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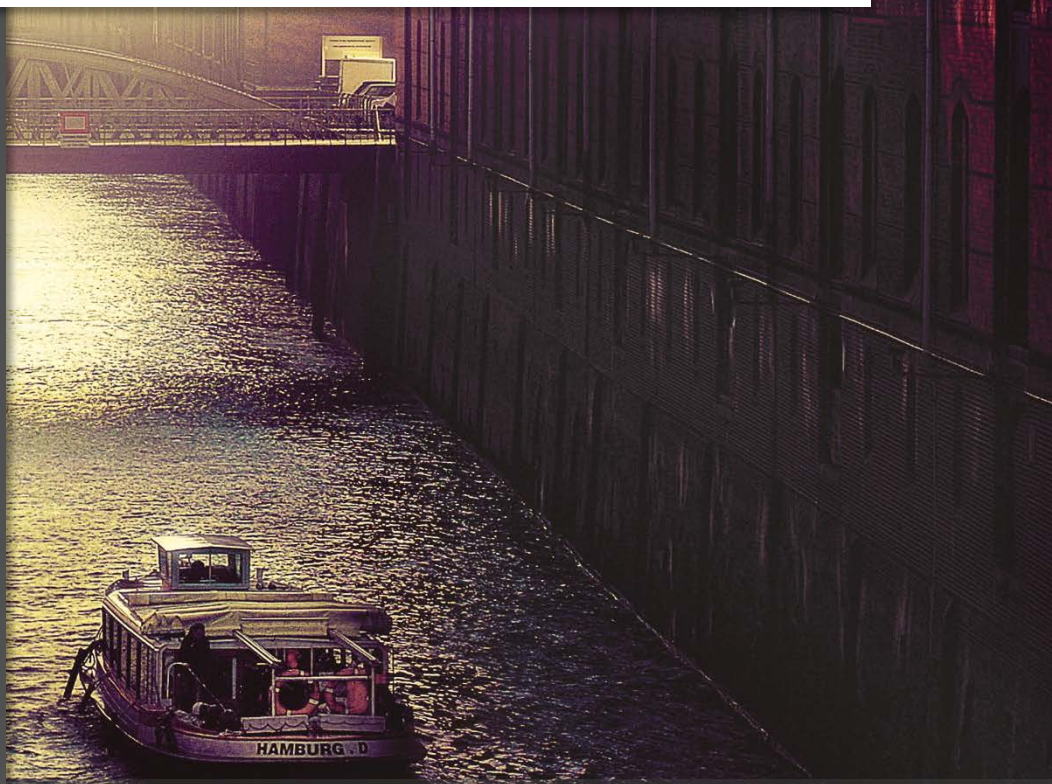

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Cooperation Strategies among SMEs for Implementing Industry 4.0

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Industry 4.0 is expected to bring several conversions for industrial value creation, encompassing entire value-added networks. Small and medium-sized enterprises (SMEs), which play an important role for both the German as well as the European economy, struggle to integrate the concept of Industry 4.0 within their value creation. However, due to the high importance of SMEs for industrial value creation networks, their integration is essential to successfully establish Industry 4.0 across value chains. Several SMEs struggle to obtain the resources required for equipment and machinery or do not possess the required market shares or market access to establish new business models. Large enterprises are often seen as too powerful to be a partner for a SME. Nevertheless, cooperation strategies among SMEs may present a viable alternative to successfully implement Industry 4.0 across the value chain. In this context, literature lacks of a well-founded investigation of this topic. Therefore, this study attempts to close the present the present research gap. Due to the exploratory nature of the underlying topic, we conduct a multiple case study with 68 SMEs in Germany. This paper comes up with cooperation strategies and presents the interviewees' answers regarding potentials and challenges of common technology purchasing as well as for common business models. Subsequently, we present implications for both research and practice.

Keywords: Industry 4.0; Small and Medium-sized enterprises; Cooperation strategies; Industrial Internet of Things

1 Introduction

Industry 4.0, which is internationally known as the Industrial Internet of Things, aims to establish an intelligent, self-regulating and interconnected industrial value creation (Kang et al., 2016) ensuring future competitiveness of the manufacturing industry (Kagermann et al., 2013; Lasi et al., 2014). Given the topic's importance and actuality, research on Industry 4.0 focuses rather on technological developments related to cyber-physical systems (Brettel et al., 2014; Liao et al., 2017) than on their organizational implementation (Arnold et al., 2016; Ehret & Wirtz, 2017). Recently, scholars begin to study the value creation implications of Industry 4.0 (Kans & Ingwald, 2016; Kowalkowski et al., 2013; Rennung et al., 2016). However, according to Kowalkowsi et al. (2013), researchers investigating this topic mainly focus on large companies (Radziwon et al., 2014).

Large organizations constitute a minority, as SMEs play an important role in the overall network of industrial value creation. In the European Union, SMEs represent over 99% of all companies. Additionally, SMEs employ between 50 and 70% of all European full time equivalents and generate a gross value added share that encompasses about 50% of the European economy (Airaksinen et al., 2015; Bundesministerium für Wirtschaft und Energie, 2014).

With this paper we attempt to further examine SMEs in order to fully understand the mechanisms and implications of Industry 4.0 implementation. The legitimacy for our research lies in a lack of fundamental knowledge about Industry 4.0. along with SMEs' impact on value creation and their importance for the overall economy.

Existing literature shows that SMEs and large organizations fundamentally differ in terms of size, processes, and availability of resources (Ihlau et al., 2013). Therefore, SMEs require different strategies to successfully implement Industry 4.0 in comparison to large companies. In this context, an important question is how the characteristics of a company, such as size and resource base affect its ability to implement new technologies. For instance, the adoption of ERP systems, a technological precursor to Industry 4.0, is differently approached in SMEs and was found to be more challenging in SMEs than in large companies (Buonanno et al., 2005). Correspondingly, the implementation of Industry 4.0 tools may be more difficult in SMEs, as such companies often have lower digitization levels, caused by their operation in niche markets (Knight, 2000), their smaller production series, as well as due to their smaller production series as well as their limited access to resources and knowledge. Particularly, SMEs lack resources and knowledge that

is, however, critical for the successful implementation of Industry 4.0. Existing literature shows that SMEs often cooperate with other companies to achieve better access to financial as well as personnel resources (Ihlau et al., 2013). Thus, using cooperation strategies appears to be a suitable approach for SMEs to successfully implement Industry 4.0 within an organization. However, literature provides no implications on how such cooperation strategies among SMEs should be designed and how they actually influence the implementation of Industry 4.0. That is why the aim of this study is to investigate which specific benefits as well as challenges exist regarding cooperation strategies among SMEs for implementing Industry 4.0.

2 Theoretical background

2.1 Industry 4.0

The term Industry 4.0 encompasses the expectations of politics and corporate practice that industrial manufacturing heads towards the fourth Industrial Revolution. The previous three Industrial Revolutions have achieved high productivity increases, driven by a few, fast spreading general-purpose technologies, such as mechanization, electricity and IT (Veza et al., 2015). These general-purpose technologies resulted in strong technical improvements and initiated further complementary developments (Bresnahan & Trajtenberg, 1995). The general-purpose technologies for Industry 4.0 are cyber-physical systems, whose technological infrastructure are based on the concept of the Internet of Things (Kagermann et al., 2013; Lasi et al., 2014; Xu, 2012). Cyber-physical systems are intended to establish an interconnection between the physical world and the cyber-space (He & Xu, 2015; Lee et al., 2015; Ren et al., 2013). Cyber-physical systems hereby offer mechanisms for human-to-human, human-to-object and object-to-object interactions along the entire value-added chain (Wan, 2011). Especially the task of integrating humans into this concept is perceived to be an enormous challenge as it faces employees' resistance (Frazzon et al., 2013; Gorecky et al., 2014; Hirsch-Kreinsen, 2016; Schuh et al., 2014). Humans' integration into industrial manufacturing leads to cyber-physical production systems (Schlechtendahl et al., 2015). Cyber-physical production systems enable several data-based services, such as predictive condition monitoring or balancing and reducing energy consumption within production (Lee et al., 2013; Shin et al., 2014; Tao et al., 2011).

Manufacturers place high expectations on cyber-physical production systems because they enable machinery safety, real-time control, self-organization and self-maintenance, autonomous navigation through production facilities and error predictability(Meyer et al., 2011; Monostori, 2014) along the entire lifecycle of machinery and products (Lennartson et al., 2010). Aside from cyber-physical production systems, Industry 4.0 is driven by technological developments such as service-oriented architectures (Guinard et al., 2010; Mikusz, 2016; Raja et al., 2013; Vogel-Heuser et al., 2015), which enable the creation of new services and product-service bundles (Ehret & Wirtz, 2017).

Those developments in sum result in the concept of smart production, also termed smart manufacturing (Davis et al., 2012; Feeney & Weiss, 2014; Radziwon et al., 2014; Wang et al., 2016; Zuehlke, 2010). Smart production has been discussed to be a core element of smart factories (Radziwon et al., 2014; Zhang et al., 2014). The latter use flexible and adaptive production processes to dynamically solve the problems of complex economic environments. Smart Production is characterized by manufacturing of smart, personalized products as well as high levels of collaboration through production networks, among several enterprises (Kagermann et al., 2013; Lasi et al., 2014; Veza et al., 2015; Xu et al., 2014).

Besides the German initiative Industry 4.0, the EU has initiated a public-private partnership under the title ”Factories of the Future” to achieve sustainable and competitive production in the future (European Commission, 2016). In the US, similar ideas are encouraged through the Industrial Internet Consortium with founding members such as AT&T, CISCO, GE, IBM and INTEL (Pike, 2014). The ”Internet Plus initiative” in China integrates current technological developments such as cloud computing and big data enabling state-of-the-art manufacturing (Keqiang, 2015), while South Korea has introduced the ”Manufacturing Innovation 3.0” (Kang et al., 2016).

2.2 Small and medium-sized enterprises

The term small and medium-sized entreprises refers to companies with less than 50 million Euro in sales and less than 500 employees regardless of their industry (Bundesministerium für Wirtschaft und Energie, 2013; Günterberg & Wolter, 2002). In our paper we investigate SMEs and how to implement Industry 4.0 with cooperation strategies because of several reasons:

First, potentials of Industry 4.0 can primarily be expected because of the horizontal and vertical network of the value chain. In the German industry, SMEs represent an essential part, as they represent 99,6% of all enterprises generating more than 50% of the GDP. In turn, integrating SMEs is perceived to be key to the success of Industry 4.0.

Second, existing studies show that SMEs' specific challenges differ from those of large companies. Therefore, SMEs require solutions tailored to meet their specific challenges. Management in SMEs already recognizes the importance of of Industry 4.0. However, research mainly focuses rather on large enterprises than on SMEs (Bischoff et al., 2015).

Third, the upper management of SMEs in contrast to that of large companies seems to be able to keep track of the whole enterprise. Interviewing them may reveal much information about our research topic. Further, their hierarchical position allow them to give holistic statements why SMEs qualify for examination. SMEs' managers may assess interfaces and provide both an external as well as an internal perspective (Ihlau et al., 2013).

3 Method and research design

3.1 Multiple case study

Our study's goal is to investigate potentials and challenges for cooperation strategies among SMEs for implementing Industry 4.0 and to provide an integrative, systematic, and comprehensive understanding about this topic.

In order to address this goal, we use a qualitative empirical methodology and conduct a multiple case study. We chose this methodology because it allows us to investigate the topic in a wider context, to gain a complete and holistic view, and to derive valid and generalizable results (Bryman & Bell, 2011; Gibbert et al., 2008). Asthis topic is novel, evolving, and a contemporary phenomenon, a case study design is the best method that can be used, which is especially true for research in the setting of operations or IT (Dubé & Paré, 2003; Eisenhardt, 1989; Eisenhardt & Graebner, 2007; Voss et al., 2012; Yin, 2009). Instead of relying on a single case, we use multiple cases to increase both the robustness and the generalizability of our results (Eisenhardt & Graebner, 2007).

3.2 Data collection

We use semi-structured expert interviews with qualified and experienced managers as main source following common handling in qualitative research (Mason, 2002). Interviews of this manner allow collecting data structurally while keeping the openness that is necessary to gather all important information (Yin, 2009).

We interviewed 68 German managers of SMEs between May and July 2016 . 48 of the 68 SMEs have 100 to 500 employees, whereas 20 of the SMEs have up to 100 employees. We chose the industry sectors machine and plant engineering, electrical engineering and automotive. Our choice is based on the facts that these industries all contribute a great deal to the German Cross Domestic Product and the chosen mix well represents the industry landscape in Germany. Furthermore, the chosen industries are considered to be the ones that are most affected by and to benefit the most from Industry 4.0 (Kagermann et al., 2013). We chose Germany because of its representative character for an industrial nation, its leading economical position within the European Union and its high achievements in technological and digital development. Using a wide variety of empirical material helps to counteract negative effects of sample bias in our research (Yin, 2009).

The interviewed manager steam from middle and top management positions respectively. Those managers know the most about their firm's cooperation strategies for implementing Industry 4.0, which makes them the best suitable interview partners in our research. The interviews last between 20 and 60 minutes. In order to avoid any language barriers, we conduct the interviews in German, the mother tongue of both the interviewees and interviewers. For confidentiality reasons, we anonymize detailed case data. Corresponding to the exploratory nature of this study, the development of the interview guide was inspired by literature but followed the principle of openness and flexibility to allow unexpected and novel topics to emerge (Kasabov, 2015).

The interview guideline consists of three parts: First of all, the interviewed managers are questioned about their professional background and their areas of responsibility. In doing so, we ensure that the interview partners are suitable for the purpose of the study. Second, we ask the interviewees questions concerning potentials and challenges of cooperation strategies in technology purchasing. Third, we question the interview partners concerning potentials and challenges in jointly run new business models among SMEs . We introduce this differentiation in order to ensure the high importance of new, partner or platform based

business models within the concept of Industry 4.0 (Kagermann et al., 2013; Wu et al., 2013).

3.3 Data analysis and reliability of the study

The 68 audio-recorded interviews were transcribed into text material before analyzing them. We study the transcription applying a qualitative content analysis to identify and interpret common patterns, themes, and categories (Huber & Power, 1985; Miles & Huberman, 1994). Applying an inductive coding procedure (Charmaz, 2006; Gioia, Corley, & Hamilton, 2013; Krippendorf, 2013) helpes us not to restrict our results but generate novel knowledge (Graebner & Eisenhardt, 2004). We conduct the entire coding process as a team to achieve the best interpretations and most profound understanding (Weston et al., 2001). An application of a frequency analysis following Holsti (1969) simplifies the identification of the most important potentials and challenges for cooperation strategies among SMEs. We enhance the validity and robustness of our results by applying triangulation of secondary data from annual reports and company websites to verify the interviewees' statements (Eisenhardt & Graebner, 2007; Yin, 2009). Furthermore, we assure the respondents full anonymity and confidentiality addressing potential key informant bias. The multiple case study approach supported the mitigation of the negative effects of observer bias (Eisenhardt & Graebner, 2007).

4 Results

4.1 Common technology purchasing regarding Industry 4.0

Table 1 shows the potentials for common technology purchasing regarding Industry 4.0, sorted by their frequency of naming. Our interviews indicate the reduction of financial commitment to be the most important reason for common technology purchasing. Furthermore, interviewees mention the distribution of risks, the exchange of ideas, and strengthened partnership as further potentials.

Table 2 shows the challenges for common technology purchasing regarding Industry 4.0, sorted by their frequency of naming. In this context, we found trust between partners, loss of confidential information, and coordination efforts to be

the most common challenges for SMEs. Further challenges for common technology purchasing are preferred autonomy, increasing dependencies, only near-term benefits, no suitable partners, the lack of legal conditions, and reluctant behavior towards Industry 4.0.

4.2 Common business models for Industry 4.0

Table 3 shows the benefits of common business models among SMEs for Industry 4.0. We find three potentials for common business models: 24 participants mentioned the optimum usage of virtual interconnection, 20 mentioned the decrease of existing challenges through Industry 4.0, and three mentioned cost reductions.

Finally, Table 4 provides an overview of the challenges of common business models among SMEs for Industry 4.0. Overall, our results indicate nine challenges: Business model innovations are no a core competence, business model is not understood, legal uncertainty, lack of resources, no customer demand, preferred autonomy, coordination efforts, no risk diversification, and loss of flexibility.

Table 1: Potentials for common technology purchasing

Category	Frequency	Explanation
Reduction of financial commitment	33	Through the generation of compound effects and bargaining power, SMEs can reduce required financial capital.
Distribution of risks	19	Commonly purchasing distributes the risks of misinvestments among partners.
Exchange of ideas	11	Common purchasing leads SMEs to exchange ideas more openly and generate new ideas.
Strengthened partnerships	4	Through close financial ties , SMEs are able to establish new or strengthened partnerships.

Table 2: Challenges for common technology purchasing

Category	Frequency	Explanation
Trust between partners	25	Lacking trust between partners, e.g. opportunistic or dishonest behavior, hinders the implementation.
Loss of confidential information	24	In their purchasing strategy, SMEs incorporate confidential and strategic information that could be made public.
Coordination efforts	22	High coordination efforts oppose the compound effects generated by common purchasing.
Preferred autonomy	9	SMEs, especially owner-run companies, prefer autonomy in their purchasing activities.
Increasing dependencies	7	Dependencies between partners, which cannot be reversed are feared.
Only purchasing benefits	5	Common purchasing is only seen as beneficial for purchasing, not for further operations.
No suitable partners	5	The required partners are not willing to cooperate or no adequate partners exist.
Lacking legal conditions	2	The legal conditions are not fully determined for data-based purchasing within Industry 4.0.
Reluctant behavior towards Industry 4.0	2	The topic of Industry 4.0 is still unfamiliar to many SMEs.

Table 3: Potentials for common business models for Industry 4.0

Category	Frequency	Explanation
Optimum usage of virtual interconnection	24	Common business models among SMEs become viable and easy to coordinate.
Decrease of existing challenges for SMEs.	20	Establishing virtual interconnection, SMEs may gain the bargaining power and market share of larger enterprises.
Cost reductions	3	Compound effects may lead to cost reductions for all partners.

Table 4: Challenges for common business models for Industry 4.0

Category	Frequency	Explanation
Business model innovations are not a core competence	22	The development of business models is not seen as a core competence of SMEs what may hinder the development of new business models within Industry 4.0.
Business model is not understood	22	Up to now, SMEs have not fully understood the concept of business models, and thus they are mainly process or product oriented.
Legal uncertainty	17	Data-based business models come into question because of legal uncertainty regarding data theft and data property.
Lack of resources	7	As far as resources are concerned, SMEs are not seen as capable of establishing new business models.
No customer demand	7	To date, customers do not demand new business models.
Preferred autonomy	5	SMEs prefer to be independent and refrain from establishing new business models with partners.
Coordination efforts	4	The Coordination between partners is perceived to be both time and cost-intensive.
No risk diversification	3	SMEs become increasingly committed within a business model, so they are not able to diversify which in turn increases risks.
Loss of flexibility	2	SMEs might lose their core strengths such as providing individual and fast solutions, tailored to customer demands.

5 Discussion

This chapter discusses cooperation strategies to overcome SMEs' lack of resources and knowledge (Ihlau et al., 2013) and thus help to implement Industry 4.0 in their organization. In this context, commonly purchasing technologies as well as jointly developing business models are perceived to be adequate strategies, first of all examining potentials and challenges that come along with them. Keeping the results of our research in mind, the potentials and challenges can be discussed to derive implications how such cooperation strategies shall be designed to foster the implementation of Industry 4.0.

The first strategy investigated is commonly purchasing new technology among SMEs. About 37% of the interviewees mentioned a lack of trust between partners and 35% named a potential loss of confidential information, making those aspects the biggest challenges of common technology purchasing. Therefore, special attention should be given to these aspects when establishing a cooperation to make it a success. A lack of trust may stem from perceiving a partner's high negotiation power and low opportunity costs to withdraw from a cooperation. In order to establish a well-based cooperation, trust is the key to success. It is without saying that communicating trustworthily and acting reliably is the basis of a trustful cooperation. Bearing in mind not only the financial benefit, but also the importance of credibility towards partners, SMEs can act more collaboratively in negotiations. In addition, increasing its own opportunity costs by higher financial commitments on the partnership may increase the credibility of a partner.

Further, 33 % of the interviewees mention high coordination efforts in maintaining a cooperation to commonly purchase technology. This result indicates the importance of simplifying any form of cooperation to benefit comprehensively while suppressing the costs. Therefore, special attention should be drawn to interfaces in order to avoid any non-value adding processes. Automated communication and interactions, as proposed by Industry 4.0 in general, may lead to decreasing transaction costs, which in turn decreases coordination efforts. Additionally, resources may be provided to lower coordination costs for SME. Our results indicate that SMEs tend to prefer autonomy (13%) and fear increasing dependencies (10%). When setting up a cooperation, it is important to work together as closely as necessary for an adequate cooperation while respecting each partner's freedom. SME can be integrated into decisions, which may give them a sense of freedom in their decision-making process. A key aspect in this context is to create a partner's awareness for the importance of the cooperation, providing

reasons for both the required efforts and the dependency and respecting the individual, often owner-based, nature of SMEs.

As a further insight, this study reveals reducing financial commitment as the most important potential of a cooperation in terms of technology purchasing. 49% of interviewees name this aspect to be vital. Another potential for common technology purchasing is the distribution of risks, mentioned by 28% of respondents. Given these aspects' importance, the emphasis should be placed on the financial benefits of the cooperation and its visibility to all partners. In this context, it seems reasonable to distribute financial benefits among partners in a fair way so that all partners involved benefit from and value the cooperation. Apart from financial benefits, an equal distribution may help to increase trust, as explained in the section before.

Lastly, the exchange of ideas is mentioned to be an important potential when cooperating among SMEs (16%) to purchase technology. Apart from the financial gains, our research reveals that one should nevertheless emphasize not primarily financial aspects. Providing the partner with knowledge about processes and sharing best-practice cases may offer further incentives to enter into a cooperation. Reciprocal exchange of knowledge does not only provide benefits for one partner, but may lead to benefits for all partners in the cooperation

Another strategy analyzed is establishing common new business models between SMEs.

In our study, we show that SMEs tend to see new business models with particular caution and there are several reasons to explain this. 33% of our interviewees state that it is not SMEs' core competence to develop business models and therefore they intend to refrain from doing so. Another reason is that SMEs may not fully understand the concept of business models. The results therefore reveal interesting insights how to cooperate among SMEs regarding Industry 4.0. First, the key to success is to properly share information. Partners with little knowledge about business models may gain the relevant knowledge just after entering a cooperation. Sharing information in a cooperation may increase total knowledge about business models. Second, apart from knowledge sharing, a cooperation allows to share resources such as working time and human capabilities. One company may not be able to develop new business models and thus have other core competences, but sharing resources in a cooperation provides the cooperating parties with the basis to do so. Last, a cooperation may help to increase the sense of urgency and the perception of business model's strategic relevance due to group effects.

Legal uncertainty is an important challenge mentioned by 25% of all interviewees as issues concerning data security and data property are present. Legal uncertainty indeed is an issue that is widely discussed in research and public opinion without a silver bullet to solve it. However, entering a cooperation bundles resources, that can be used to invest in data security, to give one example. Further, data may be stored in a decentral way, reducing the vulnerability and the probability for data loss. Last, a cooperation has more influence to ask authorities and legislation to provide SMEs with an environment that guarantees the necessary ecosystem for Industry 4.0

Our study furthermore reveals that SMEs fear, even when working together in a cooperation, to not have enough resources to create new business models (10%). The lack of resources might be an issue but working together summarizes the resource base of several companies or at least increases the possibilities to get further resources, such as external capital. Cross-subsidization with financial benefits for instance from commonly purchasing technology may help to overcome this issue.

As a potential, 35% of our interviewees name the optimum usage of virtual interconnection. 29% of the interviewees believe another potential of common business models for Industry 4.0 is the decrease of existing challenges for SMEs. In combination with cost reductions, named by 3% in our sample, especially the potentials of cost reductions and new value propositions though new business models should be fostered in a potential cooperation among SMEs to overcome the challenges named and make benefits more visible and understandable. In a second step, further benefits of common business models as its understanding within cooperating SMEs rises, could unfold.

6 Conclusion

The aim of this study was to examine cooperation strategies among SMEs for implementing Industry 4.0. We find challenges for SMEs and benefits for both technology purchasing as well as developing business models. We explain this as our interviewed SMEs are at a rather early stage in the implementation of Industry 4.0. At this stage, SMEs may not consider cooperation strategies as an important tool to support their future business. This becomes especially apparent for the challenges of joint business model development among SMEs regarding Industry 4.0, which is not seen as a core competence of SMEs as well as the

concept of business models is not understood entirely by 22 out of 68 SMEs in our sample. Due to this, relatively early stage of implementation regarding Industry 4.0, where this understanding can still be generated and increased, our study presents valuable contributions for the current stage.

However, this paper is limited to a short-term perspective of cooperation strategies regarding Industry 4.0 among SMEs. Moreover, further research needs to be conducted to generalize our results in further cultural context. We recommend to further investigate cooperation strategies among SMEs within different industry sectors. A comparison with industries at a more mature stage of implementation Industry 4.0 for example the IT or software industry related to industrial production. This allows uncovering industry differences and deriving explanatory approaches.

For corporate practice, we recommend to develop new business models in context of Industry 4.0 working together in cooperation. Also, we advise to consider reorganize corporate culture such as openness to develop business models in cooperation. Further, we suggest policy makers to provide corporate practice with legal conditions such as data standards and data property supporting efforts to work in cooperation.

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