at* [name of first-tier supplier], *we had to cooperate with suppliers to improve our results; we gathered data* – Premium OEM 1, Head of Supply Chain *We have a higher competitiveness if we are Industry 4.0 not only inside, but also with suppliers.* [. . .] *We bear the cost of the technology; we work on data formats* – Premium OEM 2, Head of Industry 4.0 *The true potential of SCM is still untapped, there is limited interest, starting from the OEMs. We should minimize the working capital in the system, but the contrary is happening* – Supplier 3, Head of Purchasing	**Traceability** [**B5**] *Since these projects have a cost, we are interested in implementing them only for large and critical suppliers* – Supplier 2, General Manager *We carry the costs of the technology and made available the data for suppliers to carry out their own analytics* – Commercial OEM, Head of Industry 4.0 **Quality** [**B6**] [**B7**] *The tiered structure in automotive foresees a strong role of first-tier suppliers in coordinating and monitoring product quality. We must support our suppliers, who are usually smaller companies* – Supplier 2, Head of R&D *From a technical point of view, we could always share data from our connected working stations, but OEMs do not ask this* – Supplier 2, Head of Production	**Service access/provision** [**C1**] [**C2**] [Name of first-tier supplier] *tried to commercialize an app, the customer had to install a box in the car. It was a failure: the relationship is with the car brand* – Luxury sports OEM, Head of Connected Vehicles *Those who are doing the business are the automakers. If they shared the data, they would share the profit* – Supplier 2, Head of R&D *We must be owners of the data if we want to build customer-centric value propositions* – Commercial OEM, Head of Digital Transformation **Quality/New product development** [**C7**] *The responsibility is with us. We are the ones who translate what you get out of data into a product* – Premium OEM 2, Head of Innovation *We don't share data. The more we analyze them, the more we can* [. . .] *find patterns, isolate the causes, alert the customer, and have them come back in* – Premium OEM 1, Director of Connected Vehicles *The interdependencies among the various systems need to be considered* – Commercial OEM, Head of Connected Vehicles
Environmental complexity and dynamism **Interrelated and rapid environmental changes**	*High environmental complexity and dynamism* Data shared because of: – high demand/supply variability – high pace of innovation	**Planning** [**A2**] [**A3**] *We can confirm customer orders in real time, as we can determine the feasibility considering* [supplier visibility]. *This is important in the face of more frequent demand variations* – Supplier 1, Supply Chain Manager *There is more supplier visibility working on a make-to-order basis* – Mass market OEM, production manager *More and more we face SC disruptions, as during the Covid outbreak. This prompted us to look for visibility, so that we can see what parts can be pulled ahead to guarantee continuity* – Supplier 3, Head of Purchasing **Traceability** [**A7**] *Just ten years ago, our product was made of 20 parts, now up to 70, 50 are purchased. In the case of quality issues, we need to report OEMs within 24 hours. We need new ways of handling a staggering amount of data* – Supplier 1, Head of R&D	**Process optimization/maintenance** [**B8**] [**B9**] *We feel that we need to be faster, technology is evolving so rapidly. That's why we have data-based collaborations with external players* – Supplier 2, ICT Director *Data sharing depends on the sense of urgency around a specific topic. Whenever the customers feel that the industry is moving fast, they are more willing to share* – Metal equipment, CIO	**Service access/provision** [**C4**]*Question is who is going to be faster. We chose to run both strategies. We work with big tech to be fast and share data with them, with the risk of being decoupled from the customer. The market is developing very fast, but we try not to sell our soul* – Premium OEM 2, Head of Innovation*Slowly but alone is a nonsense in these days* – Supplier 1, Head of R&D
	Low environmental complexity and dynamism Data not shared in stable environments	**Planning** [**A2**] *We don't have real-time visibility on suppliers. As far as they comply with our requests, we have no interest* – Premium OEM 1, Head of Production		

(***continued***)

Table 5

Factor and analysis		Illustrative quotes on data sharing practices [A] Data sharing practices related to process connectivity	[B] Data sharing practices related to asset/ equipment connectivity	[C] Data sharing practices related to product connectivity
Assimilation of technological/ communication standards Definition and adoption of common technical specifications	*High assimilation* Data shared when: – there are standards/ common data formats – digital platforms and the blockchain allow to overcome the issue	**Logistics** [**A4**] [**A5**] *Since a few years, our system has been based on GTL, Global Transport Labels. We can involve both suppliers and customers. It is also possible to change the label through electronic links reported in a cloud-based system* – Supplier 3, Head of Purchasing **Traceability** [**A7**] *The blockchain creates an interoperability layer between the information systems of the different firms* – Supplier 1, Supply Chain Manager		**Service access/provision** [**C1**] [**C5**] [**C6**] *Large fleet operators own trucks of multiple brands. They have their own systems and access raw data agnostically* – Commercial OEM, Head of Connected vehicles *We agreed to data exchange for mixed fleets through aggregation platforms and by making our API available* – Commercial OEM, Head of Digital Transformation «*Platforms can share and store data to be processed in large volumes and that are not specific to any OEM* – Premium OEM 1, Director of Connected Vehicles
	Low assimilation Data not shared in the absence of standards/ common data formats	**Planning** [**A1**] [**A2**] [**A3**] *One problem is the lack of standards and technologies for SC data exchange beyond dyadic level* – Supplier 2, General Manager *Data sharing in SC is only going to work if we have standards.* [. . .] *This is why we are working with* [Supplier 2] *on a platform and we joined industry initiatives* – Commercial OEM, Head of Digital Transformation *People talk much about process integration along the SC. It is a bit naïve today. You can define formats for data exchanges with your suppliers, but then you are "married" to them. It is a non-sense in today's business environment, where everything is changing so fast. The other possible strategies are collaboration platforms and interoperability standards; in this case, it might work* – Supplier 1, ICT Director **Logistics** [**A4**] [**A5**] *We are collaborating with large logistics providers. They have their own systems; they will always object to the system of their customers* – Supplier 3, Head of Purchasing	**Process optimization/maintenance** [**B8**] [**B9**] *There are many firms that would like to share data, but the press manufacturer has its own idea, the mold-maker its own. . . and so on. There have been attempts to standardize data exchanges, but there is no top-down direction* – Plastic equipment, CIO «*Machines have different connectivity technologies and data formats, which prevent data sharing even within the group* – Supplier 1, ICT Director *Usually, manufacturers do not collaborate on data projects with every machine producer they bought from. Greenfield investments have already started off with this logic. One provider is building the whole plant. Whenever the plants have adopted different technologies over the years, the best thing is to work with system integrators* – Metal equipment, Head of PM *To enable data sharing, we have worked on a common ontology and semantic* – Metal equipment, CIO	**Service access/provision** [**C3**] [**C4**] [**C5**] [**C6**] *Most cars are still not connected. We discussed many times with OEMs about getting the data through data ports and Bluetooth connectivity with the user's cell phone. However, this is not easy. There is no standard* – Supplier 2, Head of R&D *As regards to vehicle-to-vehicle communication large groups are doing it on their own, but until there is a standard for everyone this is not going to fly* – Luxury sports OEM, Head of Connected Vehicle *I doubt the industry will move towards a complete standardization of connected vehicle data. There are significant customizations of on-board devices and services. There are already some standards; there will be more going forward. However, this will not cover all possible data and parameters* – Luxury sports OEM, Head of Connected vehicle

Source: Author's own creation

Supply Chain Management: An International Journal
Volume 29 · Number 7 · 2024 · 1–27

data, OEMs controlled data flows to engage partners offering non-differentiating services (**C3**).

In the face of DT, companies redefined their core competences. This was determined by servitization opportunities stemming from data analysis of connected processes (e.g. planning and logistics optimization; **A3**, **A6**), assets/machines (e.g. maintenance and process optimization; **B9**; **B8**) and products (e.g. service access, development and provision; **C1, C2, C3**, **C4**, **C5** and **C6**). Against these opportunities, however, firms' decisions regarding the extent of data sharing were still determined by core-relatedness.

Considering *fungibility*, the comments confirmed reluctancy (e.g. with respect to data that could be used in price negotiations and exposing confidential information; **A2**, **B8** and **C7**). There seemed to be a higher likelihood of sharing data exclusively related to the activity performed together with the business partner (e.g. specific deliveries; **A5**, **B2**, **B3**; machines/production steps; **B5**, **B6**) and from a limited timeframe (e.g. **B8**, **C7**). According to the informants, DT technologies could increase control over data fungibility. Cloud computing simplified the sharing of supplier-specific process data (**A1**). Similarly, the Internet of Things enabled the connectivity of customer-specific machines and deliveries (e.g. **B2**, **B3**, **B5**). This entailed some complexities; in the case of connected vehicles, it was too costly to isolate component data (e.g. **C7**).

4.2.2 Factors related to relational preconditions (sRQ2)

Exemplary quotes for relational preconditions are presented in Table 4 according to the factors that pertain to the RDT. Regarding the *need for complementary capabilities*, data were shared whenever an external party was required to make sense of the data. For example, suppliers were engaged in analyzing data from defective components (e.g. **C7**). Conversely, the presence of internal capabilities reduced the extent of sharing (even for data not perceived as risky): smart maintenance was mostly performed in-house for simple machines (**B9**), fleet operators did not leverage OEMs' services when they had in-house analytics (**C1**), and firms did not engage external parties in production planning (e.g. **A3**). Data were not shared whenever the problem-solving capabilities of the firm owning the data exceeded those of its business partners (e.g. **B6**).

Interestingly, several OEMs and first-tier suppliers developed data management and analytics capabilities to keep pace with DT (**B8**). Nevertheless, it was still common for manufacturers to seek external help, especially when initially embracing DT and new technologies (e.g. machine vision). Data were shared to adjust collection and analysis procedures (e.g. **B8**, **B9** and **C4**). Large manufacturers looked for *ad hoc* collaborations, whereas smaller companies were likely to have their data wholly managed. Similarly, it is important to note that data were shared either continuously (e.g. the algorithm for processing connected car data was operated by the supplier/technology provider – **C4**) or for the time needed to set up a specific project (e.g. when connecting production machines and building their digital models – **B8**). Another peculiarity was cases of sharing due to complementarity among data sets owned by different firms, especially when using artificial intelligence and machine learning approaches. Examples related to matching product/process data for quality improvements (e.g. **B6**) and large-volume logistics and connected vehicle data (e.g. **A6** and **C6**).

Concerning the *level of dependence* and *dependence asymmetry*, our evidence corroborates previous views, with limited new elements. The case findings confirmed the link between relational orientation and data sharing. The presence of strongly entwined business processes – as in the case of JIS/JIT models (**B8**) – determined more widespread practices, especially those related to real-time integration. A high level of dependence was also conducive to easier adoption of common data formats and interfaces, for example, in logistics (e.g. **A4**, **A5**) and with respect to the blockchain (**A7**). Similarly, dependence asymmetry was a consistently relevant factor, as large and powerful buyers more easily requested data from suppliers and logistic operators and had them adopt their technological solutions (e.g. **A2**, **A4**, **A5**, **A7** and **B5**).

In terms of *protection mechanisms*, we found the application of usual contractual clauses, although a slow update of corporate policies was identified as a roadblock. Specific to DT, the use of new technologies was associated with higher data security and confidentiality (e.g. **A8**, **C5** and **C6**). Moreover, as intermediaries within the SC, digital platforms were indicated as a solution to benefit from visibility while avoiding connected risks (e.g. **A3**). New legal arrangements were also discipling the use and ownership of shared data, for example, data pooling with competitors for joint analytics and sharing with third parties (e.g. **B8**, **B9**, **C1**, **C3** and **C4**).

Regarding *benefit distribution mechanisms*, we did not find agreements besides joint ventures. Many comments indicated that data were shared whenever the benefits were mainly appropriated by the sharing firm (e.g. **B8**, **B9**, **C1**, **C5** and **C6**).

4.2.3. Factors related to Network-Level dynamics (sRQ3)

We framed evidence of network-level dynamics according to CAS (Table 5). On a general level, data sharing practices developed according to the existing *network governance structure*. The relatively low spread of data sharing practices concerning upstream process visibility, traceability and quality control (e.g. **A2**, **B5** and **B6**) were often attributed to a limited interest by OEMs in improving suppliers' efficiency, whereas the automotive tiered structure indicated a strong role of first-tier suppliers in upstream SCM.

The impact of DT was significant for the connected product data. On the one hand, the increasing prevalence of electronic components meant higher integration efforts; thus, OEMs required data from first-tier suppliers (**C7**). On the other hand, OEMs orchestrated connected vehicle data flows for service provision, thus capturing the value generated.Whereas data were shared to enable partners' service provision, OEMs maintained ownership and control (**C1, C2**).

Factors related to e*nvironmental complexity and dynamism* were also reported. Higher demand unpredictability determined by product customization and the risk of disruptions (e.g. in the aftermath of the COVID-19 outbreak) prompted firms to focus on upstream SC visibility (**A2**, **A3**). Similarly, traceability initiatives were called forth by higher product complexity (**A7**). The effects of DT appeared related to the pace of innovation; thus, manufacturers increasingly shared data with technology providers (e.g. **B8**, **B9** and **C4**).

Finally, several comments pointed to the *assimilation of technological and communication standards*. The lack of standards caused frictions, as each player would rather use their own system. Although some standardization efforts were ongoing, the informants perceived that they would not cover all possible data and parameters. The evidence showed that some challenges could be partially overcome by implementing solutions specific to DT. Concerning connected assets/equipment, industrial technology providers became system integrators (**B8**, **B9**), while digital platforms and blockchains offered new ways to share data (e.g. **C5**, **C6**, **A7** and, to a limited extent, **A3**).

5. Discussion

One key question that arises in the context of DT is the alignment between theoretical models and the dynamics unfolding in this evolving landscape (Hanelt *et al.*, 2021; Culot *et al.*, 2020a). In the face of today's profound transformations, there is a call for potential new theoretical perspectives (Hendriksen, 2023; Paolucci *et al.*, 2021). However, it is essential to commence the journey by assessing compatibility with established models to prevent hypes and misunderstandings. Starting from a comprehensive review of the relevant SCM literature, supplemented by concepts from adjacent managerial disciplines, we developed an initial conceptual framework (Figure 1). This served as the lens through which we interpreted the empirical evidence gathered from 16 firms within an extended supply network in the automotive industry.

The findings outlined in subsection 4.1 reveal that the untapped potential of new digital technologies for interorganizational data sharing in SCs persists. Except for the cost of technology and the limited digital maturity of firms, informant comments suggest that overcoming these challenges may not merely be a matter of time. In line with theoretical predictions, the interviews underscored that data sharing is influenced by factors related to their characteristics (RBV), relational preconditions at the dyadic level (RDT) and network-level dynamics (CAS). Subsection 4.2 delves into the specifics of these dynamics in the context of DT.

The results are synthesized in Figure 2, which illustrates the interpretation of the novel elements based on the three theoretical perspectives underpinning this study. Adhering to Busse *et al.*'s (2017) methodological recommendations to handle contextual idiosyncrasies as boundary conditions (Bacharach, 1989; Dubin, 1969), we accommodate the impact of DT by revising relationships and constructs. Relationships are refined through moderators (**mod**) (describing a different shape and intensity of causal relationships; Bamberger, 2008) and mediators (**med**) (accounting for different causal pathways; Busse *et al.*, 2017). Constructs are reformulated to capture changes in their meanings (Suddaby, 2010).

5.1 Implications pertaining to data characteristics (RBV)

Regarding core-relatedness, in many ways, DT is simplifying data sharing practices that were pursued even before the advent of new technology, although less efficiently, accurately and timely. Growing servitization trends are driving a redefinition of what represents core business in the automotive industry alongside many other industries (Culot *et al.*, 2020b; Bohnsack *et al.*, 2021; Peerally *et al.*, 2022). As highlighted in the literature (e.g. Chen *et al.*, 2021; Dalenogare *et al.*, 2022; Porter and Heppelmann, 2015), servitization implies that data are shared for service orchestration and provision, which can be absolved by the initial firm receiving the data (e.g. OEMs) and/or dementated to third parties (e.g. service centers, insurers, technology providers). Servitization opportunities are not limited to connected products but also affect processes (e.g. outsourcing of production and logistics planning for data-driven optimization) and assets/machines with process optimization and maintenance (Dalenogare *et al.*, 2022; Cepa, 2021). Against these opportunities, however, the principle of core-relatedness holds, as firms hesitate to share data closely tied to their core business (e.g. production parameters), regardless of potential benefits. Similar considerations arise when considering services that firms are offering/developing internally or rather through external parties. In Figure 2, we propose a causal pathway in which firms decide on DT-related servitization opportunities based on the assigned value of the data to be shared.

Considering data fungibility, concerns persist about sharing data, potentially leading to opportunistic behavior in buyer–supplier negotiations and new product development. We also noted that firms can now share data with greater granularity and specificity than in the past. This aspect is peculiar to direct connectivity (Culot *et al.*, 2020a; Münch *et al.*, 2022) and allows, for example, suppliers to share data generated by assets/machines operated exclusively or predominantly for one customer without disclosing other information. A similar effect is obtained through cloud computing, as it enables access to a specific data environment while preventing the unauthorized use of data. We view DT as amplifying firms' control over data fungibility, consequently increasing data sharing opportunities. In Figure 2, we introduce a moderating effect.

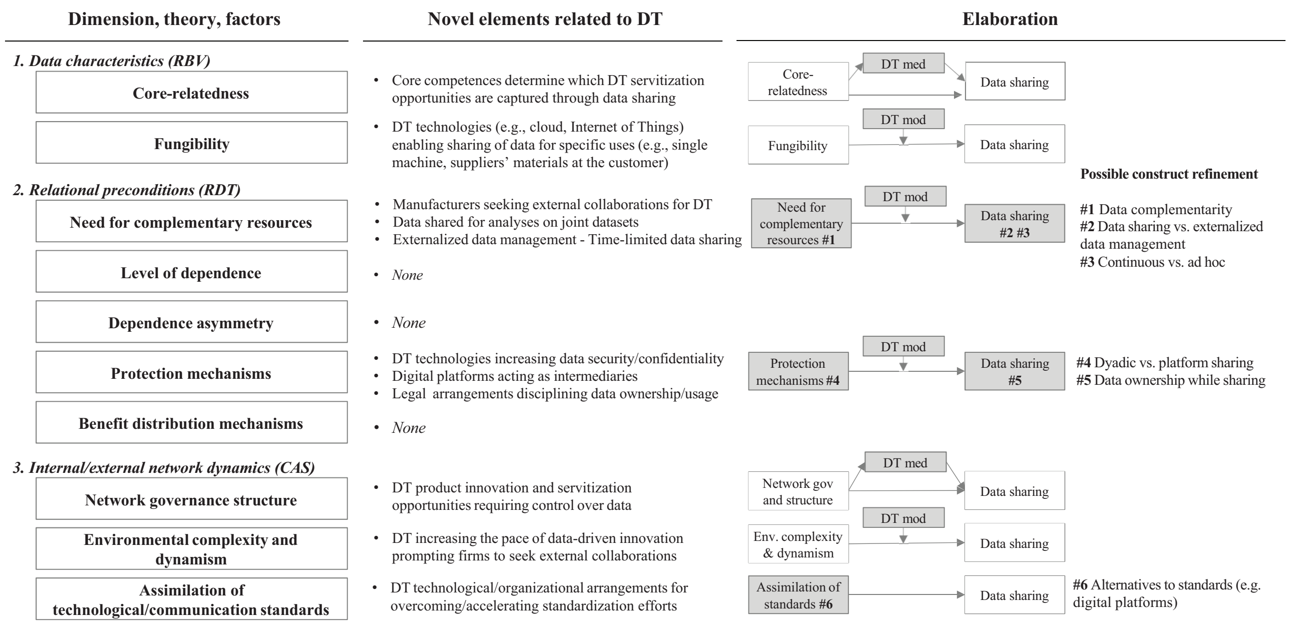
5.2 Implications pertaining to relational preconditions (RDT)

Data sharing still hinges on firms' need for complementary resources to interpret and use their data. Importantly, DT is raising the bar for these capabilities, now encompassing expertise beyond the scope of many manufacturing firms (e.g. data science and system integration) and scarce on the market (Cepa, 2021; Münch *et al.*, 2022). In Figure 2, we thus introduce a moderating effect of DT, suggesting that with increased adoption of technologies involving data analytics, firms are more likely to engage in data sharing with specialized external parties.

In addition, we identified other peculiarities of DT that can be reconciled with the general logic of RDT through construct refinement. We propose the introduction of amendment **1** in the independent variable to consider complementarity between data sets with similar (e.g. connected vehicle data within data aggregation platforms) or different scopes (e.g. product quality and suppliers' process data). Technologically, this is motivated by the network effects of artificial intelligence, whose value is enhanced by more data (Gregory *et al.*, 2021; 2022). Furthermore, we advocate for construct refinement **2** to distinguish between data sharing and data management externalization facilitated by cloud computing (Novais *et al.*, 2019). This occurs when firms, especially smaller

Supply Chain Management: An International Journal
Volume 29 · Number 7 · 2024 · 1–27

Figure 2 Final framework: dimensions and factors determining data sharing in the context of DT



Source: Author's own creation

ones, lack the necessary data infrastructure and have digital platforms that serve as data aggregators. Moreover, in amendment **3**, we incorporate a temporal dimension to account for varying degrees of data sharing. For instance, during the implementation of asset/machine and product connectivity, manufacturers can either share data in the ramp-up phase or continuously (i.e. algorithms are operated by the technology provider).

Concerning the level of dependence and dependence asymmetry, our study confirms the relevance of these factors while not highlighting any major discontinuity in DT. Despite the potential for end-to-end SC visibility (e.g. Calatayud *et al.*, 2018; Dolgui and Ivanov, 2022) and the advent of "trustless" systems (Babich and Hilary, 2020), data sharing still mostly occurs between business partners linked by a direct relationship. Even the decision to adopt multi-tier data sharing technologies (such as the blockchain) is motivated by prior SC relationships.

Regarding protection mechanisms, technologies enhance data security and confidentiality, resulting in increased efficacy in cybersecurity solutions (Corallo *et al.*, 2020). We propose a moderating effect hypothesis to account for this. Additionally, DT is linked to the rise of digital platforms acting as "middlemen" for sharing sensitive data (Legenvre and Hameri, 2023). To address this, construct adjustment **4** is suggested to incorporate protection mechanisms for both dyadic data sharing and digital platforms as an emerging organizational solution. Finally, construct refinement **5** highlights the importance of legal arrangements specifying ownership of shared data and acknowledging potential variations in risks and benefits for the sharing firm.

Finally, for the last factor pertaining to RDT, we could not find any major implications of DT in terms of benefit distribution mechanisms. This aspect, despite being amply advocated in the literature (Ganesh *et al.*, 2013), is still mostly neglected in practice.

5.3 Implications pertaining to network-level dynamics (CAS)

The network governance structure is normally understood in manufacturing as the distribution of coordination responsibilities (Choi *et al.*, 2001; Gereffi *et al.*, 2005). Connected products and related servitization call for greater attention to aspects such as customer relationships (i.e. who signs in for data access with the final user) and value capture (i.e. how to protect the margins related to services). According to the literature (e.g. Hanelt *et al.*, 2021; Porter and Heppelmann, 2015), data sharing is inherently higher when implementing connected products, and it is important to consider the overall governance of data flows. In Figure 2, we suggest different pathways, depending on whether DT is implemented in support of manufacturing processes or for servitization opportunities.

In terms of environmental complexity and dynamism, our results indicate that a high pace of innovation requires collaboration based on data sharing, thus suggesting a moderating effect. The assimilation of technological/communication standards also encompasses interoperability initiatives and the creation of data repositories. Technologies such as blockchains build interoperability layers between different firms' information systems (Nandi *et al.*, 2020; Sauer *et al.*, 2022). Moreover, although the presence of intermediaries in SC relationships is not new (e.g. Gast *et al.*, 2019; Mena *et al.*, 2013), digital platforms can substitute or partially compensate for the lack of industry-wide standards and should be accounted for in the independent variable (construct refinement **6**).

5.4 Summary: How DT is changing factors behind interorganizational data sharing

Returning to our main RQ, DT is changing some aspects of interorganizational data sharing, as new technologies allow the sharing of data with greater granularity, volume and timeliness, which better align to the needs of SCs in fast-changing environments and provide new avenues for value generation. Nevertheless, managerial decisions remain rooted in common business sense and consolidated SCM practices. Overall, innovative aspects are emerging, although they are still categorized within the overarching framework of grand theories. Namely, DT can positively moderate the relationship between certain factors and data sharing (e.g. by prompting companies to look for data-driven collaborations and by offering new ways of sharing and protecting data). In other cases, DT can be seen as a mediator (e.g. when data are shared consistent with a redefinition of core competences). More nuances can then also be captured by working on constructs (e.g. by specifying different forms of data sharing, such as the externalization of data management).

6. Conclusion

This study clarifies the factors that drive or prevent interorganizational data sharing in the context of DT. Building on the key learnings from prior research, we developed a case study analysis within an extended supply network in the automotive industry with the aim of theory elaboration (Dubois and Gibbert, 2010; Ketokivi and Choi, 2014). The findings indicate that interorganizational data sharing today can still be explained through established theories (i.e. RBV, RDT and CAS). However, there are some situations peculiar to the new contextual conditions. These were examined to provide middle-range theoretical insights into the phenomenon (Busse *et al.*, 2017; Merton, 1957; Mintzberg, 1977). An integrative framework (Figure 2) illustrates how DT partially changes the meaning of previous constructs and their relationships. We account for these through the refinement of definitions and by positing new moderators and mediators (Bamberger, 2008; Suddaby, 2010).

This study makes two distinct contributions to the academic debate on DT in extended supply networks. First, we draw attention to the issue of interorganizational data sharing, which up until now has not been treated with all the due breadth and depth. By making explicit the key dimensions and factors, our study provides a structured perspective that is applicable to academic research across the range of technological opportunities at hand.

Second, we integrate three theories central to the study of interorganizational relationships (i.e. RBV, RDT and CAS). The application of these theories to our empirical evidence showed that data sharing is inherently a multi-faceted phenomenon that ought to be examined from different points of view. This is also relevant in the light of recent calls for a better understanding of the fit between established models and emerging trajectories (e.g. Hanelt *et al.*, 2021). We present some approaches to increasing their accuracy and applicability in today's business environment. Despite the alleged disruptive impact of DT and the allure of new theoretical perspectives, we show that researchers can still resort to grand theories to make sense of managerial decisions. However, we also acknowledge that some elements represented a higher degree of novelty with respect to already theorized dynamics. These refer to opportunities to share data in different forms (i.e. at the individual level, in real time, in bulk and anonymized) as well as to fully outsource data management. We accounted for this by arguing for a refinement of the construct "data sharing" based on the specific context and situations. These differences should be made explicit in future studies investigating this phenomenon.

From a managerial perspective, the main contribution of this study is that it clarifies what firms' decision makers should consider when approaching the data sharing conundrum. Until now, the discussion has been rather polarized. On the one hand, managers have been perceiving data as "the new oil." On the other hand, emerging narratives of digitally integrated SCs and ecosystems have often downplayed potential risks. Hence, the explication of key dimensions and factors can support a more structured and analytical approach to the issue. This can also be useful in deciding whether to invest in new interorganizational technologies that might not be welcomed by the firm's business partners. Practically, managers can take our final framework (Figure 2) as an analytical tool to decide whether to adopt a specific technology as well as to assess the risks of taking part in a data sharing initiative. Moreover, by reporting the experiences of 16 firms, we provided several practical examples.

Further empirical studies are needed to improve and refine our elaborations. Our decision to focus on a single industry, although methodologically justified to keep extraneous variables under control, has the drawback of not allowing a comparison between contexts. Similarly, we should acknowledge the possible effects of the COVID-19 pandemic, which contributed to creating a sense of urgency around SC visibility. Due to the use of theory, the analysis minimizes these drawbacks; however, it can be appropriate to investigate other settings. In the study, we pursued analytical generalization, that is, the process of generalizing from empirical observations to theory rather than to a population (Gibbert and Ruigrok, 2010; Yin, 2018). In this respect, our final framework (Figure 2) provides an updated view of the factors identified by prior literature in the context of DT. Constructs and relationships can extend across industries; however, there might be a need to verify specific dimensions, mostly those related to network structure and governance, and to consider DT in industries where product connectivity is not extensively pursued. We thus suggest cross-sectional studies of data sharing practices related to specific areas of interorganizational collaboration (e.g. logistics, planning, service provision). Additional insights might emerge by leveraging other theoretical underpinnings, such as transaction cost economics (Coase, 1937; Williamson, 1985), agency theory (Eisenhardt, 1989a; Mitnick, 1975; Shapiro, 2005), the information processing view (Galbraith, 1974; Tushman and Nadler, 1978) and institutional theory (DiMaggio and Powell, 1983). Moreover, further theoretical insights are possible at the interface between RBV and dynamic capabilities (Teece *et al.*, 1997) when investigating the reasons leading firms to establish different kinds of external collaborations and share data in the context of DT. Finally, the still limited adoption of some new technologies calls for further updates. Extensive testing of results to overcome the limitations peculiar to qualitative studies is also a clear avenue for future research.

References

Ackoff, R.L. (1989), "From data to wisdom", *Journal of Applied Systems Analysis*, Vol. 16 No. 1, pp. 3-9.

Ahuja, G., Lampert, C.M. and Novelli, E. (2013), "The second face of appropriability: generative appropriability and its determinants", *Academy of Management Review*, Vol. 38 No. 2, pp. 248-269.

Aldrich, H.E. and Pfeffer, J. (1976), "Environments of organizations", *Annual Review of Sociology*, Vol. 2 No. 1, pp. 79-105.

Arcidiacono, F., Ancarani, A., Di Mauro, C. and Schupp, F. (2022), "The role of absorptive capacity in the adoption of smart manufacturing", *International Journal of Operations & Production Management*, Vol. 42 No. 6, pp. 773-796.

Bacharach, S.B. (1989), "Organizational theories: some criteria for evaluation", *The Academy of Management Review*, Vol. 14 No. 4, pp. 496-515.

Bamberger, P. (2008), "From the editors: beyond contextualization–using context theories to narrow the micro-macro gap in management research", *Academy of Management Journal*, Vol. 51 No. 5, pp. 839-846.

Battaglia, D., Galati, F., Molinaro, M. and Pessot, E. (2023), "Full, hybrid and platform complementarity: exploring the industry 4.0 technology-performance link", *International Journal of Production Economics*, Vol. 263, p. 108949.

Barney, J. (1991), "Firm resources and sustained competitive advantage", *Journal of Management*, Vol. 17 No. 1, pp. 99-120.

Bechtsis, D., Tsolakis, N., Iakovou, E. and Vlachos, D. (2021), "Data-driven secure, resilient and sustainable supply chains: gaps, opportunities, and a new generalised data sharing and data monetisation framework", *International Journal of Production Research*, Vol. 60 No. 14, pp. 1-21.

Bergh, D.D., Ketchen, D.J., Orlandi, I., Heugens, P.P. and Boyd, B.K. (2019), "Information asymmetry in management research: past accomplishments and future opportunities", *Journal of Management*, Vol. 45 No. 1, pp. 122-158.

Babich, V. and Hilary, G. (2020), "OM forum—distributed ledgers and operations: what operations management researchers should know about blockchain technology", *Manufacturing & Service Operations Management*, Vol. 22 No. 2, pp. 223-240.

Barthélemy, J. and Quélin, B.V. (2006), "Complexity of outsourcing contracts and ex post transaction costs: an empirical investigation", *Journal of Management Studies*, Vol. 43 No. 8, pp. 1775-1797.

Bohnsack, R., Kurtz, H. and Hanelt, A. (2021), "Re-examining path dependence in the digital age: the evolution of connected car business models", *Research Policy*, Vol. 50 No. 9, p. 104328.

Bouncken, R.B. and Kraus, S. (2013), "Innovation in knowledge-intensive industries: the double-edged sword of coopetition", *Journal of Business Research*, Vol. 66 No. 10, pp. 2060-2070.

Busse, C., Kach, A. and Wagner, S. (2017), "Boundary conditions: what they are, how to explore them, why we need them, and when to consider them", *Organizational Research Methods*, Vol. 20 No. 4, pp. 574-609.

Calatayud, A., Mangan, J. and Christopher, M. (2018), "The self-thinking supply chain", *Supply Chain Management: An International Journal*, Vol. 24 No. 1.

Cannas, V.G., Ciano, M.P., Saltalamacchia, M. and Secchi, R. (2023), "Artificial intelligence in supply chain and operations management: a multiple case study research", *International Journal of Production Research*, Vol. 62 No. 9, pp. 1-28.

Cepa, K. (2021), "Understanding interorganizational big data technologies: how technology adoption motivations and technology design shape collaborative dynamics", *Journal of Management Studies*, Vol. 58 No. 7, pp. 1761-1799.

Carter, C.R., Rogers, D.S. and Choi, T.Y. (2015), "Toward the theory of the supply chain", *Journal of Supply Chain Management*, Vol. 51 No. 2, pp. 89-97.

Cecere, L. (2022), "Tradelens discontinues operations. why you should care", Forbes, available at: www.forbes.com/sites/loracecere/2022/12/05/tradelens-discontinues-operations-why-you-should-care/?sh=5b5829204cec (accessesed: 11 February 2023).

Chen, Y., Visnjic, I., Parida, V. and Zhang, Z. (2021), "On the road to digital servitization–the (dis) continuous interplay between business model and digital technology", *International Journal of Operations & Production Management*, Vol. 41 No. 5, pp. 694-722.

Choi, T.Y. and Kim, Y. (2008), "Structural embeddedness and supplier management: a network perspective", *Journal of Supply Chain Management*, Vol. 44 No. 4, pp. 5-13.

Choi, T.Y., Dooley, K.J. and Rungtusanatham, M. (2001), "Supply networks and complex adaptive systems: control versus emergence", *Journal of Operations Management*, Vol. 19 No. 3, pp. 351-366.

Choudhury, V. and Sampler, J.L. (1997), "Information specificity and environmental scanning: an economic perspective", *MIS Quarterly*, Vol. 21 No. 1, pp. 25-53.

Coase, R.H. (1937), "The nature of the firm", *Economica*, Vol. 4 No. 16, pp. 386-405.

Colicchia, C., Creazza, A., Noè, C. and Strozzi, F. (2019), "Information sharing in supply chains: a review of risks and opportunities using the systematic literature network analysis (SLNA)", *Supply Chain Management: An International Journal*, Vol. 24 No. 1, pp. 5-21.

Corallo, A., Lazoi, M. and Lezzi, M. (2020), "Cybersecurity in the context of industry 4.0: a structured classification of critical assets and business impacts", *Computers in Industry*, Vol. 114, p. 103165.

Culot, G., Nassimbeni, G., Orzes, G. and Sartor, M. (2020a), "Behind the definition of industry 4.0: analysis and open questions", *International Journal of Production Economics*, Vol. 226, p. 107617.

Culot, G., Orzes, G., Sartor, M. and Nassimbeni, G. (2020b), "The future of manufacturing: a Delphi-based scenario analysis on industry 4.0", *Technological Forecasting and Social Change*, Vol. 157, p. 120092.

Davis, G.F. and Cobb, J.A. (2010), "Resource dependence theory: Past and future", *Stanford's organization theory renaissance, 1970–2000*, Emerald Group Publishing, Bingley.

Dalenogare, L.S., Le Dain, M.A., Benitez, G.B., Ayala, N.F. and Frank, A.G. (2022), "Multichannel digital service delivery and service ecosystems: the role of data integration within smart Product-Service systems", *Technological Forecasting and Social Change*, Vol. 183, p. 121894.

De Prieëlle, F., De Reuver, M. and Rezaei, J. (2020), "The role of ecosystem data governance in adoption of data platforms by internet-of-Things data providers: case of Dutch horticulture industry", *IEEE Transactions on Engineering Management*.

DiMaggio, P.J. and Powell, W.W. (1983), "The iron cage revisited: institutional isomorphism and collective rationality in organizational fields", *American Sociological Review*, Vol. 48 No. 2, pp. 147-160.

Dolgui, A. and Ivanov, D. (2022), "5G in digital supply chain and operations management: fostering flexibility, end-to-end connectivity and real-time visibility through internet-of-everything", *International Journal of Production Research*, Vol. 60 No. 2, pp. 442-451.

Dubin, R. (1969), *Theory Building*, Free Press, New York, NY.

Dubois, A. and Gadde, L.E. (2002), "Systematic combining: an abductive approach to case research", *Journal of Business Research*, Vol. 55 No. 7, pp. 553-560.

Dubois, A. and Gibbert, M. (2010), "From complexity to transparency: managing the interplay between theory, method and empirical phenomena in IMM case studies", *Industrial Marketing Management*, Vol. 39 No. 1, pp. 129-136.

Dyer, J.H. and Singh, H. (1998), "The relational view: cooperative strategy and sources of interorganizational competitive advantage", *The Academy of Management Review*, Vol. 23 No. 4, pp. 660-679.

Eisenhardt, K.M. (1989a), "Agency theory: an assessment and review", *The Academy of Management Review*, Vol. 14 No. 1, pp. 57-74.

Eisenhardt, K.M. (1989b), "Building theories from case study research", *The Academy of Management Review*, Vol. 14 No. 4, pp. 532-550.

Eriksson, P. and Kovalainen, A. (2008), "Case study research", *Qualitative Methods in Business Research*, Sage Publications, London, pp. 115-136.

Estrada, I., Faems, D. and de Faria, P. (2016), "Coopetition and product innovation performance: the role of internal knowledge sharing mechanisms and formal knowledge protection mechanisms", *Industrial Marketing Management*, Vol. 53, pp. 56-65.

Fawcett, S.E. and Magnan, G.M. (2002), "The rhetoric and reality of supply chain integration", *International Journal of Physical Distribution & Logistics Management*, Vol. 32 No. 5, pp. 339-361.

Fawcett, S.E., Osterhaus, P., Magnan, G.M., Brau, J.C. and McCarter, M.W. (2007), "Information sharing and supply chain performance: the role of connectivity and willingness", *Supply Chain Management: An International Journal*, Vol. 12 No. 5, pp. 358-368.

Fawcett, S.E., Wallin, C., Allred, C., Fawcett, A.M. and Magnan, G.M. (2011), "Information technology as an enabler of supply chain collaboration: a dynamic-capabilities perspective", *Journal of Supply Chain Management*, Vol. 47 No. 1, pp. 38-59.

Franzè, C., Paolucci, E. and Pessot, E. (2024), "Sustained value creation driven by digital connectivity: a multiple case study in the mechanical components industry", *Technovation*, Vol. 129, p. 102918.

Forrester, J.W. (1958), "Industrial dynamics. A major breakthrough for decision makers", *Harvard Business Review*, Vol. 36 No. 4, pp. 37-66.

Frank, A.G., Dalenogare, L.S. and Ayala, N.F. (2019), "Industry 4.0 technologies: implementation patterns in manufacturing companies", *International Journal of Production Economics*, Vol. 210, pp. 15-26.

Frohlich, M.T. (2002), "E-integration in the supply chain: barriers and performance", *Decision Sciences*, Vol. 33 No. 4, pp. 537-556.

Galbraith, J.R. (1974), "Organization design: an information processing view", *Interfaces*, Vol. 4 No. 3, pp. 28-36.

Ganesh, M., Raghunathan, S. and Rajendran, C. (2013), "Distribution and equitable sharing of value from information sharing within serial supply chains", *IEEE Transactions on Engineering Management*, Vol. 61 No. 2, pp. 225-236.

Gast, J., Gundolf, K., Harms, R. and Collado, E.M. (2019), "Knowledge management and coopetition: how do cooperating competitors balance the needs to share and protect their knowledge?", *Industrial Marketing Management*, Vol. 77, pp. 65-74.

Gereffi, G., Humphrey, J. and Sturgeon, T. (2005), "The governance of global value chains", *Review of International Political Economy*, Vol. 12 No. 1, pp. 78-104.

Gibbert, M. and Ruigrok, W. (2010), "The 'what' and 'how' of case study rigor: three strategies based on published work", *Organizational Research Methods*, Vol. 13 No. 4, pp. 710-737.

Goodhue, D.L., Wybo, M.D. and Kirsch, L.J. (1992), "The impact of data integration on the costs and benefits of information systems", *MIS Quarterly*, Vol. 16 No. 3, pp. 293-311.

Grant, R.M. (1996), "Toward a knowledge-based theory of the firm", *Strategic Management Journal*, Vol. 17 No. S2, pp. 109-122.

Grant, R.M. and Baden-Fuller, C. (2004), "A knowledge accessing theory of strategic alliances", *Journal of Management Studies*, Vol. 41 No. 1, pp. 61-84.

Gregory, R.W., Henfridsson, O., Kaganer, E. and Kyriakou, H. (2021), "The role of artificial intelligence and data network effects for creating user value", *Academy of Management Review*, Vol. 46 No. 3, pp. 534-551.

Gregory, R.W., Henfridsson, O., Kaganer, E. and Kyriakou, H. (2022), "Data network effects: key conditions, shared data, and the data value duality", *Academy of Management Review*, Vol. 47 No. 1, pp. 189-192.

Gulati, R. and Sytch, M. (2007), "Dependence asymmetry and joint dependence in interorganizational relationships: effects of embeddedness on a manufacturer's performance in procurement relationships", *Administrative Science Quarterly*, Vol. 52 No. 1, pp. 32-69.

Gulati, R., Nohria, N. and Zaheer, A. (2000), "Strategic networks", *Strategic Management Journal*, Vol. 21 No. 3, pp. 203-215.

Gulati, R., Puranam, P. and Tushman, M. (2012), "Meta-organization design: rethinking design in interorganizational and community contexts", *Strategic Management Journal*, Vol. 33 No. 6, pp. 571-586.

Hasija, A. and Esper, T.L. (2022), "In artificial intelligence (AI) we trust: a qualitative investigation of AI technology acceptance", *Journal of Business Logistics*, Vol. 43 No. 3, pp. 388-412.

Halinen, A. and Törnroos, J.Å. (2005), "Using case methods in the study of contemporary business networks", *Journal of Business Research*, Vol. 58 No. 9, pp. 1285-1297.

Hanelt, A., Bohnsack, R., Marz, D. and Antunes Marante, C. (2021), "A systematic review of the literature on digital transformation: insights and implications for strategy and organizational change", *Journal of Management Studies*, Vol. 58 No. 5, pp. 1159-1197.

Harland, C.M., Caldwell, N.D., Powell, P. and Zheng, J. (2007), "Barriers to supply chain information integration: SMEs adrift of eLands", *Journal of Operations Management*, Vol. 25 No. 6, pp. 1234-1254.

Hart, P. and Saunders, C. (1997), "Power and trust: critical factors in the adoption and use of electronic data interchange", *Organization Science*, Vol. 8 No. 1, pp. 23-42.

Hartley, J.L. and Sawaya, W.J. (2019), "Tortoise, not the hare: digital transformation of supply chain business processes", *Business Horizons*, Vol. 62 No. 6, pp. 707-715.

Hendriksen, C. (2023), "AI for supply chain management: disruptive innovation or innovative disruption?", *Journal of Supply Chain Management*, Vol. 59 No. 3, pp. 65-76.

Hernández-Espallardo, M., Rodríguez-Orejuela, A. and Sánchez-Pérez, B.J. (2010), "Interorganizational governance, learning and performance in supply chains", *Supply Chain Management: An International Journal*, Vol. 15 No. 2, pp. 101-114.

Hillman, A.J., Withers, M.C. and Collins, B.J. (2009), "Resource dependence theory: a review", *Journal of Management*, Vol. 35 No. 6, pp. 1404-1427.

Holland, J.H. (1995), *Hidden Order*, Addison-Wesley, Reading, MA.

Holmström, J., Holweg, M., Lawson, B., Pil, F.K. and Wagner, S.M. (2019), "The digitalization of operations and supply chain management: theoretical and methodological implications", *Journal of Operations Management*, Vol. 65 No. 8, pp. 728-734.

Huang, Y., Han, W. and Macbeth, D.K. (2020), "The complexity of collaboration in supply chain networks", *Supply Chain Management: An International Journal*, Vol. 25 No. 3, pp. 393-410.

Im, G. and Rai, A. (2008), "Knowledge sharing ambidexterity in long-term interorganizational relationships", *Management Science*, Vol. 54 No. 7, pp. 1281-1296.

Iskandar, B.Y., Kurokawa, S. and LeBlanc, L.J. (2001), "Adoption of electronic data interchange: the role of buyer-supplier relationships", *IEEE Transactions on Engineering Management*, Vol. 48 No. 4, pp. 505-517.

Kache, F. and Seuring, S. (2017), "Challenges and opportunities of digital information at the intersection of big data analytics and supply chain management", *International Journal of Operations & Production Management*, Vol. 37 No. 1.

Kamble, S.S., Gunasekaran, A., Ghadge, A. and Raut, R. (2020), "A performance measurement system for industry 4.0 enabled smart manufacturing system in SMMEs-a review and empirical investigation", *International Journal of Production Economics*, Vol. 229, p. 107853.

Katz, D. and Kahn, R.L. (1978), *The Social Psychology of Organizations*, 2nd ed., Wiley, New York, NY.

Kembro, J. and Näslund, D. (2014), "Information sharing in supply chains, myth or reality? A critical analysis of empirical literature", *International Journal of Physical Distribution & Logistics Management*, Vol. 44 No. 3, pp. 179-200.

Kembro, J., Selviaridis, K. and Näslund, D. (2014), "Theoretical perspectives on information sharing in supply chains: a systematic literature review and conceptual framework", *Supply Chain Management: An International Journal*, Vol. 19 Nos 5/6, pp. 609-625.

Kembro, J., Näslund, D. and Olhager, J. (2017), "Information sharing across multiple supply chain tiers: a Delphi study on antecedents", *International Journal of Production Economics*, Vol. 193, pp. 77-86.

Ketokivi, M. (2006), "Elaborating the contingency theory of organizations: the case of manufacturing flexibility strategies", *Production and Operations Management*, Vol. 15 No. 2, pp. 215-228.

Ketokivi, M. and Choi, T. (2014), "Renaissance of case research as a scientific method", *Journal of Operations Management*, Vol. 32 No. 5, pp. 232-240.

Kiel, D., Arnold, C. and Voigt, K.I. (2017), "The influence of the industrial internet of things on business models of established manufacturing companies–a business level perspective", *Technovation*, Vol. 68, pp. 4-19.

Klein, R. and Rai, A. (2009), "Interfirm strategic information flows in logistics supply chain relationships", *MIS Quarterly*, Vol. 33 No. 4, pp. 735-762.

Klöckner, M., Schmidt, C.G. and Wagner, S.M. (2022), "When blockchain creates shareholder value: empirical evidence from international firm announcements", *Production and Operations Management*, Vol. 31 No. 1, pp. 46-64.

Kouhizadeh, M., Saberi, S. and Sarkis, J. (2021), "Blockchain technology and the sustainable supply chain: theoretically exploring adoption barriers", *International Journal of Production Economics*, Vol. 231, p. 107831.

Larson, A. (1992), "Network dyads in entrepreneurial settings: a study of the governance of exchange relationships", *Administrative Science Quarterly*, Vol. 37 No. 1, pp. 76-104.

Lavie, D. (2006), "The competitive advantage of interconnected firms: an extension of the resource-based view", *Academy of Management Review*, Vol. 31 No. 3, pp. 638-658.

Lawson, B., Petersen, K.J., Cousins, P.D. and Handfield, R.B. (2009), "Knowledge sharing in interorganizational product development teams: the effect of formal and informal socialization mechanisms", *Journal of Product Innovation Management*, Vol. 26 No. 2, pp. 156-172.

Lee, I. and Lee, K. (2015), "The internet of things (IoT): applications, investments, and challenges for enterprises", *Business Horizons*, Vol. 58 No. 4, pp. 431-440.

Legenvre, H. and Hameri, A.P. (2023), "The emergence of data sharing along complex supply chains", *International Journal of Operations & Production Management*, Vol. 44 No. 1.

Lockström, M., Schadel, J., Harrison, N., Moser, R. and Malhotra, M.K. (2010), "Antecedents to supplier integration in the automotive industry: a multiple-case study of foreign subsidiaries in China", *Journal of Operations Management*, Vol. 28 No. 3, pp. 240-256.

Lu, G. and Shang, G. (2017), "Impact of supply base structural complexity on financial performance: roles of visible and not-so-visible characteristics", *Journal of Operations Management*, Vol. 53-56 No. 1, pp. 23-44.

Mathivathanan, D., Mathiyazhagan, K., Rana, N.P., Khorana, S. and Dwivedi, Y.K. (2021), "Barriers to the adoption of blockchain technology in business supply chains: a total interpretive structural modelling (TISM) approach", *International Journal of Production Research*, Vol. 59 No. 11, pp. 3338-3359.

Marston, S., Li, Z., Bandyopadhyay, S., Zhang, J. and Ghalsasi, A. (2011), "Cloud computing—the business perspective", *Decision Support Systems*, Vol. 51 No. 1, pp. 176-189.

McKinsey & Company (2021), "Overcoming barriers to multitier supplier collaboration", available at: www.mckinsey.com/business-functions/operations/our-insights/overcoming-barriers-to-multitier-supplier-collaboration (Last accessed January 2023).

Mele, C., Pels, J. and Polese, F. (2010), "A brief review of systems theories and their managerial applications", *Service Science*, Vol. 2 Nos 1/2, pp. 126-135.

Mena, C., Humphries, A. and Choi, T.Y. (2013), "Toward a theory of multi-tier supply chain management", *Journal of Supply Chain Management*, Vol. 49 No. 2, pp. 58-77.

Meredith, J. (1998), "Building operations management theory through case and field research", *Journal of Operations Management*, Vol. 16 No. 4, pp. 441-454.

Merton, R.K. (1957), "Priorities in scientific discovery: a chapter in the sociology of science", *American Sociological Review*, Vol. 22 No. 6, pp. 635-659.

Miles, M.B. and Huberman, A.M. (1994), *Qualitative Data Analysis: An Expanded Sourcebook*, Sage.

Mindlin, S.E. and Aldrich, H. (1975), "Interorganizational dependence: a review of the concept and a reexamination of the findings of the Aston group", *Administrative Science Quarterly*, Vol. 20 No. 3, pp. 382-392.

Mintzberg, H. (1977), "Strategy formulation as a historical process", *International Studies of Management & Organization*, Vol. 7 No. 2, pp. 28-40.

Mitnick, B.M. (1975), "The theory of agency", *Public Choice*, Vol. 24 No. 1, pp. 27-42.

Mohamad, M. and Songthaveephol, V. (2020), "Clash of titans: the challenges of socio-technical transitions in the electrical vehicle technologies–the case study of Thai automotive industry", *Technological Forecasting and Social Change*, Vol. 153, p. 119772.

Müller, J.M., Buliga, O. and Voigt, K.I. (2018), "Fortune favors the prepared: how SMEs approach business model innovations in industry 4.0", *Technological Forecasting and Social Change*, Vol. 132, pp. 2-17.

Müller, J.M., Veile, J.W. and Voigt, K.I. (2020), "Prerequisites and incentives for digital information sharing in industry 4.0–an international comparison across data types", *Computers & Industrial Engineering*, Vol. 148, p. 106733.

Münch, C., Marx, E., Benz, L., Hartmann, E. and Matzner, M. (2022), "Capabilities of digital servitization: evidence from the socio-technical systems theory", *Technological Forecasting and Social Change*, Vol. 176, p. 121361.

Nandi, M.L., Nandi, S., Moya, H. and Kaynak, H. (2020), "Blockchain technology-enabled supply chain systems and supply chain performance: a resource-based view", *Supply Chain Management: An International Journal*, Vol. 25 No. 6.

Narasimhan, R. and Kim, S.W. (2001), "Information system utilization strategy for supply chain integration", *Journal of Business Logistics*, Vol. 22 No. 2, pp. 51-75.

Novais, L., Maqueira, J.M. and Ortiz-Bas, Á. (2019), "A systematic literature review of cloud computing use in supply chain integration", *Computers & Industrial Engineering*, Vol. 129, pp. 296-314.

OECD (2017), *The Next Production Revolution: Implications for Government and Business*, OECD Publishing, Paris.

OECD (2019). Enhancing Access to and Sharing of Data. Reconciling Risks and Benefits for Data Re-use across Societies, Organization for Economic Cooperation and Development, available at: www.oecd.org/publications/enhancing-access-to-and-sharing-of-data-276aaca8-en.htm (accessed January 2023).

Paolucci, E., Pessot, E. and Ricci, R. (2021), "The interplay between digital transformation and governance mechanisms in supply chains: evidence from the Italian automotive industry", *International Journal of Operations & Production Management*, Vol. 41 No. 7, pp. 1119-1144.

Patton, M.Q. (2002), *Qualitative Research & Evaluation Methods*, Sage, London.

Peerally, J.A., Santiago, F., De Fuentes, C. and Moghavvemi, S. (2022), "Towards a firm-level technological capability framework to endorse and actualize the fourth industrial revolution in developing countries", *Research Policy*, Vol. 51 No. 10, p. 104563.

Pessot, E., Zangiacomi, A. and Fornasiero, R. (2022), "Unboxing the hyper-connected supply chain: a case study in the furniture industry", *Production Planning & Control*, Vol. 35 No. 6, pp. 1-19.

Peteraf, M.A. (1993), "The cornerstones of competitive advantage: a resource-based view", *Strategic Management Journal*, Vol. 14 No. 3, pp. 179-191.

Pfeffer, J. and Salancik, G.R. (1978), *The External Control of Organizations: A Resource Dependence Perspective*, Harper & Row, New York, NY.

Porter, M.E. and Heppelmann, J.E. (2015), "How smart, connected products are transforming companies", *Harvard Business Review*, Vol. 93 No. 10, pp. 96-114.

Ritala, P. and Hurmelinna-Laukkanen, P. (2013), "Incremental and radical innovation in coopetition—the role of absorptive capacity and appropriability", *Journal of Product Innovation Management*, Vol. 30 No. 1, pp. 154-169.

Ritala, P., Olander, H., Michailova, S. and Husted, K. (2015), "Knowledge sharing, knowledge leaking and relative innovation performance: an empirical study", *Technovation*, Vol. 35, pp. 22-31.

Salvetat, D., Géraudel, M. and d'Armagnac, S. (2013), "Inter-organizational knowledge management in a coopetitive context in the aeronautic and space industry", *Knowledge Management Research & Practice*, Vol. 11 No. 3, pp. 265-277.

Sampler, J.L. (1998), "Redefining industry structure for the information age", *Strategic Management Journal*, Vol. 19 No. 4, pp. 343-355.

Sauer, P.C., Orzes, G. and Culot, G. (2022), "Blockchain in supply chain management: a multiple case study analysis on setups, contingent factors, and evolutionary patterns", *Production Planning & Control*, pp. 1-16.

Shapiro, S.P. (2005), "Agency theory", *Annual Review of Sociology*, Vol. 31 No. 1, pp. 263-284.

Silverman, D. (2005), *Doing Qualitative Research*, Sage, London.

Sodero, A.C., Rabinovich, E. and Sinha, R.K. (2013), "Drivers and outcomes of open-standard interorganizational information systems assimilation in high-technology supply chains", *Journal of Operations Management*, Vol. 31 No. 6, pp. 330-344.

Sodhi, M.S., Seyedghorban, Z., Tahernejad, H. and Samson, D. (2022), "Why emerging supply chain technologies initially disappoint: blockchain, IoT, and AI", *Production and Operations Management*, Vol. 31 No. 6, pp. 2517-2537.

Soekijad, M. and Andriessen, E. (2003), "Conditions for knowledge sharing in competitive alliances", *European Management Journal*, Vol. 21 No. 5, pp. 578-587.

Srinivasan, R. and Swink, M. (2018), "An investigation of visibility and flexibility as complements to supply chain analytics: an organizational information processing theory perspective", *Production and Operations Management*, Vol. 27 No. 10, pp. 1849-1867.

Suddaby, R. (2010), "Editor's comments: construct clarity in theories of management and organization", *Academy of Management Review*, Vol. 35 No. 3, pp. 346-357.

Sun, Y. and Zhai, Y. (2018), "Mapping the knowledge domain and the theme evolution of appropriability research between 1986 and 2016: a scientometric review", *Scientometrics*, Vol. 116 No. 1, pp. 203-230.

Teece, D.J., Pisano, G. and Shuen, A. (1997), "Dynamic capabilities and strategic management", *Strategic Management Journal*, Vol. 18 No. 7, pp. 509-533.

Tushman, M.L. and Nadler, D.A. (1978), "Information processing as an integrating concept in organizational design", *The Academy of Management Review*, Vol. 3 No. 3, pp. 613-624.

Voss, C., Nikos, T. and Frohlich, M. (2002), "Case research in operations management", *International Journal of Operations & Production Management*, Vol. 22 No. 2, pp. 195-219.

Waller, M.A. and Fawcett, S.E. (2013), "Data science, predictive analytics, and big data: a revolution that will transform supply chain design and management", *Journal of Business Logistics*, Vol. 34 No. 2, pp. 77-84.

Wernerfelt, B. (1984), "A resource-based view of the firm", *Strategic Management Journal*, Vol. 5 No. 2, pp. 171-180.

WEF (2020), "Share to gain: unlocking data value in manufacturing", World Economic Forum, available at: www.weforum.org/whitepapers/share-to-gain-unlocking-data-value-in-manufacturing/, last (accessed January 2023).

Wiengarten, F., Humphreys, P., Cao, G., Fynes, B. and McKittrick, A. (2010), "Collaborative supply chain practices and performance: exploring the key role of information quality", *Supply Chain Management: An International Journal*, Vol. 15 No. 6, pp. 463-473.

Williamson, O.E. (1985), *The Economic Institutions of Capitalism*, The Free Press, New York, NY.

Wry, T., Cobb, J.A. and Aldrich, H.E. (2013), "More than a metaphor: assessing the historical legacy of resource dependence and its contemporary promise as a theory of environmental complexity", *Academy of Management Annals*, Vol. 7 No. 1, pp. 441-488.

Yang, Z., Zhang, H. and Xie, E. (2017), "Relative buyer-supplier relational strength and supplier's information sharing with the buyer", *Journal of Business Research*, Vol. 78, pp. 303-313.

Ye, F., Liu, K., Li, L., Lai, K.H., Zhan, Y. and Kumar, A. (2022), "Digital supply chain management in the COVID-19 crisis: an asset orchestration perspective", *International Journal of Production Economics*, Vol. 245, p. 108396.

Yigitbasioglu, O.M. (2010), "Information sharing with key suppliers: a transaction cost theory perspective", *International Journal of Physical Distribution & Logistics Management*, Vol. 40 No. 7, pp. 550-578.

Yin, R.K. (2018), *Case Study Research: Design and Methods*, Sage, Thousand Oaks, CA.

Zaheer, N. and Trkman, P. (2017), "An information sharing theory perspective on willingness to share information in supply chains", *The International Journal of Logistics Management*, Vol. 28 No. 2, pp. 417-443, doi: 10.1108/IJLM-09-2015-0158.

Zhao, K., Xia, M. and Shaw, M.J. (2007), "An integrated model of consortium-based e-business standardization: collaborative development and adoption with network externalities", *Journal of Management Information Systems*, Vol. 23 No. 4, pp. 247-271.

Zhou, L., Jiang, Z., Geng, N., Niu, Y., Cui, F., Liu, K. and Qi, N. (2022), "Production and operations management for intelligent manufacturing: a systematic literature review", *International Journal of Production Research*, Vol. 60 No. 2, pp. 808-846.

Zhu, K., Kraemer, K., Gurbaxani, V. and Xu, S. (2006), "Migration to open-standard interorganizational systems: network effects, switching costs, and path dependency", *MIS Quarterly*, Vol. 30 No. I, pp. 515-539.

Supply Chain Management: An International Journal
Volume 29 · Number 7 · 2024 · 1–27

Appendix

Table A1 Case study protocol

Section	Protocol questions
1. Background	a. Please, describe the company in terms of: • Turnover, employees, product/service offering and business lines, main clients, geographies served • Strategy and main competitors by business line • Network of relations (main suppliers, customers, technology providers, consortia or alliances, platforms) • In- vs outsourcing of key activities • DT strategy, implementation of key enabling technologies, concurrent changes in the business model b. Describe your role and your involvement in the implementation of digital projects
2. Technology-enabled data sharing practices	a. Please, describe the type/direction of the data flow, type of business partner involved, characteristics of the relationship, underpinning technology, rationale for sharing. Highlight how these flows were impacted by emerging technologies over the last 5/10 years, considering: • Suppliers and upstream partners and intermediaries • Customers and downstream partners and intermediaries • Technology providers (including machinery and equipment manufacturers, digital companies) • Others (e.g. competitors, industry consortia, alliances, platforms) b. Is there any plan to implement other interorganizational data sharing projects in the next few years? c. Were there any missed opportunities for higher data sharing? • Promoted by the company toward external players • The company was invited but did not take part
3. Drivers, barriers and implementation process	a. Please, reflect upon: • The main drivers of the recent (5/10 years) changes in interorganizational data sharing practices • The main barriers of the recent (5/10 years) missed opportunities in interorganizational data sharing practices b. What were the main challenges the company needed to overcome during the implementation process?
4. Implications	a. Did some reconfiguration of the network of business relations happen in relation to changes in interorganizational data sharing practices? (e.g. in- vs out-sourcing, new suppliers/clients) If yes, why? b. Changes in performance • Did company experience some (positive/negative) changes in performance? How? • Were these in line with expectations? If not, why?

Source: Author’s own creation

Corresponding author

Giovanna Culot can be contacted at:giovanna.culot@uniud.it