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Information sharing and multi-tier supply chain management of  
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**Abstract**

This paper investigates the transformation of information sharing and multi-tier supply chain management (MSCM) from the perspective of small and medium-sized enterprises (SMEs) in the context of Industry 4.0. SMEs are typically sharing less information digitally, are less active in conducting MSCM, but must be integrated in digital supplier networks to achieve supply chain transparency or traceability. For this purpose, this paper empirically analyzes SMEs from the manufacturing industry in Austria and Germany are investigated regarding information sharing and MSCM. The responses are analyzed to test three hypotheses, using 81 replies from manufacturing SMEs in Austria and Germany. The three hypotheses investigate the upstream and downstream MSCM practices of SMEs as well as which kind of information is shared with and by SMEs. The results help to understand and reveal potential barriers for information sharing besides technical possibilities to SMEs in order to be actively involved in MSCM.

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**Keywords:** Industry 4.0; information sharing; multi-tier; supply chain management; supplier networks

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**1. Introduction and background**

Digital information sharing across supply networks represents a relevant topic since it enables data-based potentials such as in the concept of Industry 4.0 or for using Artificial Intelligence [1,2]. However, many companies do not recognize the importance of data availability and data quality yet. This is particularly true for small and medium-sized enterprises (SMEs), which are often impeded by missing trust, standardization, data exchange interfaces, or

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technological readiness [3-6] and do not recognize the relevance of digital technologies for their business [7]. Likewise, digital information sharing in multi-tier supply chain management (MSCM) is still in its early stages of development.

This research investigates information sharing and subsequent data analysis in MSCM, focusing on SMEs. It aims at determining basic characteristics, e.g., size and vertical network position (up- or downstream), of early adopters of data-based MSCM. Raw material suppliers and upstream suppliers have a higher probability of being pressured by large buyer companies, which demand information sharing [2]. Hence, we argue that data based MSCM is more likely to be implemented in the upstream supply chain (H1). Moreover, five categories of information were evaluated if they are shared with SMEs or by SMEs (H1a and H1b): a) inventory level, b) state of delivery, c) expected delay, d) forecast data, and e) production plan.

Hence, this paper investigates the following hypothesis:

- H1: Data-based MSCM is put into effect to a larger extent upstream (raw material suppliers and higher-tier suppliers) than downstream the supply network.

Further, the paper investigates the following sub-hypotheses based on H1:

- H1a: Information a) b) c) d) e) is shared with SMEs.
- H1b: Information a) b) c) d) e) is shared by SMEs.

## 2. Background

Small and medium-sized enterprises are part of large supplier networks in today's economy [2]. Such networks emerge from competitive pressure from suppliers and customers, and ongoing transformations based on digitization or Industry 4.0 [8,9]. As a response to these pressures, firms apply different strategies to manage their supply chain (SC) partners.

This research focuses on SMEs, since smaller firms have different preconditions than larger companies [10] and therefore, varying approaches in MSCM. For example, they are often in a position of lower bargaining power, compared to their larger partners and therefore, they must find a niche where they can motivate the larger partners to cooperate. However, those relationships and especially trust with external firms remain important to enable digital information sharing and data transparency required [10,11].

In SCM, there are several central aspects in which small and medium sized firms can be regarded different to the large enterprises. Compared to large enterprises, in SMEs (1) the level of uncertainty in demand is higher and (2) the type of SCM evolution is different [11]. Evolution is triggered by adoption of new technologies or diversification – which are hard to reach for SMEs.

In response, supply chain partners can be used by SMEs to gather competencies that are beside SME's main competences. This offers the chance to SMEs of keeping up with current technological developments, such as Industry 4.0 or digital transformation [2]. For SME whose business is not focused on IT, there might be a gap between them and large enterprises already. For instance, the usage of formalized planning and control systems supporting SCM was compared by Vaaland and Heide [7] between SMEs and large companies. They found, for example, that in SMEs there is less necessity for planning and control systems compared to large companies. Besides of lower complexity in SMEs, they believe that their business won't change greatly, whereas larger enterprises assume that their business will be a lot more technologically driven in future. This technological gap might lead to a competitive disadvantage of SMEs when handling their supply chain, especially for managing a multi-tier SCM [10]. This gap could be reduced by increasing supply chain collaboration between SMEs and larger firms. It is not necessary for SMEs to build knowledge for new technologies on their own, because they could access new technologies by network collaboration [7].

In context of Industry 4.0 implementation, the digitization of several parts of SCM must be viewed as an integral concept in order to unlock overarching potentials. For instance a better coordination of information between suppliers and a production plant can also lead to better coordination between supply and production capacities. However, both concepts require digitization and evaluation of respective data from both, data from SCM across all partners and production management on a shopfloor level [2,9]

Fig. 1 below highlights the relationship between social capital and potentials for SCM, highlighting the equal importance of non-technical prerequisites for digital information sharing [2,9,12].

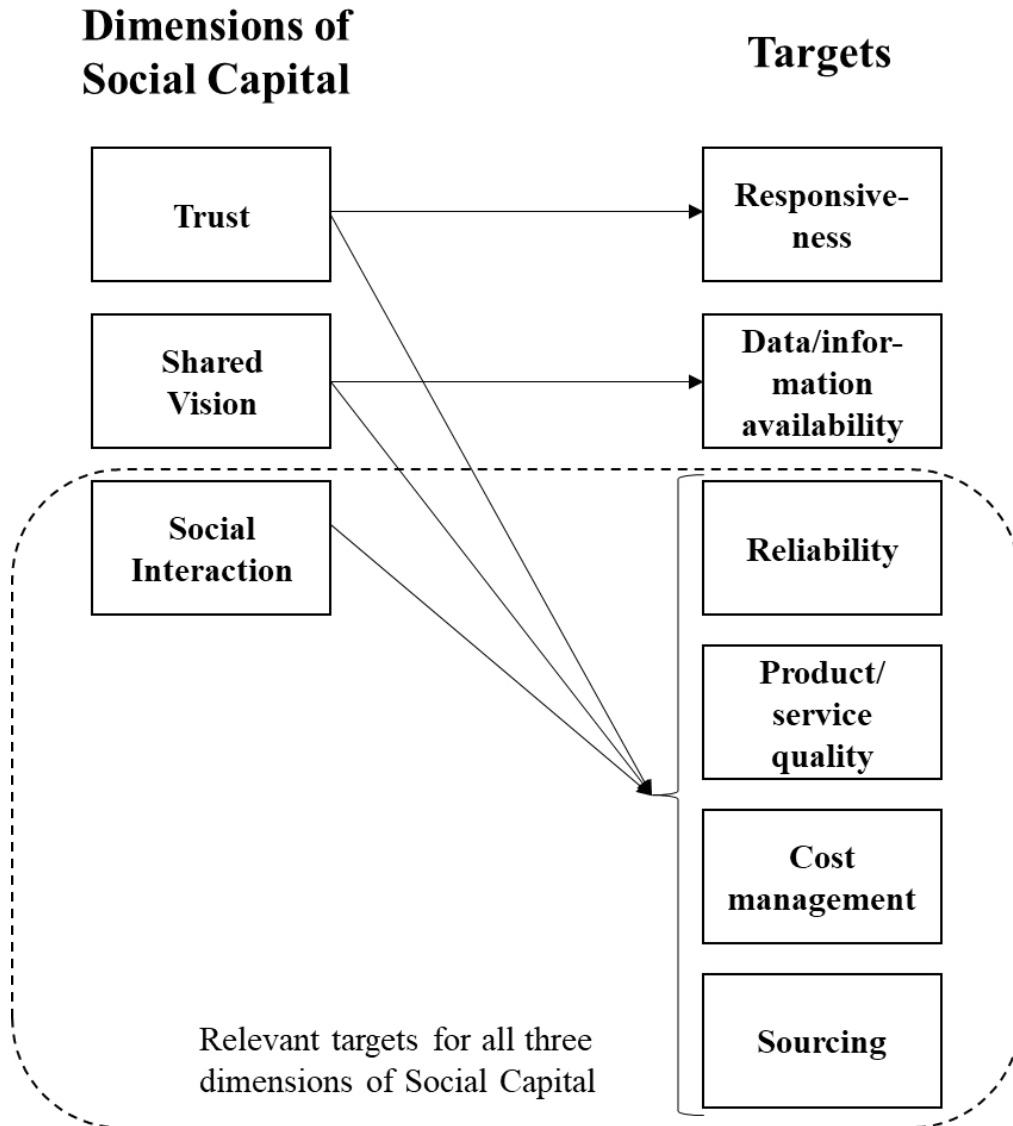


Fig. 1. Information on stock level as an example for the difference in availability between data from customer and supplier.

### 3. Method

This research is conducted in a two-step approach. In the first step, interviews with managers and CEOs of SMEs were used to generate hypotheses H1, H1a and H1b above [12]. Second, an online survey was created, based on the interviews. The target groups of the survey were manufacturing SMEs and their service providers located in Austria and Bavaria (Germany). In sum, we received 81 valid replies. The quantitative data of the survey is used to evaluate the hypotheses H1, H1a and H1b. Moreover, the survey gives insights regarding motives that drive SMEs to conduct or refrain from information sharing and supply network analyses.

#### 3.1. Data collection

The empirical study is based on an online survey, where small and medium sized companies were asked in the branches of manufacturing and logistics service providers. These conditions were queried in the survey to filter for inappropriate participants. Small and medium sized companies are defined to have up to 250 employees and up to 50 million Euros of annual turnover in the European Union.

A five-point Likert-scale was used for all questions in the main part of the survey. The Likert scale was used because it is well suited to measuring respondents' opinions and perceptions and the results can then be coded numerically. In the case of response options, direct answers are used to try to circumvent the problem that people are inclined not to fully agree with statements. Likewise, this type of response option is particularly suitable for the analysis of frequencies, which are primarily needed in the present study [13].

The survey was conducted in the form of an online questionnaire using the online survey tool Unipark. To generate sufficient coverage, e-mail addresses were collected by means of online research and the link to the questionnaire was sent to these contacts. Before the questionnaire was sent out, it was tested in a pre-test phase to ensure that it was sent out without errors [14].

586 emails were sent to potential respondents. 81 respondents completed the survey, resulting in a response rate of 13.8%.

#### 3.2. Data analysis

Besides descriptive analyses, the data evaluation was conducted with the help of IBM SPSS. Crosstabs are used for the evaluation, which generate two- or multidimensional contingency tables between variables. The rows usually contain the independent variables and the columns the dependent variables.

In the analysis, company size is taken as the independent variable in the form of annual turnover. Companies that do not meet the SME definition, i.e., companies that have more than 250 employees or have a turnover greater than 50 million euros, were left in the analysis despite the SME focus of the study to also have data on larger companies and thus a comparison. This makes it possible to filter out the extent to which company size influences the application of data-based analyses and visualizations.

In the Likert-scale, 1 was coded to be “never”, 2 was “rarely”, 3 was “sometimes”, 4 was “often”, and 5 was “always”. Statistical measures were used to test whether there is a statistical relationship between the two variables in the crosstab. For this purpose, Cramer's V and the chi-square test were applied as statistical measures.

#### 4. Results

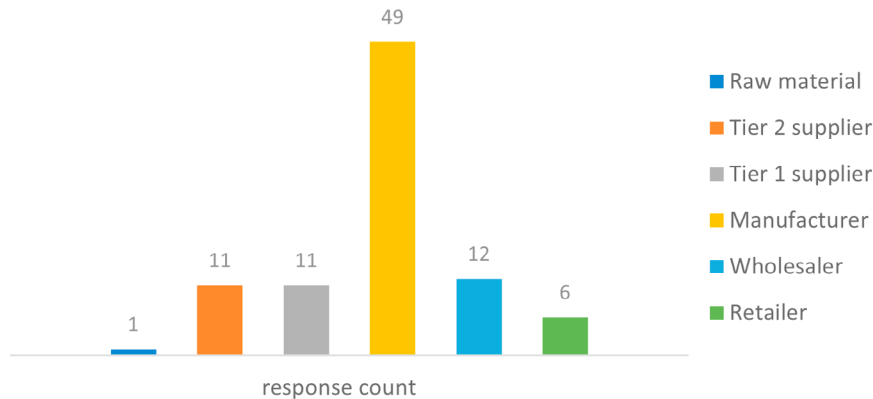


Fig.2. Count of respondents per vertical level of the supply chain.

To evaluate hypothesis 1 (H1: Data-based MSCM is put into effect to a larger extent upstream (raw material suppliers and higher-tier suppliers) than downstream the supply network), the respondents were counted by their vertical level of supply chain. If a respondent gave two levels or more, it was counted in all given levels. This yield the following numbers, which can also be seen in Fig.2. The 82 responses included 9 replies, who stated that their company was only tier 2 supplier, and 6 replies, who stated that their company was only tier 1 supplier. 40 respondents stated that their company was only manufacturer, 6 respondents stated that their company was only wholesaler, 4 respondents stated that their company was only retailer, and only respondent stated that her company was tier 1 and tier 2 supplier, Further, three 3 respondents stated that their company is tier 1 supplier and manufacturer, while 4 respondents stated said their company are manufacturers and wholesaler. Additionally, five respondents did not answer the question at all. Therefore, the responses sum up to 95 cases.



Fig. 3. Information on stock level as an example for the difference in availability between data from customer and supplier.

Fig. 3 shows the average answer of the respondents of each group. The left side shows how often companies receive information from their suppliers, while the right side shows the receiving intensity from the customers.

Regarding hypothesis 2 and 3 (H1a: Information a) b) c) d) e) is shared with SMEs. H1b: Information a) b) c) d) e) is shared by SMEs), the respondents were filtered to have an annual turnover of less or equal to 50 Mill. Euros. This was the case for 61 respondents.

Figure 4 shows the responses regarding information that is shared with SME by their suppliers or customers. It can be seen that the level is rather low generally, but questions 3 and 9 were answered with higher agreement resulting in a median of 3. Hence, the respondents' companies are informed sometimes about bottlenecks and delays in their value chains and sometimes about the delivery status of orders.

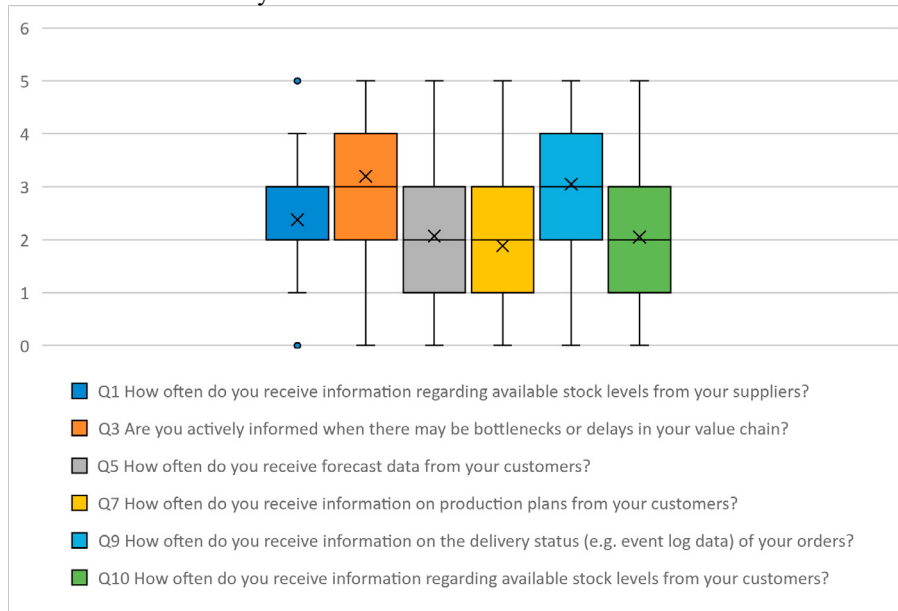


Fig. 4. Boxplots of responses for information that is shared with SME by their partners.

In Figure 5, the other direction of information flow is investigated. This is the information that is shared by SME to their partners. In their opinion, SME share often information about bottlenecks and delays with their partners. Other kind of information was answered to be shared rarely to sometimes.

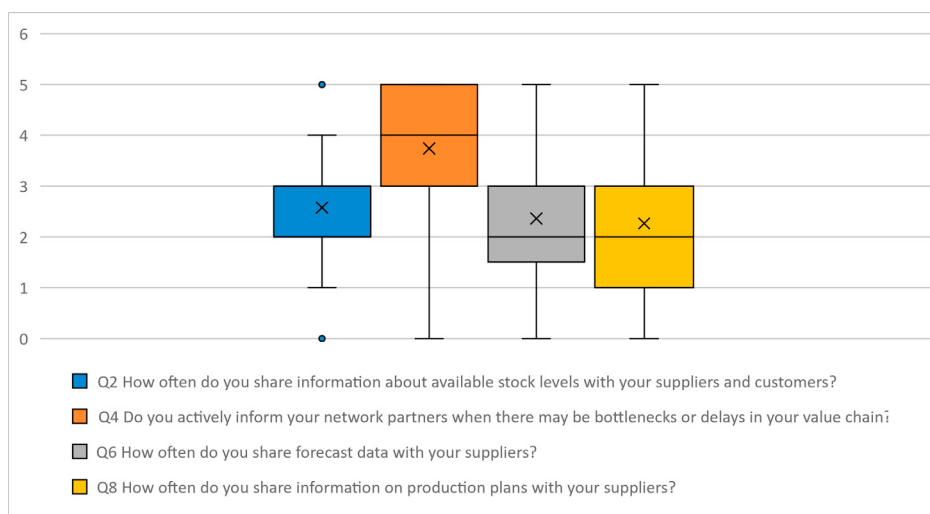


Fig. 5. Boxplots of responses for information that is shared by SME with their partners.

The results of the statistical analysis give reason to believe that there is a correlation between company size and information sharing. The strength of the correlation was determined using the Cramer's V coefficient. The strengths were medium in all kinds of information. This means that there is a need to catch up for SME regarding information sharing to direct customers and suppliers. The same may hold for information sharing in the network, meaning that information is shared between a company and its sub-suppliers and sub-customers. However, this result is not significant enough and more data has to be gathered. The results of the interviews and the survey give some additional insights to motives and reasons for data sharing and network analysis. SME mainly use data for operational purposes, for which they have a sufficient data base. However, to incorporate more sophisticated data analyses and optimization, their data base is not adequate in most cases. Accordingly, knowledge about sub-suppliers and sub-costumers is rarely available at SME, since the awareness for its benefit has not yet reached them. Nevertheless, there seems to be a common reason for strategic activities, which is the improvement of delivery reliability and quality. Regarding optimization, it can be said that SMEs very rarely practice data-based optimization. The reasons given are a lack of know-how, an insufficient database and also a lack of demand.

## 5. Discussion and Conclusion

### 5.1. Interpretation of Results

From the interviews, we derived the motives of SMEs for carrying out MSCM and to share data. Mainly, SMEs aim to serve customer requests and to be able to fulfil their own production plan. This is in line with Arend and Wisner [14], who found that conducting supply chain management (SCM) is negatively related to SME performance since they do not implement SCM thoroughly enough or do it because they are forced by more powerful partners while not having benefits for themselves. Hence, before SMEs are able to conduct profitable MSCM, data exchange must be established with mutual benefits for supply chain partners [2]. In addition, we found that not all kinds of information may be relevant for partners in the supply network. For SMEs, binary notes would often suffice, e.g., whether the delivery is on time or not.

In summary, it can be argued that SME must invest primarily in the area of data structures and availability in order to create the basis for data-based analyses. Particularly regarding network partners that are not directly connected to the company, there is a great need for data so that the entire structures can be analyzed and optimized. It is noticeable that there are differences between the companies in many areas of analysis, which result from the size of the company. Differences are particularly noticeable regarding data availability and the application of analyses in the supply chains. Larger companies are better equipped in terms of data availability and perform more analytics - presumably because they work more intensively with data and therefore also rate the potential higher than smaller ones. Likewise, larger companies have more power in the network and can therefore de facto secure better data availability from their network partners.

### 5.2. Academic contribution

This article contributes to the literature on information sharing in supply networks since it sheds light on the information that is shared by SMEs to their supply chain partners and from their partners to them [3-6], larger firms take important advantages from MSCM, SMEs might have a competitive disadvantage, if they miss the importance of data-based MSCM.

With respect to publications in the field of digital transformation and Industry 4.0 in SCM, the paper is able to contribute to the topic of information sharing. This represents an integral part to enable further potentials of Industry 4.0 and digital transformation with respect to SCM [2,15]

### 5.3. Managerial implications

From a managerial perspective, SMEs gain insight in reasons and potential barriers to share data in MSCM. This can help both SMEs and partners in the supply chain to address respective barriers that are often unknown and can be addressed by supply chain partners.

Further, the type of data shared by and with SMEs is revealed. This can help SMEs to better understand their own positioning and large enterprises can use this information to better understand their suppliers that are often represented by SMEs in their supply chain.

#### 5.4. Limitations and future research

The present paper is part of a larger study as a second, quantitative approach. The first part of the study is published as a journal article [12]. Due to the length restrictions of this conference proceeding, both studies can only be interconnected briefly.

As a limitation, the responses only amount to 81 valid responses, limiting the results in statistical significance and not allowing for a statistical comparison between large enterprises and SMEs. Therefore, for future research, we aim to extend this sample to a larger number of respondents.

Further, the study is limited to Austria and Bavaria (Germany), calling for an extended analysis in a broader geographical setting in the future. Specifically, the investigation of supply chains that span across multiple regions around the world could be of particular interest in this context.

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