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Sharing Information Across Company Borders in Industry 4.0

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Purpose: Industry 4.0's potentials can only unfold exhaustively if information is shared across company boarders and along supply chains. Exchanging information, however, implies several challenges for companies. This holds especially true if it is transmitted automatically and digitally, as promoted by the concept of Industry 4.0. In response to these challenges, this paper analyzes how information sharing changes in Industry 4.0 contexts.

Methodology: Expert interviews with 17 representatives from supply chain management departments of German industrial enterprises provide the study's database. Hereby, the renowned SCOR-model serves as a theoretical foundation to classify the insights gained during the interviews.

Findings: The types of information shared in supply chains, changes in the way information is shared, and initiatives to intensify information exchange in Industry 4.0 contexts are identified. These findings are analyzed against the background of the SCOR-dimensions plan, source, make, deliver and return.

Originality: Information sharing, a vital basis for intended horizontal and vertical integration within the concept of Industry 4.0 has scarcely been investigated in extant literature.

Keywords: Industry 4.0, Industrial Internet of Things, Supply Chain Management, Information Sharing

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1 Introduction

Industry 4.0 refers to the horizontal and vertical digitization and interconnection of industrial value creation. It provokes numerous potentials, which constitute the base for future competitiveness of manufacturing companies (Kagermann et al., 2013; Lasi et al., 2014). A fruitful horizontal and vertical interconnection requires adequate information sharing across company borders and along supply chains. This causes several concerns and thus reluctant behavior of all relevant supply chain actors, especially small and medium-sized enterprises (SMEs) (Kagermann et al., 2013; Müller et al., 2017; Voigt et al., 2019).

So far, academia and corporate practice have regarded and analyzed Industry 4.0 mainly within a company's boundaries. Despite Industry 4.0's supply chain spanning and interconnecting nature, until recently research studies predominantly have focused on company-internal and technical aspects (Birkel et al., 2019; Müller et al., 2018a). Information sharing in supply chains within an Industry 4.0 context and resulting potentials are still not sufficiently permeated and properly understood. However, predicted potentials of intelligent and interconnected value-adding processes can only be exploited entirely if supply chain partners share information virtually, interconnected by digital means (Kagermann et al., 2013; Lasi et al., 2014). Further, sharing information is fundamental to cross-company cooperation in the context of Industry 4.0. For these reasons, analyzing the topic is of utmost importance.

Motivated by the research gap along with its practical implications, this paper's research question is: How does information sharing between companies and along supply chains change in an Industry 4.0 context?

It contributes to the current state of research by analyzing the types of information shared along supply chains, changes in the way information is shared, and initiatives to intensify information exchange in Industry 4.0

The study is of qualitative-empirical nature and bases on 17 expert interviews. These were conducted with supply chain representatives from a heterogeneous set of German industrial companies. The SCOR-model is applied to found the study theoretically and to classify the insights obtained from the empirical data.

The remainder of the paper is structured as follows. First, the theoretical fundament is outlined, which depicts Industry 4.0, supplier integration, and the Supply Chain Operations Reference (SCOR) Model. Hereafter, the methodology, dealing with research design, data sample, and analysis is presented. Subsequently, the results are illustrated, interpreted and discussed using the SCOR-Model as a theoretical framework. The paper concludes with theoretical and managerial implications and indicates proposals for future research.

2 Theoretical background

2.1 Industry 4.0

Industry 4.0 implies a transformation of future industrial value creation based on the ongoing digitization and wide-ranging interconnection. This development is characterized by a horizontal and vertical digital integration of value creation actors (Kagermann et al., 2013; Lasi et al., 2014).

It is widely agreed upon that, the global economy is on the edge of a fourth industrial revolution, heralding a paradigm shift of industrial value creation. Main technological drivers for this development are cyber-physical systems and the Internet of Things. This is why the term "Industrial Internet of Things" is frequently used synonymously to Industry 4.0 (Kagermann et al., 2013; Müller & Voigt, 2018). Given future intelligent, digitally interconnected systems in industrial value creation, products, people, machines, and facilities are enabled to communicate and cooperate in real-time. Following its extensive implications for industrial value creation, Industry 4.0 paves the way for companies to create new business models (Müller et al., 2018b; Voigt et al., 2017).

According to Platform Industry 4.0 (2017), Industry 4.0 is "a new level of organization and control of the entire value chain across the life cycle of products". As it aims at horizontally and vertically interconnecting value creation, digitalization and interconnection efforts do not only cover single corporate functions, but also individual companies, their internal value creation processes, just like global value chains (Kagermann et al., 2013).

2.2 Supplier integration

Representing a form of vertical cooperation, the concept of "supplier integration", as part of supply chain management, refers to strategic and operational cooperation efforts along the supply chain. These relate to both suppliers and customers and aim at generating and securing competitive advantages (Helmold & Terry, 2016; Schoenherr & Swink, 2012; Wiengarten et al., 2016). Main prerequisite for a successful supplier integration is systematic and strategic collaboration within a company and between different companies, interlinking internal processes with external suppliers (Fazli & Afshar, 2014; Zhao et al., 2011).

The overall strategic goal of supplier integration is contributing to a company's value creation, by managing the supplier network in an efficient manner, securing demand, and decreasing supply chain costs (Helmold & Terry, 2016). In order to fulfill this objective, supplier integration intends to adequately and properly set up value creation processes, cross-company handling practices, cooperation efforts, and integration strategies, hereby sharing both chances and risks along the value creation chain (So & Sun, 2010; Zhao et al., 2015).

Supplier integration requires financial resources, people, systems, and facilities to be coordinated and harmonized on operational, tactical, and strategical levels (Stevens, 1989). The concept can draw on numerous tools, among others, IT applications related to planning and e-business systems (So & Sun, 2010).

2.3 Related work

In the era of Industry 4.0, industrial value creation faces major obstacles, such as shortening product development and product life cycles. These in turn require fast, flexible and efficient value creation processes, which emphasizes the importance of supplier integration in the context of Industry 4.0 (Hofbauer et al., 2016).

Integrating suppliers and cooperating across company boarders encompasses major challenges. Especially in the digital era, it requires an indispensable willingness to cooperate and a great candor both from buyers and suppliers, among others (Birkel et al., 2019; Kiel et al., 2017). These characteristics, however, contradict traditional approaches to conduct interactions, exchanges, and processes within present supply chains, like aggressive price negotiations. In addition, supplier integration in the digital era asks for comprehensive technological equipment and facilities, as well as, for adequately reshaping interfaces (Kiel et al., 2017; Müller et al., 2018a). Given that many suppliers are among small and medium-sized companies, particular problems arise, e.g., as for raising resources for the required technologies (Birkel et al., 2019). However, the challenges of how to establish new ways of interaction and cooperation along the supply chain and how to strengthen suppliers' positions remain unsolved (National Research Council, 2000).

Several changes are accompanied by further integrating suppliers. On a strategic level, cooperating with suppliers, conducting common activities, and sharing capabilities paves the way for gaining and securing competitive advantages and for creating new business models (Rink & Wagner, 2007; Voigt et al., 2018). On an operational level, a further supplier integration helps to reduce costs, inventory levels, and lead times, amongst others (Giménez & Ventura, 2003). An increased cost competitiveness, a greater product individualization, a shortening of product development and product life cycles and associated fast, flexible, and efficient production processes within Industry 4.0 increase the importance of supplier integration (Kagermann et al., 2013).

Despite the importance of horizontal and vertical integration within the concept of Industry 4.0, research investigating Industry 4.0 from a supply chain management perspective remains scarce in extant literature (Birkel et al., 2019; Müller et al., 2017). The variety of data types to be exchanged, different standards used across supply chains, and different interfaces that are used represent further challenges for information sharing in Industry 4.0 (Kiel et al., 2017). Adding to technical challenges, aspects such as a lack of trust hinder cross-company information sharing and collaboration. This is especially true of SMEs, who fear that they will not benefit from information sharing, but have to make large efforts to make it possible (Müller et al., 2018a).

Although there is literature on information sharing regardless of Industry 4.0 in extant literature, as shown in the previous section, this literature is only partially applicable to Industry 4.0. This is since information sharing in Industry 4.0 shall be achieved horizontally and vertically and in real-time, which will influence information sharing, innovation, and communication processes (Kagermann et al., 2013; Lasi et al., 2014).

2.4 The Supply Chain Operations Reference (SCOR) Model

The process approach for supply chain integration manifests itself in the Supply Chain Operations Reference Model (SCOR) by the Supply Chain Council, suggesting that businesses should be managed on the basis of key processes (Stewart, 1997).

The Supply Chain Operations Reference Model (SCOR) was developed by two American management consultancies to support companies in the area of supply chain management. It was published on the Supply Chain Council in 1996, which bases on a merger of the aforementioned two consultancies in cooperation with further international companies. The SCOR model represents an approach to describe an organization's supply chain and aims at optimizing business practices (Bolstorff et al., 2007; Stewart, 1997). This normative model enables an independent, effective process assessment and a performance comparison with other companies, both within an industrial sector and across sectors. The dimensions of this model can be applied along the entire supply chain from the supplier's supplier, all the way up to the customer's customer.

The SCOR model maps process elements, performance metrics, best business practices, and characteristics of carrying out supply chain activities at four levels (Stewart, 1997):

- Level one ("Process Types") concretizes a company's supply chain objectives and maps definitions of the process types "plan", "source", "make", "deliver", and "return".
- Level two ("Process Categories") defines core process categories as possible components of a supply chain.
- Level three ("Process Elements") formulates detailed process element information for categories of Level two, enabling successful planning and definition of objectives.
- Level four ("Activities") aims at company-specific supply chain improvements, which, however, are not subject of the industrial standard model.

This study will focus on the six main strategic processes of Level one, which are briefly outlined below (Bolstorff et al., 2007; Supply Chain Council, 2012):

- Plan: Demand planning concerning available resources and capacities; Inventory planning serving sales, production, and material requirements
- Source: Procurement of goods, goods receipt and testing, storage and payment instructions for raw materials, goods, finished products, and systems
- Make: Material requirement request and material receipt, production and testing of manufactured products, intermediate product storage and release for delivery
- Deliver: Execution of order processing from quotation to delivery of goods, and coordination of the information flow (e.g., data maintenance, control and monitoring of logistical processes)
- Return: Processing of returned products with defects under warranty, handling of over delivery, including receipt, inspection, disposition, and release
- Enable: Management of the supply chain according to business rules, performance, data, operating resources, equipment, contracts, supply chain network, risk management, compliance management, and legal requirements

Figure 1 summarizes the SCOR model.

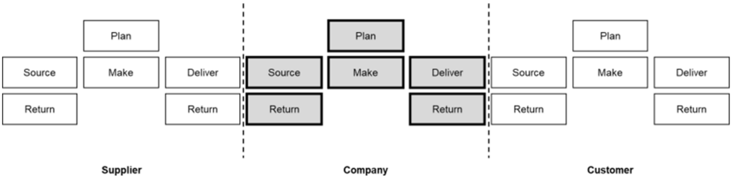

Figure 1: Strategical processes according to SCOR (Supply Chain Council, 2012

3 Methodology

The objective of this study is to analyze how information sharing between companies and along supply chains changes in an Industry 4.0 context, applying a qualitative-empirical research design (Gläser & Laudel, 2010).

The empirical database consists of interviews with 17 experts of German industrial companies. Forming a heterogeneous sample, the interviewed experts are from the areas of supply chain management, procurement, and logistics, holding lower, medium or upper management positions and possessing several years of business experience. The sample comprises German companies from various industry sectors, such as mechanical and plant engineering, automotive, electronics and electrical engineering, information and communication technology, such as chemical and pharmaceutical industry. The sizes of the companies vary from approximately 100 employees to approximately 250,000 employees respectively (data from fiscal year 2018).

The expert interviews took place between November 2018 and February 2019, lasted between 21 to 68 minutes, and were conducted in German via telephone. An interview guideline ensured a partial standardization that allowed to compare and evaluate interviews following common research standards. However, as intended by the study's nature, the interviewer could adopt questions if necessary and experts were allowed to respond openly going beyond the interview guideline, thus all interviews varied slightly in contextual length and depth (Mayring, 2015; Gläser & Laudel, 2010). With the experts' permission, all interviews were audio-recorded. Later on, the audio-files were transcribed yielding about 92 pages of text material that hereafter was analyzed as explained below.

The interviews and the respective transcripts were analyzed applying a qualitative content analysis based on Mayring (2015). Firstly, literal expert statements were paraphrased, secondly the paraphrases were reduced to their core statements, and thirdly, core statements similar in content, were analyzed and consolidated into categories. Hereafter, these categories were analyzed according to their frequency of nominations which represents an indicator for their relevance (Gläser & Laudel, 2010; Mayring, 2015).

4 Results

The results are divided into two parts. The first part consolidates findings about the current exchange of information between buyers and suppliers. The findings on the present situation include 1) ways of exchanging information, 2) types of information exchanged, and 3) frequency of exchange. The second part deals with expected changes in an Industry 4.0 context and focus on 1) the ways of exchanging information in the future, 2) changes to intensify future information exchanges, and 3) automation efforts. All findings are matched to and differentiated according to the main strategic processes of the SCOR model "plan", "source", "make", "deliver", and "return". Hereby the numbers in brackets represent the absolute number of experts indicating these aspects out of the 17 experts within the study's sample.

Table 1 gives an overview of ways and media used for exchanging information between buyers and suppliers in the present as stated by the experts in the different dimensions of the SCOR model.

Table 1: Ways of currently exchanging information

	Plan	**Source**	**Make**	**Deliver**	**Return**	**Not assigned**
E-Mail (17)	1	8	2	2	1	3
EDI Interface (14)	3	5	2	1	1	2
Phone (9)	3	4				2
Personally (9)	4	2				3
Networks and platforms (5)		2	1			2
Visit-on-site of suppliers (5)	2		1	1		1

	Plan	Source	Make	Deliver	Re-turn	Not as-signed
Supplier evaluation (3)	2					1
Direct contact/ Real-time exchange (1)						1
Fax and printed documents (2)		1				1
Mixed sources of information (1)						1

Table 2 depicts the types of information exchanged between buyers and suppliers at different stages of the supply chain.

Table 2: Types of information currently exchanged

	Plan	Source	Make	Deliver	Return	Not as-signed
Orders (6)	1	4	1			
Technical documents/ Specifications (4)	3		1			

	Plan	**Source**	**Make**	**Deliver**	**Return**	**Not assigned**
Information on product, price, conditions, etc. (4)	2	1	1			
Certificates and qualifications (3)	3					
Forecasts (3)	2	1				
Supplier performance (2)	2					
Legal documents and reclamations (2)					2	
Offers (1)		1				
Information about upstream Supply Chain stages (1)			1			
Production data (1)			1			

Table 3 outlines, how often the interviewees get in contact with their suppliers for exchanging information.

Table 3: Current frequency of exchange

	Plan	Source	Make	Deliver	Return	Not assigned
Depending on the situation (4)	1	1	1			1
Depending on the supplier (3)	2		1			
Several times a day (2)	1	1				
Daily (5)	1	1	2			1
Several times a week (1)		1				
Several times a month (1)		1				
Monthly (1)						1

The second part of the results reveals changes as for buyer-supplier information sharing in an Industry 4.0 context.

Table 4 shows the ways information is exchanged in a short to medium termed Industry 4.0 context, categorized in accordance to the SCOR model.

Table 4: Ways of exchanging information in an Industry 4.0 context

	Plan	**Source**	**Make**	**Deliver**	**Return**	**Not assigned**
Networks and platforms (13)	1	2	4	1		5
EDI Interface (3)	1	1				1
Real-time exchange (3)		1	1			1
Big Data (2)	1					1

Table 5 describes the changes in information exchange, which will occur in the next 5 to 10 years that all aim at creating a more intense way of exchanging information.

Table 5: Changes aiming at a more intense information exchange

	Plan	**Source**	**Make**	**Deliver**	**Return**	**Not assigned**
Simplified sharing of information (4)	2	1				1

	Plan	Source	Make	Deliver	Return	Not assigned
Further supplier integration (2)			2			
Matching production data (2)		1	1			
Feedback processes (1)		1				
Forecasts (1)	1					

5 Interpretation and discussion using the SCOR-model

5.1 Plan

From the sample experts' point of view, quality represents a decisive procurement goal and must take precedence over other objectives. Beyond that, further goals include efficiency gains and cost reductions.

Both customers and suppliers can be involved in the product development process. Cooperating with customers helps to integrate customer-specific requirements at an early stage and to test products in collaborative innovation centers during the development. In the same manner, integrating suppliers improves the product development process, e.g., as supplier requirements and capacities can be considered from the very beginning. Innovation platforms ease interactions between various actors and therefore improve value creation, especially against the background of shorter production cycles.

A more precise planning of requirements basing on extensive data use can smooth out demand fluctuations. Pilot projects in corporate practice already apply first approaches that take advantage of comprehensive data to reduce inefficiencies caused by demand fluctuations. Collecting and evaluating different forms of data, such as historical, macroeconomic, and point of sale data, enable a targeted identification of development indications. This paves the way for precise demand forecasts, which counteracts operational inefficiencies.

A data release and transparent data exchange between suppliers and customers simplifies negotiations of delivery conditions on a data-based level, for example, regarding future suppliers' and buyers' expectations. In turn, this allows a potential supplier to analyze whether the requested demand developments can be met in the future. Company representatives can imagine sharing and releasing data with close suppliers within cross-company cooperation. This simplifies planning and ordering processes for customers. However, the results underline that a very good relationship of trust is required and data security is to be guaranteed as a prerequisite.

Price negotiations are an essential part of buyer-supplier discussions and pricing entails further optimization potentials in buyer-supplier relationships in the context of Industry 4.0. By analyzing both historical and present customer data, it is possible to determine which product attributes add the most value for customers. Knowing individual customers' willingness to pay, customer-specific and value-based pricing can be carried out, that allows to optimize margins.

Industry 4.0 can optimize supplier selection and cooperation as well. Apart from this, further potential of Industry 4.0 bases on a automation, traceability, and inter-connecting functional processes.

5.2 Source

Basing on a data- and fact-based planning, the development towards Industry 4.0 offers great benefits for procurement activities. Applying technological solutions, such as cloud systems, big data operations, sensor systems, chips and associated system integration leads to a comprehensive interconnection alongside a high degree of process automation and increased efficiency.

New solutions are required for inventory management in operative purchasing to be able to meet future requirements for flexible delivery of complex products. In the future, real-time data, a further automation of warehouse logistics, and augmented reality could potentially help in this manner. By equipping incoming and outgoing goods with sensors, movements and locations can be mapped in real time, for example using big data and cloud systems. With regard to the analysis of raw materials' usability, the experts see great potential in processing a large amount of data using Big

Data analyses. In addition, goods could autonomously be transported to their destination by means of drones and robots. Using augmented reality, warehouse employees could manage a warehouse both more efficiently and effectively. These solutions may reduce lead times, which ultimately leads to increased customer satisfaction.

Information transparency and data release play an important role for future cross-company value creation. This enables suppliers to carry out early, precise, and efficient production planning, which could have a positive effect on the customers' willingness to pay. Automation of basic and simple procurement processes is particularly desirable. Complex goods, that are of high value, individualized special products, products ordered in large quantities, and transport specifications, should still be negotiated by experienced human buyers. Anyways, the process can be streamlined and simplified through data sharing, while customers and suppliers must agree on the nature and extent of data release and exchange.

5.3 Make

By equipping components in the production process with sensors, their actual states can be digitally mapped in real time. In connection with historical and diagnostic plant data, failure prediction models could be generated, which enable both scheduling optimal maintenance intervals and minimizing downtimes.

There are concepts for generating more accurate forecasts and analyses via a comprehensive data collection in the manufacturing processes. The Virtual Plant concept promises to combine physical process data from production and data from upstream and downstream value creation stages in a digital real-time model to be able to forecast changes in production. Besides, the Virtual Plant concept offers possibilities for simulating changes concerning the processes or workplace design, and thus allows analyzing optimization potentials and ultimately reducing production costs. Using a digital twin, deviations can be simulated, analyzed, and predicted in the running production process.

Interconnecting systems in the production process enable real-time monitoring of the supplier by its customer. This leads to a close and automated coordination of requirements between suppliers and manufacturers and therefore contributes to optimize value creation.

Given a data disclosure, manufacturing processes will be subject to security risks in the course of the development towards Industry 4.0. System failures must be prevented, especially if data and systems are interconnected. In order to guarantee this, external competence is desired.

5.4 Deliver

Regarding means of transportation, delivery times, and transport conditions can be made transparent to all partners in the value chain, using sensors and digitally mapping products. This in turn reduces waiting and processing times and has the potential to increase customer satisfaction. Besides, tracing products provides the advantage to guarantee and check their quality. A greater transparency towards customers and improved quality controls enable interconnected logistics.

Instead of offering a standalone product, system solutions can be provided. Digital services, e.g., basing on the Internet of Things and cloud solutions, play a decisive role in this context. The combination of traditional products with innovative services may lead to smart product solutions.

5.5 Return

As for the return section, currently non-automated, analogue, and inefficient processes result in insufficient or wrong information concerning recycling and disassembly. This leads to resource wastage and possibly recyclable raw materials being thrown.

Technological developments, data exchange, and new forms of analyses in the context of Industry 4.0 pose the potential to reshape return processes. In addition, transaction costs can be optimized in return processes via automated orders, invoicing, and documentation processes. In this regard, returns are optimized by sharing recycling and disassembly information across the supply chain, such as manuals and certificates.

6 Conclusion

6.1 Theoretical and Managerial Implications

With regard to the "plan" process, ensuring data security and trust are key prerequisites. Although the experts see great potential in interconnected demand and procurement planning, there still seems to be certain skepticism about disclosing data, for example, to upstream value-adding stages.

Following the research results at the "source" process level, skepticism as for information transparency further increases in future buyer-supplier information sharing. Among others, risks are located in either becoming dependent on a particular supplier or in facing disadvantages due to excessive data transparency. The results reveal that it remains essential to continue negotiating procurement efforts about complex and new products as well as specific material traditionally. In the case of standardized goods, however, automated purchasing processing seems conceivable, with delivery conditions and the price range being determined in advance. Suppliers and customers have to individually agree on the extent of information transparency depending on the relationship of trust.

The study reveals hurdles in the "make" process stage. Comprehensive data security turns out to be very important, basing on two aspects. On the one hand, data security is about protecting data against third parties outside the supply chain. On the other hand, data security deals with stability in the generation and transmission of data.

Corporate practice and managers alike can make use of the insights provided by the paper and include its managerial implications into their decisions and actions. First, the basis of successful information sharing in the future is knowledge as for technologies, processes, organizational aspects, and strategy. Managers are asked to allocate sufficient resources and provide a budget to build up knowledge either internally or with the help of external partners.

Second, it becomes crucial to transform corporate culture and corporate strategy including a holistic consideration of buyers and suppliers. Thinking and acting not as a stand-alone company but as a value creation chain and ecosystem is decisive against the backdrop of further digitization and interconnection.

Third, a company is ought to build up necessary infrastructure, to shape interfaces properly, and to adapt to standards in order to prepare future information sharing. Fourth, creating mutual trust between buyers and suppliers and dispel concerns, e.g., as for data security, are further requirements. Fifth, streamlining company internal processes and conducting operational refinements, is a further step. Last but not least, sharing information is a competitive factor that can serve to differentiate from competitor. Hence, constantly checking, revising, and adapting information sharing efforts and further observing technological developments is a key to successfully manage companies in the future.

6.2 Limitations and future research

Using qualitative-empirical data, this study analyzes information sharing between buyers and suppliers based on the SCOR model. Despite its contribution to research and implications for corporate practice, the study maintains some weaknesses that are discussed in the following. Furthermore, opportunities for further research are indicated.

First, the qualitative-empirical nature of the study serves to answer the research question addressing the research gap. However, it is limited in scope and content, e.g., it does neither analyze effect sizes nor interrelations. Second, the sample exclusively comprises German companies that has to be kept in mind when transferring the study's results to different context, e.g., in terms of culture and infrastructure. Third, it must be admitted that the sample size is restricted which in turn may further limit its generalizability. Future studies could address these limits and further validate the findings for example extending the data sample and using quantitative methods.

The course of the analysis uncovered a great variety of research gaps in the context of information sharing leaving space for future research. Among others, research should shed light on future requirements as for information sharing. For instance, studies may focus on technical prerequisites and may uncover what is an adequate infrastructure.

Given numerous systems and actors in cross-company information sharing, the question of how to properly shape interfaces becomes vital but research has not sufficiently addressed this topic yet. Analyzing the perspectives of cooperating partners within a supply chain and including further stakeholders, e.g. logistics providers, complements the state of research and may help to better understand interrelations. Differentiating between various company characteristics, e.g., product manufacturer, service providers, company sizes, and industry sectors, would shed light on influence factors and drivers and help to unveil further mechanisms. Digital platforms, e.g., virtual marketplaces, interconnect various supply chain partners and hold manifold potentials for value creation in the digital era. They have a great impact on information sharing and, among others, influence the way to exchange information and the intensity wherefore research studies are ought to further analyze their implications.

A further limitation of the study can be assigned to the fact that, relating to the sparse investigation of information sharing in Industry 4.0, the study cannot build on existing literature and therefore is only partially grounded in literature. Although there is literature on information sharing regardless of Industry 4.0 in extant literature, this literature is only partially applicable to Industry 4.0. The extension of this literature base, therefore, represents a further recommendation for future research.

In a similar regard, many of the concepts and forms of information sharing mentioned do not necessarily relate to the technologies and forms of information sharing that Industry 4.0 intends. Although Industry 4.0 implementation is still at an initial stage, it seems that the sample consists of many companies that have not evolved proactively in this direction to a large extent yet. Therefore, the inclusion of more advanced companies in this regard is recommended for future research.

Going beyond platforms, ecosystems include direct actors in the value creation process and indirect actors, e.g., educational institutions. Digital and automated information sharing lead to significant changes in entire ecosystems and therefore should be subject of further research studies as well.

References

Bolstorff, P. A., Rosenbaum, R. G., and Poluha, R. G. 2007. Spitzenleistungen im Supply Chain Management. Berlin, Heidelberg: Springer.

Birkel, H. S., Veile, J. W., Müller, J. M., Hartmann, E., & Voigt, K. I., 2019. Development of a risk framework for Industry 4.0 in the context of sustainability for established manufacturers. Sustainability, 11(2), pp. 384-411.

Fazli, S., and Afshar, Z. A., 2014. The Role of Drivers on Supply Chain Integration. Asian Journal of Research in Business Economics and Management, 4(12), pp. 347–359.

Giménez, C., and Ventura, E., 2003. Supply Chain Management as a Competitive Advantage in the Spanish Grocery Sector. The International Journal of Logistics Management, 14 (1), pp.77–88.

Gläser, J. and Laudel, G., 2010. Experteninterviews und qualitative Inhaltsanalyse: Als Instrumente rekonstruierender Untersuchungen (4th Edition). Wiesbaden: Springer.

Helmold, M. and Terry, B., 2016. Lieferantenmanagement 2030: Wertschöpfung und Sicherung der Wettbewerbsfähigkeit in digitalen und globalen Märkten. Wiesbaden: Springer Gabler.

Hofbauer, G., Mashhour, T., and Fischer, M., 2016. Lieferantenmanagement: Die wert¬orientierte Gestaltung der Lieferbeziehung (3rd Edition). Berlin, Boston: De Gruyter Oldenbourg.

Kagermann, H., Wahlster, W., and Helbig, J., 2013. Umsatzempfehlungen für das Zukunfts¬projekt Industrie 4.0 – Deutschlands Zukunft als Produktions-standort sichern. [online] Available at: <https://www.bmbf.de/files/Umsetzungsempfehlungen_Industrie4_0.pdf> [Accessed 8th May 2019].

Kiel, D., Müller, J.M., Arnold, C., and Voigt, K.-I., 2017. Sustainable Industrial Value Creation: Benefits and Challenges of Industry 4.0. International Journal of Innovation Management, 21(8), p. 1740015.

Lasi, H., Fettke, P., Kemper, H.G., Feld, T., and Hoffmann, M., 2014. Industry 4.0. Business & Information Systems Engineering, 6(4), pp. 239–242.

Mayring, P., 2015. Qualitative Inhaltsanalyse: Grundlagen und Techniken (12th Edition). Weinheim: Beltz.

Müller J.M., Kiel, D., and Voigt K.-I., 2018a. What Drives the Implementation of Industry 4.0? The Role of Opportunities and Challenges in the Context of Sustainability. Sustainability, 10(1), pp. 247-271.

Müller J.M., Buliga, O., and Voigt, K.-I., 2018b. Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. Technological Forecasting and Social Change, 127, pp. 2-17.

Müller, J. M., and Voigt, K. I., 2018. Sustainable industrial value creation in SMEs: a comparison between Industry 4.0 and Made in China 2025. International Journal of Precision Engineering and Manufacturing-Green Technology, 5(5), 659-670.

Müller, J.M., Maier, L., Veile, J., and Voigt, K.-I., 2017. Cooperation strategies among SMEs for implementing Industry 4.0. Hamburg International Conference on Logistics (HICL).

National Research Council, 2000. Surviving Supply Chain Integration. Surviving Supply Chain Integration. National Academies Press.

Plattform Industrie 4.0, 2017. Was ist Industrie 4.0? [online] Available at: <https://www.plattform i40.de/I40/Navigation/DE/Industrie40/WasIndustrie40/was-ist-industrie-40.html> [Accessed 6th May 2019].

Rink, C. and Wagner, S.M., 2007. Lieferantenmanagement: Strategien, Prozesse und systemtechnische Unterstützung. In W. Brenner and R. Wenger (eds.). Elektronische Beschaffung: Stand und Entwicklungstendenzen, pp. 39–62, Berlin, Heidelberg: Springer.

Schoenherr, T. and Swink, M., 2012. Revisiting the arcs of integration: Cross-validations and extensions. Journal of Operations Management, 30(1), pp. 99–115.

Stevens, G., 1989. Integrating the supply chain. International Journal of Physical Distribution & Logistics Management, 19(8), pp. 3–8.

Stewart, G., 1997. Supply chain operations reference model (SCOR): the first cross-industry framework for integrated supply-chain management. Logistics Information Management, 10(2), pp. 62–67.

Supply Chain Council., 2012. SCOR Supply Chain Operations Reference Model Revision 11.0 (11.0). Supply Chain Council.

Voigt, K. I., Müller, J. M., Veile, J. W., Becker, W., and Stradtmann, M. 2019. Industrie 4.0–Risiken für kleine und mittlere Unternehmen. In: Geschäftsmodelle in der digitalen Welt (pp. 517-538). Springer Gabler, Wiesbaden.

Voigt, K. I., Kiel, D., Müller, J. M., and Arnold, C. 2018. Industrie 4.0 aus Perspektive der nachhaltigen industriellen Wertschöpfung. In Digitalisierung im Spannungsfeld von Politik, Wirtschaft, Wissenschaft und Recht (pp. 331-343). Springer Gabler, Berlin, Heidelberg.

Voigt, K. I., Buliga, O., and Michl. K., 2017. Business Model Pioneers - How Innovators successfully implement New Business Models. Cham: Springer.

Wiengarten, F., Humphreys, P., Gimenez, C., and McIvor, R., 2016. Risk, risk management practices, and the success of supply chain integration. International Journal of Production Economics, 171(3), pp. 361–370.

Zhao, G., Feng, T., and Wang, D., 2015. Is more supply chain integration always beneficial to financial performance? Industrial Marketing Management, 45, pp. 162–172.

Zhao, X., Huo, B., Selen, W., and Yeung, J. H. Y., 2011. The impact of internal integration and relationship commitment on external integration. Journal of Operations Management, 29, pp. 17–32.