12-1-2019

How SMEs can participate in the potentials of Big Data within Industry 4.0

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Short Paper

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Abstract

Through digital interconnection along the value chain, the concept of Industry 4.0 aims to generate data transparency that results in the generation of Big Data. To approach the expected potentials, several barriers exist in the context of Small and Medium-Sized Enterprises (SMEs). On the one hand, large enterprises are much better prepared to profit from the value of big data in comparison to SMEs, which are often suppliers in global value chains and do not have contact to end customers. Further, the data generation within SMEs is often too small and unstandardized in order to generate sufficient input for Big Data. On the other hand, large enterprises require their suppliers, often SMEs, to share their data so that Big Data can be generated in the first place. This paper builds on a literature review on extant research in the field of Industry 4.0, Big Data, and SMEs, and describes insights from an industrial case study. Condensing the findings of literature review and case study, the paper shows approaches how SMEs can be integrated within the concept of Industry 4.0, providing benefits for both, SMEs, and their often larger customers. Thereupon, implications for future research and managerial practice are derived.

Keywords: Industry 4.0, Industrial Internet of Things, Big Data, Small and Medium-Sized Enterprises, Barriers and Solutions, Digital Transformation

Introduction

Industry 4.0, internationally also known as the Industrial Internet of Things, describes the digitally enabled horizontal and vertical interconnection of industrial value creation (Kagermann et al., 2013; Lasi et al., 2014). The concept, describing an intended fourth industrial revolution, has gained large interest in managerial practice and academic research throughout several research disciplines. While technological research and showcases on Industry 4.0, often limited to single factories, are leading research and practical implementation, several topics are lagging behind and need to be addressed better (Horváth and Szabó, 2019; Kiel et al., 2017).

In particular, Small and Medium-Sized Enterprises (SMEs) have been regarded considerably less in extant research on Industry 4.0 (Horváth and Szabó, 2019; Müller, Buliga and Voigt, 2018; Moeuf et al., 2018). Comparably, the implementation of Industry 4.0 across the supply chain, often consisting of SMEs, remains little understood in comparison to other research areas of Industry 4.0. However, the integration of SMEs within the concept of Industry 4.0, also encompassing the supply chains they are active in, is of vital importance (Kagermann et al., 2013; Veile et al., 2019).

Many potentials of Industry 4.0 are grounded on the generation of Big Data across industrial supply chains, enabling several potentials, such as new, data-driven business models, or data transparency and data analytics (Kagermann et al., 2013; Kiel et al., 2017; Lasi et al., 2014). However, the understanding of how value can be generated out of Big Data for SMEs remains little understood. For instance, SMEs' own data generation is far too small, whereas they have little to no transparency on further data within the supply chain. Hence, their own willingness to generate or even share data is limited, as they fear to be too transparent to often larger customers, among other reasons (Birkel et al., 2019; Müller, Buliga and Voigt, 2018).

In response to this research gap, this paper analyzes extant literature on Industry 4.0 and SMEs and links these findings with extant research on Industry 4.0 and Big Data (Gölzer, Cato and Amberg, 2015; Günther et al., 2017a; Günther et al., 2017b; Witkowski, 2017). Further, several insights from an industrial case study are integrated to contribute to the understanding of SMEs, Industry 4.0 and Big Data in an integrated research perspective.

Background

Industry 4.0

The term Industry 4.0 is derived from an expected industrial revolution, after three previous industrial revolutions. These include steam power in the first industrial revolution, electrification and mass production in the second industrial revolution, and automation in the third industrial revolution. While the previous industrial revolutions were described ex-post, Industry 4.0 was proclaimed ex-ante. The term Industry 4.0 first occurred in 2011 at the Hanover Fair as a concept of the German government to safeguard the competitiveness of the manufacturing industry (Kagermann et al., 2013; Lasi et al., 2014).

In its core, Industry 4.0 has its technological foundation in Cyber-Physical Systems, allowing to merge the physical and virtual worlds. This requires sensors to replicate the physical world in the virtual one, data processing and analysis capabilities, and capabilities for communication and interaction. Interconnection is established by a second central technology of Industry 4.0, the Internet of Things (Kagermann et al., 2013; Kiel et al., 2017; Lasi et al., 2014).

Across literature, Industry 4.0 is described to have three central characteristics that are enabled from the introduction of Cyber-Physical Systems and the Internet of Things: Horizontal interconnection, vertical interconnection, and end-to-end engineering. Horizontal interconnection refers to digital interconnection across company boundaries, i.e., the supply chain. Vertical interconnection describes the digital interconnection within enterprises, i.e. company functions. Further, end-to-end engineering describes interconnection from product development, production, usage, and recycling, i.e., the entire product lifecycle. The digital interconnection of these dimension is enabled by Cyber-Physical Systems, sensors,

data processing and transmission capabilities, and thereupon data analysis techniques, as described above (Kagermann et al., 2013; Lasi et al., 2014).

Overall, Industry 4.0 aims for benefits in all three dimensions of sustainability, i.e., economic, ecological, and social dimensions. For instance, new business models, more efficient processes, or the assistance of employees is predicted. However, at the same time, challenges in all three dimensions of sustainability are expected. This includes costs and viability of new technologies, required energy for data transmission and resources for new machinery, and loss of traditional jobs in industry (Kagermann et al., 2013; Kiel et al., 2018; Müller and Voigt, 2018).

Therefore, alongside technical considerations, social and organizational transformations are described as following the technical changes (Barata and Rupino Cunha, 2018; Kiel et al., 2017). This refers to terms such as 'Digital transformation' following Industry 4.0 (Bordeleau and Felden, 2019) or organizational transformation and new requirements that follow from Industry 4.0 (Birkel et al., 2019; Matthiae and Richter, 2018).

Worldwide, comparable concepts to Industry 4.0 have been initiated, often under the same term, as for many European countries, or with different names. These include, for instance, 'Factories of the Future' in the European Union, the 'Industrial Internet Consortium' in the United States, or 'Made in China 2025' in China, among many further concepts worldwide (Müller and Voigt, 2018).

Big Data in the Context of Industry 4.0

Big Data and Big Data Analytics attract increasing attention in research in the past years (Chen, Chiang and Storey, 2012; Waller and Fawcett, 2013; Wamba et al., 2015). Big Data is often characterized by the 'three Vs': volume, variety and velocity. In short, this refers to large amounts of data (volume), that have different standards and formats (variety), and must be processed at a high speed (velocity). These characteristics of Big Data, especially their combination, lead to several challenges, requiring new approaches for data collection, storage, transmission, and analysis (Chen, Chiang and Storey, 2012; Hofmann, 2017; Waller and Fawcett, 2013; Wamba et al., 2015).

As mentioned in the previous section, the horizontal and vertical interconnection of industrial value creation leads to comparable challenges of large amounts of data, from different origins, that need to be collected, stored, transferred, and analyzed (Kagermann et al., 2013; Lasi et al., 2014; Kiel et al., 2017). The characteristics of data in Industry 4.0 can therefore be characterized with comparable properties as those of Big Data. There are several authors in Industry 4.0-related research that refer to the terms of Big Data in the context of Industry 4.0 (Kagermann et al., 2013; Kiel et al., 2017). However, research that merges the disciplines of Industry 4.0 and Big Data is rare in extant literature (Gölzer, Cato and Amberg, 2015; Günther et al., 2017a; Günther et al., 2017b; Witkowski, 2017); Xu and Duan, 2019). Further authors refer to Big Data and Industry 4.0 in sustainability contexts (Müller and Voigt, 2018; Tseng et al., 2018) or in the context of digital platforms (Müller, 2019b).

Small and Medium-Sized Enterprises in the Context of Industry 4.0

Following the definition of the European Union, SMEs are defined as enterprises with up to 250 employees, and an annual turnover of up to 50 million Euros. Throughout Europe, SMEs make up about 99 per cent of all enterprises, contribute about 50 per cent of annual turnover and employ more than 50 per cent of full-time equivalents in the European Union (Airaksinen et al., 2015). SMEs have a high importance for national economies and industrial value chains, often acting as suppliers. In industrial value chains, SMEs typically contribute their highly specialized knowledge and expertise, that is vital for industrial value creation (Müller, Buliga and Voigt, 2018).

Regardless of SMEs' importance for national economies in general and industrial value chains specifically, research on Industry 4.0 in SMEs remains scarce compared to other research fields. However, SMEs' integration within the concept of Industry 4.0 is of high importance for the successful implementation of

Industry 4.0 across the industrial value chain (Horváth and Szabó, 2019; Kagermann et al., 2013; Müller, Buliga and Voigt, 2018).

Extant research on Industry 4.0 and SMEs emphasizes that the potentials of Industry 4.0 are often harder to approach for SMEs than for large enterprises (Horváth and Szabó, 2019; Müller, Buliga and Voigt, 2018). In contrast to larger enterprises, SMEs often do not yet understand or cannot approach the strategic potentials arising for Industry 4.0. This can be explained, among other reasons, by limited resources, niche-oriented business models, or little automation and unstandardized operative processes, that hamper to approach the potentials of Industry 4.0 (Horváth and Szabó, 2019; Mittal et al., 2018; Müller, 2019a).

Further, different data standards, interfaces, and company boundaries represent a challenge for Industry 4.0 implementation. This is especially true for SMEs with limited resources, capabilities, and since SMEs fear dependencies and increased transparency. While the potentials offered through Industry 4.0 are predicted to bring several benefits to industrial value creation in economic, ecological, and social regards, several risks and barriers need to be overcome to implement the concept, especially across the supply chain, and in SMEs (Birkel et al., 2019; Kiel et al., 2017; Moeuf et al., 2019; Müller, Buliga and Voigt, 2018; Veile et al., 2019).

Findings

Typical characteristics of SMEs that oppose Industry 4.0 and Big Data

In the following, typical characteristics of SMEs that hamper the implementation of Industry 4.0 are condensed from extant literature (Horváth and Szabó, 2019; Mittal et al., 2018; Mittal et al., 2019; Moeuf et al., 2018; Moeuf et al., 2019; Müller, Buliga and Voigt, 2018):

- Low financial resources
- Low degree of automation
- Low data competencies
- Low R&D share and few alliances with universities/research institutions
- High degree of specialization
- Low degree of standardization
- High level of important activities are outsourced
- High dependence on collaborative network
- Strong personal supplier and customer relations

These typical characteristics of SMEs lead to several barriers for the implementation of Industry 4.0 and to approach the potentials of Big Data, which are explained in the following section.

Barriers for SMEs to approach the potentials of Big Data

In the following, Table 1 summarizes extant research findings on barriers for SMEs to approach the potentials of Big Data within the concept of Industry 4.0.

Table 1. Extant literature on barriers for SMEs to approach the potentials of Big Data

Barrier	Description	Exemplary References
Feared transparency to customers and competitors	SMEs fear that they might have high efforts for establishing data transparency in the first place. Then, they fear that their customers might get insights that they can use in price negotiations or	(Horváth and Szabó, 2019; Moeuf et al., 2019; Müller,

	to replace them. Further, SMEs fear that trade secrets might be passed on to competitors.	Buliga and Voigt, 2018)
Data security	SMEs fear that adequate data security cannot be afforded by SMEs, lacking data and information to third parties.	(Birkel et al., 2019; Moeuf et al., 2019)
High investment costs and unclear economic benefit	Limited resources of SMEs must be scattered across several potential Industry 4.0 projects, but economic return is unclear and might only be achieved in the long term.	(Birkel et al., 2019; Kiel et al., 2017; Moeuf et al., 2019)
No clear strategy and priority	The often owner-driven strategy of many SMEs has several advantages, but if the owner does not recognize the benefits of Industry 4.0, implementation is slowed down.	(Birkel et al., 2019; Horváth and Szabó, 2019)
Lacking skill and knowhow in Big Data and required technologies	SMEs do not have the required skills and cannot afford the required specialists.	(Mittal et al., 2018; Moeuf et al., 2019)
Internal resistance and innovation culture	Fear of job losses and company culture that builds on flexible "all-rounders" rather than specialists.	(Müller and Voigt, 2018)
Too little data generation within the SME	The internal processes are not sufficient to generate Big Data within a SME.	(Müller, Buliga and Voigt, 2018)
Data quality, storage, and availability	Data generation is not sufficient for the generation of Big Data in SMEs.	(Birkel et al., 2019)
No access to the overall data generation in the supply chain and to product data in usage	SMEs can hardly benefit from product data in usage, since they often act as suppliers with no direct contact to the end customer.	(Müller, 2019a; Müller, Buliga and Voigt, 2018)
Processes with little or no digitization	SMEs tend to have semi-automated processes that are hard and costly to digitize.	(Müller, Buliga and Voigt, 2018)
Unstandardized data and interfaces	Low standardization of data generation and interfaces in SMEs, which does not bring benefits for them.	(Mittal et al., 2019; Müller, Buliga and Voigt, 2018)

Table 1. Extant literature on barriers for SMEs to approach the potentials of Big Data

On the other hand, entire supply chains must collect data in order to have sufficient data transparency for the generation of Big Data. Further, only data generated across the supply chain can serve to approach potentials such as balancing of logistics processes and production loads, energy savings, new, data-driven business models, or traceability across the supply chain. (Kagermann et al., 2013; Hofmann, 2017; Waller and Fawcett, 2013; Wamba et al., 2015). As SMEs are often suppliers in industrial value chains, or also contribute to recycling activities, it is vital to integrate SMEs in the concept of Industry 4.0 and to have them generate and share data across the supply chain. (Müller, Buliga and Voigt, 2018; Tseng et al., 2018). In order to do so, their specific barriers named in Table 1 must be addressed, for which possible solutions are presented in the next section.

Possible solutions for SMEs to approach the potentials of Big Data

In the following, Table 2 summarizes extant research findings on solutions for SMEs to approach the potentials of Big Data. In order to extend the findings in extant literature, which can only be found quite

scarcely, these solutions are enriched by the findings in a case study that was conducted with a German industrial company and its suppliers.

Table 2. Extant literature on solutions for SMEs to approach the potentials of Big Data		
Approach	Description	Exemplary Reference
Technology transfer from large enterprises to their SME suppliers	In order to help SME suppliers in generating and transferring data, they can get technology transfer from larger enterprises.	Only based on case study
Skill and knowhow transfer from large enterprises to their SME suppliers	Comparably to technology transfer, the often lacking skills and knowhow can be provided by larger enterprises to their SMEs suppliers.	Only based on case study
Benefit sharing for data generation and sharing, Value chain and ecosystem business models	If SMEs can participate in the potentials that the end products achieve, such as data flowing back from product usage to their own product development, they might be more open to data sharing	Only based on case study
Cloud or platform-based, decentralized data storage with equal access rights	Data is shared on secure platform or cloud solutions available for the entire value chain, including SME suppliers.	(Müller, 2019b)
Cooperation among SMEs for Big Data competencies and Big Data generation	In an environment among equals (SMEs), approaches suitable for them and compound effects can be generated.	(Müller, 2019b)
Business models grounded on data analytics or further services for SMEs	While SMEs often cannot generate sufficient data themselves, a focus on service-based business models, such as data aggregation and data analytics, can put them in a new position.	(Müller, Buliga and Voigt, 2018)

Table 2. Possible solutions for SMEs to approach the potentials of Big Data

Naturally, a combination of these solutions can be reasonable and generate compound effects or different solutions can be used in different contexts. In this regard, it must be mentioned that the above named solutions will also have to overcome the willingness of SMEs to stay independent, especially from their larger customers. This is especially true for the first two solutions (technology, skill and knowhow transfer). Therefore, approaches that treat SMEs on a more equal level, or build on self-controlled business models, might be preferable for many SMEs (Müller, 2019b). A SME's role as a provider of Industry 4.0 technologies should be preferable to provide service-based business models based on data analytics (Müller, Buliga and Voigt, 2018).

Conclusion

For research in the field of Industry 4.0, SMEs, and Big Data, this paper gives an overview of existing characteristics of SMEs that oppose Industry 4.0 implementation, and thereupon highlights barriers for SMEs to approach the potentials of Big Data within Industry 4.0. By condensing the research streams on Industry 4.0, SMEs and Big Data, the paper contributes to each literature stream individually, but especially to their respective intersection. In particular, the understanding that SMEs play a vital role in industrial value creation, and that SMEs are indispensable for the further proceeding of Industry 4.0 and potentials of Big Data is a relevant insight for research and practice alike. By presenting several approaches to let SMEs better approach the potentials of Big Data within the concept of Industry 4.0, future studies as well as managerial practice can develop the respective understanding and future projects accordingly.

As a limitation of this paper, it must be noted that the solutions described are exclusively based on the perspective of supporting or including SMEs in the value of Big Data generation. Approaches that large enterprises might pursue, such as choosing alternative suppliers or backsourcing value chain activities in-house, among other approaches, are not discussed in this paper. Therefore, the paper is limited to the perspective of transforming existing industrial value chains so that SMEs can participate in the potentials of big data, not the emergence of new configurations of industrial value chains or new SMEs on the market, such as start-ups.

For future research, this paper recommends to better investigate the effects of SMEs' products, their embeddedness in the value chain, and their market position on their experience of barriers towards Industry 4.0 implementation and how they approach the potentials of Big Data. For instance, the nature of products and services provided by an SME, and if these are capable of data collection or represent components without such capabilities, could play a decisive role of a SME's positioning. In a similar vein, the influence of personality and of SMEs' owners could present a fruitful research avenue. Further, it is of vital importance to better understand what kind of data within the concept of Big Data will lead to which potential and requires which strategy for a SME.

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