sustainability

MDPI

Article

Antecedents to Digital Platform Usage in Industry 4.0 by Established Manufacturers

Julian Marius Müller

Department of Logistics and Operations Management, Salzburg University of Applied Sciences, 5412 Puch bei Hallein, Austria; julian.mueller@fh-sazburg.ac.at

Received: 26 December 2018; Accepted: 18 February 2019; Published: 20 February 2019

check for updates

Abstract: Digital platforms are expected to have the potential for a multitude of purposes for industrial enterprises, for instance when integrated within the concept of Industry 4.0. Despite its relevance for industrial value creation, little research on platforms in the industrial context has been undertaken so far. Owing to the lack of research in this field, the paper aims to investigate the potentials and challenges of digital platforms in order to generate an understanding of the antecedents to the use of digital platforms by established manufacturers. In the qualitative-exploratory study, the paper uses a qualitative empirical research approach, relying on in-depth expert interviews. The sample comprises interviews with managers of 102 German and Austrian industrial enterprises from several industrial sectors. All of the enterprises regarded have practical experiences with digital platforms. The results show that the main potentials of digital platforms are reducing transaction costs, combining strengths of enterprises, and realizing economies of scale as well as economies of scope. Yet, digital platforms bring challenges, such as a lack of trust, competitive thinking, high coordination efforts, and loss of confidential information. The paper further distinguishes between various industry sectors revealing interesting differences. Based on the results, the paper indicates possibilities for future research and provides corporate practice with implications.

Keywords: Industry 4.0; industrial internet of things; digital transformation; digital platforms; qualitative-empirical study; small and medium-sized enterprises

1. Introduction and Problem Outline

Industry 4.0 is expected to lead to vertically and horizontally interconnected industrial value creation networks [1,2]. In this context, the industrial landscape is predicted to undergo fundamental changes, accompanied by benefits, but also several challenges [3]. Because of its technological and economic implications, Industry 4.0 has the potential to transform ordinary industrial value creation of industrial companies and relocate it onto digital platforms [4].

When companies engage in digital platforms, those are expected to create novel economic ecosystems and revolutionize future value creation [5]. Via their virtual interconnection on digital platforms, several entities are combined on one single space for gathering, processing and managing data. So-called multi-sided platforms combine customers, suppliers, and partners on one single platform, serving all stakeholders' interests [6]. By engaging in platforms, stakeholders lay the foundation for new forms of interaction between stakeholders inaugurating new ecosystems. In the consumer industry, platform providers already have radically transformed traditional businesses, e.g., Airbnb, Amazon, and Alibaba [4]. Thus, platforms also pave the way for new, innovative business models in the industrial sector [7].

Up to now, using digital platforms in the industrial sector are yet to grow due to some unsolved theoretical and practical issues. Whereas companies in the information technology sector have been developing such platforms for years [5], industrial companies are still significantly less active on this path [8,9]. It remains unclear which potentials digital platforms imply for the industrial sector, as developments unfolding in business to consumer (B2C) markets might have different effects in the business to business (B2B) context [10]. Further, there are challenges caused by remaining questions, for instance, data ownership, management and control of platforms, and relationships between the entities [11]. Addressing these questions and solving these issues is of high importance, as digital platforms are expected to generate large potential for industrial value creation [7].

Despite its relevance, little research on digital platforms in the industrial context has been undertaken so far. This raises calls for empirical research that helps to better understand challenges and potentials, as well as practical experiences gained in the field [12].

Given its importance for future value creation, research has lately begun to turn its focus on platforms. So far, most academic studies so far almost exclusively examine platforms of non-industrial contexts, neglecting digital platforms in industrial contexts and their potential and challenges respectively [13,14]. In response, research calls for studies that complement the findings of digital platforms in a B2C context [3,10,12].

Digital platforms in the context of Industry 4.0 are scarcely understood, calling for research for the underlying benefits and challenges by academic papers [3,10,12–14]. The extant literature in the field of digital platforms is quite sparse, and a comprehensive understanding of digital platforms in an industrial context has not been developed yet [3,10–12].

For instance, the majority of the papers that examine digital platforms in the industrial contexts from an empirical perspective so far rely on single cases, but are not able to generate a holistic understanding of digital platforms [5,10,12]. However, a comprehensive overview of potentials and challenges provides a fruitful insight for academia, as described by several authors [3,10]. Platforms in the industrial context are just beginning to generate high interest, but also concerns of industrial manufacturers [1,4]. Relating to this early stage of development, but the numerous potentials known from B2C contexts, research is required in order to investigate the possibilities to transfer digital platforms to the B2B context [5,10]. Furthermore, the specific requirements and challenges of digital context need to be investigated in detail [3,11].

Additionally, it has been found that in the case of Industry 4.0 as well as for digital platforms, industry-specific differences can be observed regarding the implementation and unfolding of Industry 4.0 and digital platforms respectively [3,5,10,12]. Hence, this paper attempts to compare the findings among several industry sectors.

In sum, the following research questions are addressed within this paper:

RQ 1: What are the underlying challenges that impede the unfolding of digital platforms in an industrial context?

RQ 2: Which are the potentials that can be achieved through the usage of digital platforms in an industrial context?

RQ 3: How do challenges and potentials of digital platforms in an industrial context differ among industry sectors?

Concomitant with the high interest of academia in digital platforms, the paper further intends to investigate digital platforms from the perspective of corporate practice. Therefore, the paper aims to provide insights about the potential of digital platforms and reasons to use them in corporate industrial value creation. In addition, the paper indicates challenges of platforms, unveiling critical aspects of platform usage and differentiate those for different industry sectors. In that way, industrial firms shall receive as close guidance as possible for their respective requirements and frame conditions.

The remainder of the paper is organized as follows. In Section 2, Industry 4.0 and digital platforms are introduced, whereas Section 3 describes the method. Section 4 presents the results, providing a comprehensive overview of benefits and challenges of digital platforms. Based on the empirical findings of this paper, those are discussed with extant literature in Section 5, highlighting the theoretical contributions of this paper. The paper further provides managers with practical implications, followed by limitations and suggestions for future research in Section 6.

2. Theoretical Background

2.1. Industry 4.0

The term Industry 4.0 refers back to a concept of the German federal government and indicates a de novo change of paradigm in industrial value creation. The concept aims at shifting the industrial value creation towards the digital future to secure the future competitiveness of the industrial sector [2]. It is based on the expectation that industrial value creation is about to undergo a fourth industrial revolution [1]. The first three industrial revolutions have led to significant increases in productivity [15]. They were driven by technological developments such as mechanization, electrification, and the application of information technologies, respectively [16].

Cyber-physical systems form the technological basis of Industry 4.0, enabling real-time interconnection of the physical and virtual world as well as smart data analyses [17]. These systems offer mechanisms for human-to-human, human-to-object, and object-to-object communication. Their application in industrial production leads to cyber-physical production systems [18] enabling condition monitoring, preventive diagnostics and maintenance, and self-regulating control of machines [19]. Applying these systems and functions within the industrial context paves the way for creating a so-called smart factory. In turn, connecting several smart factories leads to smart production networks that represent whole supply chains [20–22].

Industry 4.0 is a concept that is based on the Internet of Things. Relating to an application of the Internet of Things in industry, it is sometimes described as an equivalent to the Industrial Internet of Things [1,2]. Still, the exact definition of Industry 4.0 remains disputed. It varies among academic disciplines, and aspects relevant for each discipline tend to be highlighted [23]. Most authors relate to horizontal and vertical interconnection across the life cycle of products, machines and humans by the means of cyber-physical systems in real time [1,7,23]. However, the majority of current definitions or understandings of the term Industry 4.0 does not include a management perspective. Hereby, management of digital transformations, for instance of business models, can be regarded as a central aspect of Industry 4.0 [3,7,23].

Similar concepts to the German Industry 4.0 emerge worldwide [24]. These include the Industrial Internet Consortium in the USA [25], the Internet Plus concept within the Made in China 2025 program in China [26], and Manufacturing Innovation 3.0 in South Korea [27].

These attempt to help companies managing and coping with changing environmental conditions such as globalization, increased uncertainty of markets, intensified competition, shortened innovation and product life cycles. Further potentials include flexibility and productivity increases, development of new business models, ecological potentials such as reducing energy consumption, and social potentials like smoothly integrating people into adaptive working environments [1,14]. The reasons for adopting Industry 4.0 technologies differ depending on several company characteristics [28].

Industry 4.0 is expected to pose several challenges to existing companies including high investments, disrupted existing business models, and employees' fear to be replaced [3]. These challenges are especially harmful for small and medium-sized enterprises (SMEs), which are frequently intimidated and ask for special attention [7].

So far, research has primarily focused on technological aspects of Industry 4.0. In contrast, economic aspects of Industry 4.0 have been less regarded [23,24,29,30]. This contrasts with Industry 4.0 promising new, data-centric, and platform based business models with large potentials for industrial manufacturers, which research has examined scarcely [3,31,32].

2.2. Digital Platforms

Digital platforms are expected to create novel economic ecosystems and revolutionize value creation [5]. They have numerous implications for industrial value creation, including the transformation of value chains into digital value creation networks [4]. By gathering, managing, and analyzing data, platforms unite, e.g., partners, customers, and suppliers on one platform serving the interests of several players [3,6,31]. In general, digital platforms are expected to foster innovation and collaboration between partners by easing communication and coordination among several stakeholders [21,32]. Further, customers can be integrated into the value creation process [33], e.g., in open innovation contests [34]. Because platforms open up new perspectives as well as new forms of interactions and relationships, they provide the basis for creating new business models [35].

In the study, digital platforms are understood as "products, services, and technologies that are organized in a common structure through which a company can create derivative products, services, and technologies" [5]. They in turn provide the basis for external companies to be able to contribute their products, technologies, and services. Thereby, they pave the way for new economic ecosystems as well as new logics for value creation [5,35]. Furthermore, the paper uses the extension of the definition by Hagiu and Wright [6] according to whom "multi-sided platforms" are characterized by two core elements: First, these platforms must enable direct interaction between two or more players while, second, each player is connected to the platform. As a result, the digital platform fulfills the needs of several customer groups, combining their needs for which a common business model finds synergies and compound effects [5,6].

In that sense, digital platforms differ from traditional technology platforms. Such technology platforms are typically characterized by the provision of several products and services by a platform provider to its customers. The combination of several customer groups, that can also partially serve as providers of, for instance, data for other customers, as well as their interconnection in real time is not seen in traditional technology platforms [5,6,10]. Hence, the technological requirements, as well as the underlying logics for value creation for the customers, differ significantly between technology platforms and digital platforms.

Information technology companies have been developing such platforms for years [36], while the rather traditional industrial sector undertakes less effort in this respect [8]. In particular in the industrial context, established enterprises face the challenge to find partners to create digital platforms and to develop new competitive business models [9,37]. In addition, digital platforms call for the development of adequate IT competencies, which does not represent a core competence of traditional industrial manufacturers [38]. Additionally, further issues remain unresolved, such as, to whom data belongs to, how to control such platforms, and how to manage the relationships between players adequately [11].

Despite the relevance of platforms, especially for the industrial context, there are hardly any scientific studies examining the effects and implications of digital platforms from a management perspective or in an industrial context [12–14]. In addition, existing research rather refers to a specific understanding or to partial aspects than generating a holistic picture [8,11,39–41]. Nevertheless, digital platforms help addressing future challenges that should call for researchers' interest [12]. New, data-centric business models are expected through platforms within the concept of Industry 4.0 [42]. Further, some authors show successful application examples of platforms in the context of the Internet of Things [43–46].

2.3. The Interplay of Industry 4.0 and Digital Platforms towards Sustainability

Industry 4.0 is expected to generate numerous benefits towards sustainability in the context of the Triple Bottom Line, i.e., economic, ecological and social benefits. Concomitant challenges in all three dimensions of the triple bottom line of sustainability have to be considered. This is especially the case for their interplay, for instance short-term economic efforts that are necessary to achieve long-term benefits in all three dimensions of sustainability, has just started to be considered from an academic perspective. However, understanding the interdependencies between the three dimensions of the Triple Bottom Line in the context of Industry 4.0 is of vital importance in order to support its implementation [3,26,28].

From an economic perspective, process efficiency can be increased on an operational level through interconnection along the supply chain [1,5]. Relating to the use of digital platforms, production capacities among several production plants can be coordinated, whereas logistics processes can be better aligned. Hereby, digital platforms can serve as the communication and coordination means among several enterprises, especially among multiple stakeholders in a supply chain [3]. This also contributes to the ecological benefits of Industry 4.0, for instance, through the reduction of transport routes, reduction of energy consumption, or reduction of idle times and downtime. Further benefits include a reduction of waste and enhanced recycling processes. [3,28]. Digital platforms can assist here not only to optimize production and logistics processes from an economic, but also from an ecological perspective [3,26]. However, increased energy consumption through emerging new technologies, such as server capacities and data transmission on data hubs through digital platforms, must not be neglected as a negative ecological effect of digital platforms [26]. Furthermore, especially SMEs are reluctant to share information and data digitally, as they fear to become more transparent. As a result, they fear, for instance pressure to lower prices through increased transparency to larger enterprises with a higher bargaining power, among other possible scenarios [7].

On a strategic level, new business models shall be developed in the context of Industry 4.0. In this regard, digital platforms are seen in a prominent manner as a means to generate novel business models [1]. For instance, data generation, data transmission and data evaluation can be eased through the use of digital platforms. However, emerging new business models also raise fears of established firms that not them, but the platform providers will be able to generate value that the customers are willing to pay for. Consequently, established firms fear being driven into niche segments, losing their established market shares and revenues through the emergence of digital platforms [3,7].

From a social perspective, Industry 4.0 is expected to generate several benefits for employees. One example includes workers on the shop floor, for which the reduction of monotonous tasks or physically exhausting process steps can be achieved through new technologies housed under the term Industry 4.0, such as human–machine interaction systems, collaborative robotics, or augmented reality, among further examples [1,3]. However, the introduction of new, data-driven technologies also raises fears among employees to be replaced thorough machines, to be transparent and subject to data collection, and to lose decision power to artificial intelligence [3,28].

With regard to the use of data-driven approaches, innovation management shall be enhanced in Industry 4.0, for instance, through an eased backflow of data from products in use to product development. Thereby, product development can be improved while also including ideas of several stakeholders in the supply chain, or additionally including the ideas of the customers. In this context, digital platforms can help to bundle information related to product usage and customer requests on a common platform to which all stakeholders of a platform have access. Using this approach, the fear that one stakeholder in the supply chain might become to dominant can be decreased [1,3]. Still, SMEs are again reluctant to share such information, as they fear losing market share and confidential information to competitors [7].

In sum, it has to be noted that digital platforms in the context of Industry 4.0 could lead to benefits in all three dimensions of the Triple Bottom Line of Sustainability. So far, little is known about the antecedents that influence platform usage and therefore their broader implementation. This paper is therefore devoted to give insights on the little regarded topic of digital platforms usage by established manufacturers.

3. Methodology

3.1. Research Design

The paper is of exploratory nature since management research does not provide an integrative, holistic, and systematic investigation of Industry 4.0 platforms so far. Following common research practice, a qualitative empirical research approach based on inductively analyzed in-depth expert interviews is applied [47,48]. This method was chosen for several reasons: First, it is well-suited for analyzing contemporary, novel and complex phenomena within their real-life contexts [49–51], which is true for Industry 4.0 platforms. Second, qualitative research has proven to be effective in the context of information systems that constitute the core of Industry 4.0 technologies [52]. Third, relying on multiple interviews instead of a single case increases the robustness and generalizability of the findings [48].

3.2. Data Sample

In the qualitative research, semi-structured in-depth expert interviews with managers from corporate practice are used as main source of empirical material [52]. This approach facilitates a structured data collection, while maintaining the level of openness to allow unexpected and novel knowledge to emerge, which corresponds to the exploratory nature of this study [50,53].

Between December 2016 and May 2017, 494 German and Austrian managers of companies with varying firm sizes and from varying industry sectors were randomly selected and contacted via email. The companies were asked to present their most suitable representative regarding Industry 4.0 and digital platforms. Regarding digital platforms, the companies as well as their representative were required to have practical experience, which as validated in the first part of the questionnaire. In total, a final sample of 102 enterprises that participated in the study was achieved, resembling a response rate of 20.65 per cent. These include mechanical and plant engineering (n = 37), electrical and ICT engineering (n = 25), plastics engineering (n = 14), steel and metal processing (n = 12), automotive (n = 8), wood processing (n = 5), and a single participant from the medical engineering industry.

All of the representatives are experienced in the implementation of Industry 4.0, which was ensured by the interview results and secondary case data. Furthermore, all of the companies are using at least one digital platform. In this regard, all 102 companies use supply chain management or purchasing platforms. Moreover, 46 of the 102 companies use production management platforms, e.g., for scheduling and coordinating production capacities. Also, 22 out of the 102 companies are using innovation management platforms, that can be used for sharing and commonly developing ideas among several enterprises. Finally, five out of 102 companies have launched their own digital platform, and are simultaneously using digital platforms in the contexts named above. The low number of only five enterprises can be reasoned by the early stage of implementation of digital platforms that are provided by established manufacturers themselves [1,3].

The average turnover is 123.86 million euros with an average of 590 employees. Regarding annual sales 62 out of 102 enterprises can be classified as SMEs with an annual turnover below 50 million euros, according to the definition of the European Union [7]. A detailed list of interviewees can be found in Appendix A. The heterogeneity of the empirical material counteracts potential negative effects of sample bias on the findings and follows Yin's [50] recommendation for multiple case study sampling.

Germany and Austria were chosen because of their representative character for developed and industrialized economies, their importance for the European market, and their advanced experiences in Industry 4.0. The sectors chosen are among the industries that contribute the most to the gross domestic products of Germany and Austria respectively. Furthermore, Industry 4.0 mainly targets these industries [1].

The interviews lasted between 35 and 80 min. They were conducted in German, the native language of the interviewees and interviewers, to avoid language or cultural barriers, and to ensure comparability. For confidentiality reasons, the interviewees' data is anonymized.

Corresponding to the exploratory nature of the study, the development of the interview guide was informed by literature but followed the principle of openness and flexibility. Thereby, it allowed unexpected and novel topics to emerge [54]. It consists of three parts. The first part aims at verifying the interviewees' reliability and knowledgeability. Therefore, it deals with general and personal questions, e.g., the expert's job position, company tenure, and understanding of Industry 4.0 and digital platforms. The second part contains questions about benefits that the respective companies faces in the context of digital platforms:

- Which company-internal economic benefits did you experience by using digital platforms?
- Which economic benefits achieved together with other platforms members did you experience by using digital platforms?
- Which further benefits did you experience by using digital platforms?

The third part of the interview guideline includes questions about challenges related to the usage of digital platforms. The questions are mainly inspired by the framework of Kiel et al. [3], relating to challenges experienced in economic, social, technical and legal terms:

- Which economic challenges did you experience by using digital platforms?
- Which organizational, relating to company-internal challenges did you experience by using digital platforms?
- Which organizational, relating to challenges with other platform members did you experience by using digital platforms?
- Which technical challenges did you experience by using digital platforms?
- Which legal challenges did you experience by using digital platforms?

3.3. Data Analysis and Reliability of the Study

The empirical material is analyzed applying a qualitative content analysis in accordance with the well-established procedure of Miles and Huberman [55]. The transcription of the 102 audio-recorded interviews resulted in almost 1200 pages of text material. A qualitative content analysis is applied to identify and interpret common patterns, themes, and categories of the interviews. The categories are mainly defined inductively but are also informed by extant literature, allowing novel aspects and concepts to emerge [56–58]. For triangulation purposes, expert interviews are verified using secondary data, e.g., annual reports, whenever possible [50,59].

To increase methodological rigor, the paper follows the established procedure of Gioia, Corley, and Hamilton [56]. Initially, first-order (informant-centric) concepts were developed. Subsequently, these concepts were synthesized into second-order themes, followed by the creation of final categories. The entire coding process was conducted in a team comprised of the study's authors to achieve rich interpretations and profound understandings [60]. Finally, a frequency analysis according to Holsti [61] was conducted. Key informant and retrospective biases are addressed by selecting experts who are experienced, assuring all interviewees of full anonymity and confidentiality, and using secondary data for triangulation reasons [48,50,62]. This approach helps to further increase the robustness of the results as well as to account for routine criticisms in qualitative research designs [48,50].

4. Empirical Results

4.1. Potential of Digital Platforms

The results indicate several potentials for digital platforms which are presented in Table 1. The most important potential of digital platforms is reducing transaction cost which is mentioned by 53 out of 102 interviewees. The reduction of transaction cost is mainly caused by two developments. First, one common platform allows establishing standards, interfaces, and norms. This helps to overcome issues that would be the result of differing standards, interfaces, and norms, e.g., slower data exchange, non-value adding processes, and loss of data. Second, interactions and communication via platforms are more efficient than regular forms of doing business. Instead of having a multitude of interaction and communication channels, a platform provides an exclusive way to consolidate all transactions. According to the interviewees, this helps to support and relieve employees in communication, relating to potential social benefits.

As mentioned by 23 interviewees, combining companies' strengths represents another potential. Instead of acquiring single customers and closing individual contracts with them, a platform allows addressing a large customer base simultaneously and at low cost. Furthermore, companies that are active on a platform are able to combine their assets and financial resources. For instance, know-how can be shared in order to achieve a common goal. Another aspect is that companies on a platform can share risks, e.g., production capacity can be split among players so that production peaks may be balanced preventing production downtimes.

Likewise, important are economies of scale and economies of scope discussed by 21 experts. First, companies can purchase commonly, which increases their buying power and volume, and in turn, helps them to negotiate favorable conditions and discounts. Second, sharing helps companies to improve efficiency. For instance, companies can divide financial investments in infrastructure for a platform and later on use it commonly. As platforms allow scaling output easily, fixed cost are divided by large volume leading to lower costs for each player. Furthermore, this allows to achieve ecological benefits, as the overall resource and process efficiency can be enhanced.

Open innovation (named by 19 experts), benchmarking, and developing partnerships (each named by 7 experts) are further important potentials revealed by the study.

Table 1. Potentials of Industry 4.0 platforms.

First-Order Concept	Second-Order Theme	Frequency *	Exemplary Statements
Reducing transaction costs	▪ Reducing communication efforts ▪ Establishing standards, inter-faces, and norms	53	"With platforms, every communication, every pay-ment, every transaction becomes more efficient." (Interview no. 32)
Combining strengths	▪ Addressing a large customer base ▪ Combining assets and financial means, sharing risks	23	"Especially small enterprises are able to virtually combine their abilities on a platform." (Interview no. 2)
Economies of scale and economies of scope	▪ Reducing costs when purchas-ing commonly ▪ Sharing resources and capacities	21	"By combining purchasing activities, economies of scale can be generated." (Interview no. 49)
Open innovation	▪ Opening and extending innova-tion processes ▪ Enabling virtual product devel-opment	19	"Virtual product devel-opment, located at different geographical places, can be integrated." (Interview no. 96)
Bench-marking	▪ Facilitating access to best- practice examples ▪ Establishing a community for process optimization	7	"On a platform, best practice examples, [. . .] can be interchanged easily." (Interview no. 6)
Developing partnerships	▪ Fostering existing partnerships ▪ Building up trust	7	"Partners on a platform can communicate and interact much more easily." (Interview no. 67)

* Multiple answers possible.

4.2. Potentials Differentated According to Industry Sectors

The potentials of using platforms in the industrial value creation vary in different industry sectors. Figure 1 depicts the detailed differences while the aspects attracting attention are discussed in the following. The single respondent of the medical engineering industry is not shown. Furthermore, the results of the wood processing industry, although showing quite distinct results, have been excluded from the interpretation of the results due to the low number of cases.

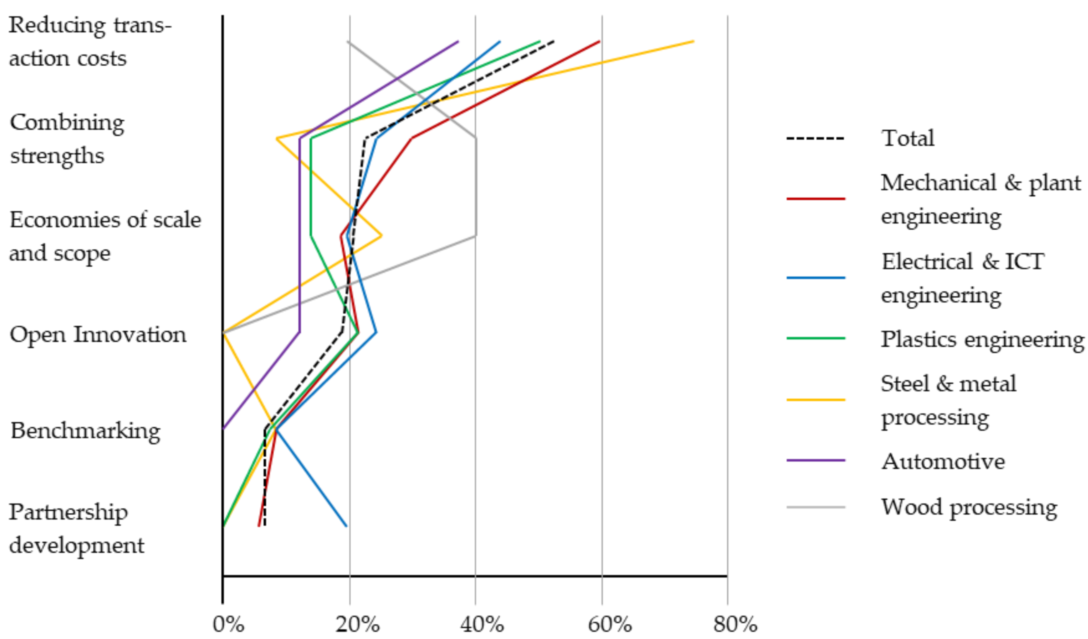

Figure 1. Industry-specific differences as for potentials of Industry 4.0 platforms.

Steel and metal processing as well as mechanical and plant engineering foresee potential especially in the reduction of transaction costs. This can be explained partially by the characteristics of the respective industry sectors. For instance, in the mechanical engineering industry, negotiating contracts usually consumes many resources. This is a result of the complexity of products, as especially plant engineering enterprises sell complex products to their customer. These also require more complex contracts, as products are often tailored specifically to customer demands, having "lot size one" characteristics. Further aspects that could be relevant in this context are, for instance, more complex liability of plants or when having service business models in place that go beyond selling a product.

The results also show that both potentials, combination of strengths and economies of scale and scope, play only a subordinate role in the automotive and in the plastics engineering industries. In particular, SMEs profit from the combination of strengths and economies of scale and scope when doing business on a platform the most. The sample contains major players as for the automotive industry and the plastics engineering industry, whereas SMEs dominate in the other industry sectors that can explain the different perceptions. Furthermore, the automotive industry is known for already achieving high economies of scale and having efficient supply chain management practices in place. Therefore, platforms might not be seen as having such an impact on improving the efficiency in comparison to other industry sectors.

Open innovation does not play a role as for potentials of platforms in the steel and metal processing industry. This might be referred back to that open innovation in these sectors generally is not as important as in other sectors due to the characteristics of the products and services in those industries. In the steel and metal processing industry, rather large quantities and less specific products are produced. Hence, an integration of the customer in the innovation process might not be seen as important as for industries that provide products and services that are tailored more specifically to customer demands.

Interestingly, the electrical and information and communications technology (ICT) engineering uses and appreciates platforms to further develop their partnerships. In this context, the closeness of electrical and ICT engineering to IT solutions, and thereby to digital platforms, might play a significant role.

Having presented the potentials of digital platforms and their differentiation among industry sectors, the following sections list challenges of digital platforms found and differentiate those for several industry sectors.

4.3. Challenges of Digital Platforms

Using platforms poses several challenges, which are presented in detail in Table 2. The results indicate the biggest challenge as for digital platforms is lacking trust between the players that hinders a smooth implementation and usage of platforms, named by 53 out of 102 experts. First, in order to ensure smooth transactions and communication between players, a certain level of transparency need to be maintained. This includes sensible data, such as infrastructure, capacities, and cost structure. Some fear that being transparent strengthens competitors instead of bringing individual profits. Second, investing in infrastructure and committing oneself to a platform, increases the costs to cut the strings and terminate the business. In turn, this decreases individual player's bargaining power as they become more dependent on a platform. Subsequently, they must accept what they might not like due to the lack of (financially reasonable) alternatives.

Fifty one out of 102 experts named competitive thinking as a challenge of digital platforms. Working together on a platform requires a collaborative and cooperative thinking. However, individual players tend to focus on their own benefits, strive for their own profit, and behave in a selfish way, which hinders smooth transactions and interactions on platforms. This may culminate in an unwillingness to cooperate impeding the idea of doing business on a platform. Furthermore, there is a lack of understanding that collective benefits in the long run are larger when players work together. Individual player might need to take the risk of suboptimal decisions from an individual perspective and lower individual short-term profits. Yet, it is a challenge to ensure an understanding for this given the individual interests and incentives of players, managers, and employees.

The results indicate the high coordination efforts represent a further challenge that was mentioned by 46 out of 102 experts. From a technical point of view, it is difficult to create interfaces between the platform and the players that enable smooth data exchange. Here it comes into question which players will prevail in setting the standards and which players need to invest to meet the interfaces' requirements. From a juridical point of view, it is difficult to enter into a contract as such contracts are rather difficult to design. When these initial challenges are overcome, there remain efforts such as to generate a common vision and strategy for the platform, requiring high short-term investments with unclear and undetermined amortization.

A likewise important challenge is the loss of confidential information that was mentioned by 45 out of 102 experts. Many companies do not trust in digital information sharing in general and prefer offline communication. Additionally, many fear that confidential information may be passed on to third parties resulting from industry espionage and hacker attacks.

Further challenges include difficulties in finding adequate partners (named by 39 experts), the fact that some players prefer being independent (discussed by 36 experts), and unsolved questions about data ownership (mentioned by 24 out of 102 experts).

Table 2. Challenges of Industry 4.0 platforms.

First-Order Concept	Second-Order Theme	Frequency *	Exemplary Statements
Lacking trust	▪ Fearing transparency ▪ Losing bargaining power	53	"All members are opponents in some way or another. This mindset needs to change." (Interview no. 27)
Competitive thinking	▪ Focusing on own benefits, selfish behavior, unwillingness to cooperate ▪ Individual, short-term orienta-tion contrasts collective long-term profits	51	"Everyone just thinks about his own profit and how to outreach competitors. But that doesn't work on platforms." (Interview no. 44)
High coordi-nation efforts	▪ Accomplishing interfaces with other firms is difficult ▪ Designing contracts for platforms is difficult ▪ Investments to generate a common vision and strategy	46	"Who do you find that integrates interfaces, aligns data exchange [...]? Everyone just runs his own processes and throws them on the platform." (Interview no. 80)
Losing confidential information	▪ Lacking trust in digital information sharing ▪ Losing confidential information (hackers or industry espionage)	45	"I wouldn't trust to share with everyone on such a platform. And many others neither do so." (Interview no. 23)
Finding adequate partners	▪ Imbalance between industrial enterprises and IT enterprises ▪ Some players do not share same vision or trust each other	39	"There are mostly manu-factures on such a platform, but too few IT experts." (Interview no. 91)
Preferring in-dependence	▪ Some players prefer doing business on their own ▪ Sustainable loyalty to the platform comes into question	36	"I believe that especially smaller enterprises want to stay on their own." (Interview no. 74)
Data owner-ship	▪ Unsolved questions about data ownership and right to use data ▪ Contracts do not satisfactory cover all issues of data security	24	"I don't know who is allowed to use the data; does the platform generate revenues with my data, like Facebook?" (Interview no. 9)

* Multiple answers possible.

4.4. Challenges Differentated According to Industry Sectors

As for the potentials, the challenges in the context of using digital platforms differ in the industry sectors, depicted by Figure 2. Comparably to Figure 1, the single respondent of the medical engineering industry is not shown. Furthermore, the results of the wood processing industry, although showing quite distinct results, have been excluded from the interpretation of the results due to the low number of cases.

The automotive industry, mechanical and plant engineering industry perceive a lacking trust as being a bigger challenge than the sample average. This can be explained because of the sensible information resulting from the complexity of the value creation, which applies for the automotive industry as well as for the mechanical and plant engineering industry. In the automotive industry, several numbers and figures, such as the overall equipment effectiveness, cycle times, or cost breakdowns are regarded as trade secrets. Those shall not be shared as companies fear that these figures will be used against them, for instance, to put pressure on them in price negotiations.

In the mechanical and plant engineering industry, as explained for the potentials of digital platforms, products have a high complexity and are tailored to customer demands. Sharing information on digital platforms might hereby be seen as losing a trade secret to competitors.

In contrast, electrical and ICT engineering rate potential lack of trust below the total sample. The electrical and ICT engineering sector might already have gained experiences with digital data exchange that has created a greater confidence in technology. This can be reasoned with their higher closeness and affinity to IT solutions, as explained for the potentials of digital platforms.

Similar relationships can be observed for competitive thinking, that can be reasoned with comparable explanations as for the previous challenges mentioned. While mechanical and plant engineering enterprises fear competitive thinking on a platform, electrical and ICT engineering rate it as a significantly less important challenge.

High coordination costs and issues of data ownership are particularly important in the steel and metal industry. These sectors might have low experience with platforms so far which possibly helps to explain these findings. Furthermore, those industry sectors typically provide products and services with lower complexity and larger lot sizes, as explained before. In contrast, coordination costs only play a minor role in the electrical and ICT engineering and in the plastics engineering industry.

The plastics engineering and the automotive industry in particular fear losing confidential information when using platforms and see this as a significant challenge. This is especially the case for the automotive industry, this might relate to figures that are seen as trade secrets and shall not be shared, as explained for lacking trust at the beginning of this section. Steel and metal processing industry as well as electrical and ICT engineering industry perceive this as a challenge that is not seen as important. For the steel and metal processing industry, this might relate to the products and services provided, whereas for the electrical and ICT engineering industry, those companies might have a higher affinity and closeness to platform solutions, as explained before.

Finding adequate partners for a digital platform seems to be no challenge for the electrical and ICT engineering industry. These industry sectors might either already have gained some experience with finding partners for platforms, especially the electrical and ICT engineering companies within the sample. As a further reason, they face a competitive environment that forces companies to search for further partnerships anyway.

Companies in the industrial sectors steel and metal processing as well as wood industry prefer being independent. In contrast to that, the electrical and ICT engineering and the plastic engineering industries face fewer issues as per this challenge.

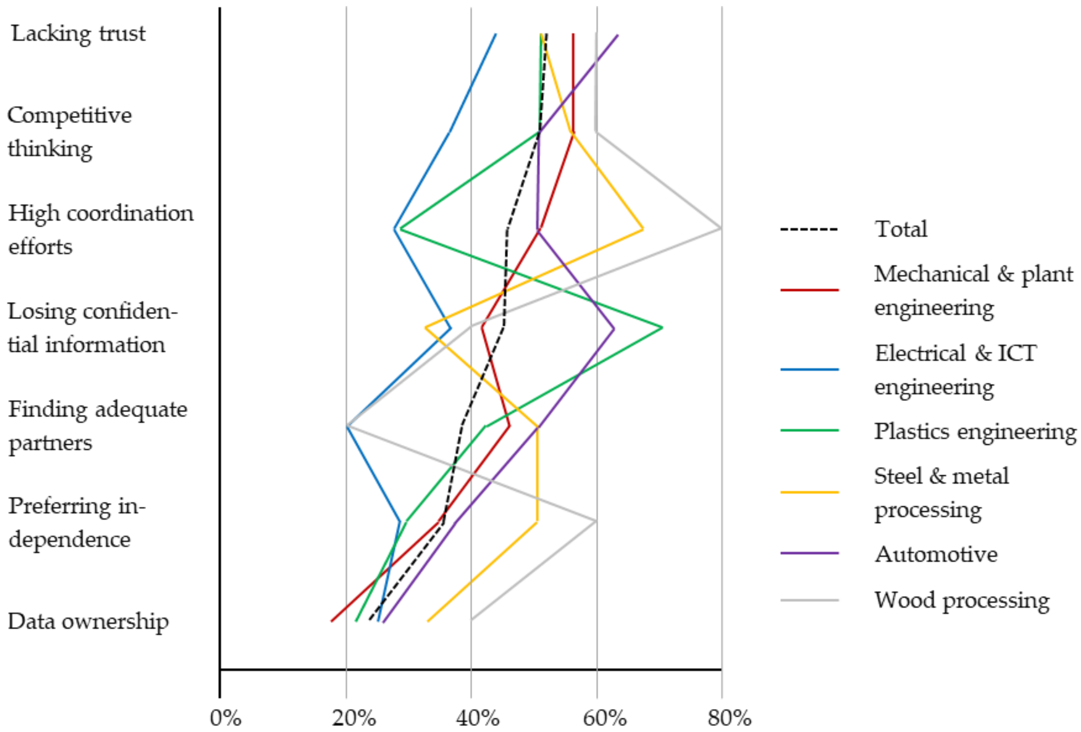

Figure 2. Industry-specific differences regarding challenges of Industry 4.0 platforms.

5. Discussion and Theoretical Contribution

The paper provides a comprehensive overview of benefits and challenges of digital platforms at the current stage of development in industrial application. In that regard, this paper adds manifold to the sparse literature that has investigated digital platforms in the context of industrial companies from a management perspective [8,9].

Furthermore, combining results from both industry-spanning and industry-specific perspectives, the paper synthesises potentials and challenges of digital platforms in the industrial context. In that sense, the paper is able to contribute to calls for research in understanding the benefits and challenges of digital platforms in an industrial context [3,10]. Additionally, the paper is able to generate a holistic overview of potentials and challenges of digital platforms, whereas the majority of extant literature relies on single cases that cannot be generalized for a broader context [5,11,12].

Using this approach, the paper contributes to the understanding of digital platforms in an industrial context, adding to extant studies that have mostly regarded platforms in non-industrial contexts [10,12–14]. In particular, the paper finds that platform-based business models, approaches to open innovation, and new forms of value creation are not yet understood entirely by industrial manufacturers [10,12].

In this regard, the paper shows that the majority of answers rather relates to operational benefits that are generated through the use of digital platforms. New ecosystems, unseen business models, or entirely new forms of value creation were not mentioned by the majority of interviewees. Such benefits as new ecosystems of new business models have been mentioned in literature regarding digital platforms for B2C contexts several times [4,5,10–12,35].

However, when regarding the current state of research regarding reasons for Industry 4.0 implementation, this orientation towards operational benefits might become clearer. As the sample consists of many SMEs, but only a few large enterprises, the findings extend and complement the main results of studies in the field of Industry 4.0. Here, it was found that operational benefits of Industry 4.0 are mainly pursued by SMEs, whereas new business models or strategically-oriented targets are only pursued by a minority [7,28]. This finding is complemented by the insights of extant literature, that describe a rather reluctant behavior of SMEs towards taking risks that might lead them to leave their, so far, successful niche [7,62].

Compared to the behavior of SMEs, rather process-oriented industries regarding Industry 4.0 are also rather operationally oriented towards digital platforms, such as steel and metal processing, or the automotive companies within this sample, which also show a pursuit of operationally-oriented potentials in this study. Those industries tend to be path-dependent on their existing success factors and logics of value creation rather than turning to new opportunities that arise from digital platforms [7,26,28].

Additionally, the findings of this study regarding a rather operationally oriented pursuit of digital platforms could relate to the current stage of development of digital platforms in an industrial context, which several interviewees stress to be at an initial phase. The majority of application examples raised by interviewees rather relate to more efficient data exchange and thereupon achieved data transparency, for instance along supply chains or in research and development (R&D), than to the aforementioned potential of "multi-sided platforms" [6,31]. As a result, the findings, to a larger extend, relate to eased collaboration and communication mentioned in current literature [21,32]. Only a smaller group interviewees relate to aspects of customer integration or open innovation approaches that can be found in extant literature [33,34].

However, the paper is able to show why digital platforms in the industrial context might still be at this stage of development, in contrast to, for instance, in the B2C market [8,36]. This is due to challenges, that have not been presented in literature so far in a comprehensive way, especially not for digital platforms in an industrial context [10–12].

As a first aspect to be named among challenges of digital platforms, this confirms that finding adequate partners represents a challenge for establishing Industry 4.0-platforms. Comparable evidence has been found for Industry 4.0 implementation in extant literature. Further, this aspect has especially been found for SMEs, claiming a challenge to find adequate partners for them for Industry 4.0 [7,9,37,38,63].

As a second aspect of challenges regarding digital platforms, considerations of data ownership and data usage rights, lacking trust, as well as and losing confidential information hamper the unfolding of digital platforms [11]. The unclear legal situation of legal and property rights can also be found for Industry 4.0, where several studies mention that those remain unclear if data is stored and transferred using digital platforms, especially via several countries [3,28,63,64].

In that sense, the findings have to be divided into three categories relating to data security and data property rights, as explained below.

First, technical security, i.e., security that protects against data theft and hackers has to be regarded. Comparable aspects are described to hamper Industry 4.0 implementation in extant literature [3,63]. SMEs in particular are not prepared to develop secure data transmission and storage solutions and their own. The acquisition of external partners for this purpose, however, cannot be afforded by SMEs in many cases [7]. In this way, the present paper is able to show the close interrelations that hinder the implementation of both Industry 4.0 and digital platforms.

Second, security against data transparency, i.e., loss of confidential information to third parties, especially competitors, has to be regarded. Again, the paper complements the findings regarding SMEs in the context of Industry 4.0, as SMEs especially fear that data might be passed on to competitors and that they do not have the necessary power to negotiate terms for data usage for third parties [63,64].

Third, the right to collect and use data have to be clarified from a legal and from a contractual perspective. Comparable insights can be found in the literature regarding Industry 4.0 [3,63]. In this regard, it remains unclear for many companies which data they are allowed to collect and store, and more importantly, to use. For instance, if a benefit is gained by data that was generated by a partner on a digital platform, it remains unclear if this benefit needs to be shared with this partner, or if this partner even has to be informed [63]. This requires among authorities and public institutions that need to ensure a dependable legal framework, as described below, a change in the mindset, as sharing data might not always lead to one's own benefit on a platform. This also relates to the found challenge of competitive thinking, that needs to be changed towards an understanding among partners [64].

In response to the aforementioned challenges arising from data security and data property, technical solutions and clear contracts between partners are one possible solution, which can, however, not be the single solution. Several papers in the context of Industry 4.0, authorities and public institutions have to adapt and extend the existing legal framework and ensure legal conditions that are dependable, especially in an international context [3,63]. For digital platforms, the paper shows that it is also necessary to adapt framing conditions accordingly.

As a third main group of challenges to be named, the paper is able to show competitive thinking and preferred independence play a central role in the context of perceived challenges of digital platforms. Such challenges have been raised in current literature, but the frequency in which they are named by the interviewees stresses their importance for successfully establishing digital platforms [3,7,11]. Especially the aspect of preferred independence is often described in literature among SMEs, which are often run by the owner [7].

Additionally, the paper complements research regarding Industry 4.0 that draws an interconnection between sustainability aspects and efforts of digitization [3,26,28]. This paper is able to contribute to this research stream, combining the findings of research on Industry 4.0 and adding sustainability aspects of digital platforms, which has not been accomplished so far in extant literature.

In particular, the paper helps to shed light on potentials and challenges of digital platforms in the context of Industry 4.0. For economic benefits, reducing transaction costs as well as generating compound effects play an important role. These findings complement the research about Industry 4.0 in general, that finds that SMEs tend to neglect strategically oriented potentials [3,28,64]. In this regard, the paper is able to show that this is valid for SMEs for both, digital platforms and Industry 4.0.

Furthermore, a generation of compound effects can also lead to ecological potentials in an indirect way. This relates to, for instance, aspects of common purchasing with optimized transport routes and less traffic generated [3,36].

Whereas the benefits of reducing transaction costs and economies of scale and economies of scope can be directly associated to economic benefits, indirect ecological benefits as a result could also be achieved in a comparable way to the generation of compound effects. For instance, more efficient production and logistics processes might also lead to more sustainable production and logistics processes from an ecological point of view. For instance, reduced energy consumption, eased accessibility of recycling guidelines, and specifications are among aspects to be named in this context.

Social aspects can be enhanced by, for instance, reducing coordination efforts of humans and reducing monotonous work for relabeling and adaption of standards, as this information can be shared easily on digital platforms. Those aspects represent compound effect of economic benefits and ecological benefits, as well as economic and social benefits, that can be confirmed in the context of digital platforms [3,63,65,66].

The benefits of combination if strengths and benchmarking can be associated to all three dimensions of the Triple Bottom Line, economic, ecological and social benefits. For instance, bringing knowledge about resource-efficient processes together easily on a digital platform, sharing information about recycling specifications, or easing the workflow of humans are possible aspects in this regard [26,63].

Additionally, open innovation and developing partnerships could can be associated to benefits in all three dimensions in the Triple Bottom Line of sustainability, economic, ecological and social. The interconnection of social enhancements with ecological and economic benefits in particular confirms findings that have been found for Industry 4.0 respectively. For instance, better partnerships and better ways of collaboration and innovation pave the way for better economic success and achieving ecological aspects together, which becomes enhances via the use of a digital platform [26,63].

On the other hand, lacking trust, competitive thinking, high coordination efforts, and losing confidential information relate to economic and social concerns simultaneously. Both categories appear simultaneously in this context, highlighting their close interrelation, which hamper the unfolding of the benefits described above. Further social and economic aspects in combination, such as finding adequate partners and preferred independence, as well as concerns from a technical and legal perspective, namely data ownership, should be considered as described above. In this regard, the paper complements findings regarding Industry 4.0, that economic and social challenges have to be mastered before being able to access the benefits possible in all three dimensions of the Triple Bottom Line of Sustainability [3,63].

In sum, it has to be noted that short-term economic efforts and addressing social concerns in particular might be necessary in order to generate benefits within all three dimensions of the Triple Bottom Line of Sustainability, as found for Industry 4.0 [3,26,63]. The paper hereby illustrates the close interrelations and dependencies between the three dimensions, also in a temporal and logical interrelation. Furthermore, the close interrelatedness and dependence of Industry 4.0 as a concept for horizontal and vertical interconnection and digital platforms, bringing together multiple stakeholders for mutual benefits, becomes apparent [1,3].

6. Conclusions

6.1. Managerial Implications

On the one hand, this paper shows that operational potential relating to a combination of strengths, economies of scale and scope, and the reduction of transaction costs can be achieved by using digital platforms. As a result, established manufacturers are advised and recommended to pursue those potentials by using digital platforms. Further, platforms providers are well advised to foster and promote those potentials, as platform users might see those potentials as most relevant at the current stage.

The paper further finds that the characteristics and complexity of the products and services provided play an essential role as to whether and how potentials and challenges of digital platforms are perceived. For instance, processing industries, different have a different approach than those of potential providers of Industry 4.0-based products and services [7,28]. In the sample, this applies in particular to the mechanical and plant engineering industry.

Furthermore, the potential affinity, experience and closeness to IT solutions might influence the perception of digital platforms. Especially the electrical and ICT engineering industries hereby partially show a different behavior than other industry sectors.

Additionally, specific characteristics of certain industries, for instance, feared transparency when sharing information digitally in the automotive industry, play a role in the perception of potential and challenges of digital platforms. Hereby, an understanding that competitive thinking must be addressed in order to operate digital platforms successfully must be created. Giving benefits and rewards for sharing information digitally, and even on a digital platform, to smaller and less powerful supply chain partners might represent a strategy from the perspective of automotive OEMs (original equipment manufacturers).

On the other hand, the paper finds that potentials of digital platforms that relate to entirely new ways of value creation, and the creation of new ecosystems, are hardly addressed within the sample. As these potentials have been found decisive and powerful in B2C contexts, those should be considered in the future in order to grasp the potentials that digital platforms offer.

In sum, the challenges identified in the study require appropriate strategies in order to be able to profit from the potential. The following five principles are derived from the results and the experts' experiences, derived as a comprehensive overview integrated into corresponding strategies in corporate practice:

First, it is essential to ensure secure and trustworthy technical solutions for data exchange and storage to address the lack of trust between partners and the risk of losing information. At the same time, it must properly be defined who owns which data on a digital platform and to what extent it may be used.

Second, a fair distribution of costs and risks as well as returns must be guaranteed to counter prevailing competitive thinking. Likewise, partnerships on platforms must be designed in a way that participating companies are not endangered.

Third, it is particularly important to promote the future reduction of transaction costs and the leverage of synergies to compensate for the initial high coordination efforts. The same applies to the optimization of processes wherefore interfaces and processes must be harmonized.

Fourth, the advantage of improving partnerships using platforms must be promoted, in particular as smaller companies can jointly establish a stronger position on the market. Appropriate and successful benchmark examples of digital platforms help to attract further suitable partners.

Fifth, the potential of digital platforms go beyond efficiency increases and, for instance, includes paving the way for new data-driven business models. This should be better emphasized and promoted in corporate practice.

6.2. Limitations and Further Research

The study faces some limitations due to its methodological nature. First, the qualitative approach allows analyzing the complex topic of digital platforms, but this approach in turn impedes general theoretical contributions. However, the study at hand consolidates and aggregates detailed information, while keeping the necessary informational content relevant. In doing so, the paper is able to derive general theoretical and managerial implications. Second, the paper presents various biases along with the measures taken to reduce their impact on the results. The approaches presented ensure methodological rigor and quality of the study. Third, this study exclusively focuses on German and Austrian companies for the aforementioned reasons. This choice may appropriately serve the study's purpose but should be kept in mind when generalizing the implications and transferring them to different cultural contexts.

Given the novelty of the research area, there are further limitations. For this reason, it is noteworthy that many of the companies examined have only been dealing with the topic of digital platforms for a short period of time. The majority of interviewees only has experience with platforms from a user's perspective, while only very few have already started their own platform. Accordingly, the study's results cover the current state that is generated before a broad use of digital platforms in industrial corporate practice. Therefore, the paper mostly relates to operational benefits of digital platforms whereas new business models, new ways of value generation or entirely new ecosystems cannot be uncovered and understood from the current sample.

Furthermore, while a majority of the interviewees only begin to fully grasp the topic of digital platforms in the context of Industry 4.0, some interviewees within the sample already have advanced experience, a few already having launched their own platform. In response, a recommendation for future research is to elaborate on the different stages of experience with digital platforms in the context of Industry 4.0. A possible outcome here could be a stage-gate model that shows the specific challenges and potentials within the stages of implementation.

An additional recommendation for future research is to investigate platform providers, although found in very few cases in industrial contexts so far, in future research. Nevertheless, this study gives valuable insights into the corporate cultural changes that are necessary. Furthermore, this provides insights regarding the challenges that must be tackled, and the environmental conditions that must be provided.

A further limitation can be found in the diverse understandings and definitions of the term Industry 4.0. Although found in journalistic publications and trade magazines, the term "digital platforms" related to cannot be regarded as entirely defined from an academic perspective. This lack of a comprehensive framework should be addressed in future research, aiming for an understanding that encompasses the understanding of several research disciplines.

Future research can help us to shed light into how to apply digital platforms in corporate practice. For instance, academia could consider investigating the experienced IT sector to be able to derive recommendations for the industrial context. Furthermore, the extent to which efficiency gains can be expected using platforms in industrial value creation is of interest. Here, academia can help to quantify efficiency gains by conducting research on existing platforms.

Funding: This research received no external funding.

Acknowledgments: The author thanks the anonymous reviewers for their helpful comments for revising the paper.

Conflicts of Interest: The author declares no conflict of interest.

Appendix A

Table A1. Detailed list of expert interviews.

Case No.	Company Years	Industry	Employees	Sales [in Million Euro]
1	>10	Wood processing	[0–200]	[10–50]
2	[3–5]	Medical engineering	[0–200]	[10–50]
3	>10	Steel and metal processing	[200–500]	[50–200]
4	>10	Plastics engineering	[200–500]	[50–200]
5	>10	Plastics engineering	[500–1000]	[50–200]
6	[3–5]	Electrical and ICT engineering	[0–200]	[0–10]
7	>10	Wood processing	[200–500]	[50–200]
8	[1–3]	Mechanical and plant engineering	[0–200]	[10–50]
9	[1–3]	Mechanical and plant engineering	[0–200]	[0–10]
10	[5–10]	Automotive	[0–200]	[10–50]
11	[1–3]	Mechanical and plant engineering	[0–200]	[0–10]
12	>10	Steel and metal processing	[0–200]	[10–50]
13	[1–3]	Mechanical and plant engineering	[0–200]	[10–50]
14	>10	Automotive	[200–500]	[10–50]
15	[5–10]	Mechanical and plant engineering	[0–200]	[10–50]
16	>10	Plastics engineering	[500–1000]	[50–200]
17	[5–10]	Mechanical and plant engineering	[200–500]	[10–50]
18	>10	Electrical and ICT engineering	[200–500]	[10–50]
19	[5–10]	Automotive	[0–200]	[10–50]
20	>10	Plastics engineering	[0–200]	[0–10]
21	>10	Mechanical and plant engineering	[1000–5000]	[200–500]
22	>10	Steel and metal processing	[0–200]	[0–10]
23	[3–5]	Mechanical and plant engineering	[0–200]	[0–10]
24	[5–10]	Steel and metal processing	[0–200]	[0–10]
25	>10	Plastics engineering	[1000–5000]	[50–200]
26	[1–3]	Steel and metal processing	[500–1000]	[50–200]
27	[1–3]	Mechanical and plant engineering	[200–500]	[10–50]

Table A1. *Cont.*

Case No.	Company Years	Industry	Employees	Sales [in Million Euro]
28	>10	Mechanical and plant engineering	[0–200]	[0–10]
29	[5–10]	Steel and metal processing	[0–200]	[0–10]
30	>10	Plastics engineering	[0–200]	[10–50]
31	[1–3]	Electrical and ICT engineering	[0–200]	[10–50]
32	[3–5]	Electrical and ICT engineering	[200–500]	[10–50]
33	[1–3]	Electrical and ICT engineering	[500–1000]	[50–200]
34	>10	Mechanical and plant engineering	[1000–5000]	[50–200]
35	[1–3]	Automotive	[0–200]	[10–50]
36	[5–10]	Automotive	[500–1000]	[50–200]
37	>10	Mechanical and plant engineering	[200–500]	[10–50]
38	[5–10]	Plastics engineering	[1000–5000]	[200–500]
39	[5–10]	Mechanical and plant engineering	[0–200]	[10–50]
40	[5–10]	Electrical and ICT engineering	[200–500]	[10–50]
41	[1–3]	Mechanical and plant engineering	[0–200]	[0–10]
42	>10	Automotive	[1000–5000]	[200–500]
43	[3–5]	Mechanical and plant engineering	[0–200]	[0–10]
44	>10	Electrical and ICT engineering	[0–200]	[0–10]
45	>10	Mechanical and plant engineering	[0–200]	[0–10]
46	[5–10]	Mechanical and plant engineering	[0–200]	[0–10]
47	>10	Steel and metal processing	[0–200]	[0–10]
48	[5–10]	Mechanical and plant engineering	[1000–5000]	[200–500]
49	>10	Electrical and ICT engineering	[200–500]	[50–200]
50	>10	Mechanical and plant engineering	[500–1000]	[50–200]
51	[1–3]	Mechanical and plant engineering	[200–500]	[10–50]
52	>10	Mechanical and plant engineering	[500–1000]	[50–200]
53	[3–5]	Steel and metal processing	[0–200]	[0–10]
54	[1–3]	Steel and metal processing	[200–500]	[50–200]
55	>10	Mechanical and plant engineering	[500–1000]	[50–200]
56	[1–3]	Electrical and ICT engineering	[0–200]	[50–200]
57	>10	Automotive	[1000–5000]	[200–500]
58	[1–3]	Automotive	[1000–5000]	[10–50]
59	[1–3]	Plastics engineering	[0–200]	[10–50]
60	[5–10]	Plastics engineering	[0–200]	[200–500]
61	>10	Electrical and ICT engineering	[500–1000]	[0–10]
62	[1–3]	Mechanical and plant engineering	[500–1000]	[10–50]
63	[5–10]	Mechanical and plant engineering	[200–500]	[10–50]
64	>10	Electrical and ICT engineering	[0–200]	[10–50]
65	>10	Mechanical and plant engineering	[5000–10000]	>500
66	>10	Wood processing	[1000–5000]	[200–500]
67	>10	Electrical and ICT engineering	[500–1000]	[50–200]
68	[5–10]	Electrical and ICT engineering	[1000–5000]	>500
69	[1–3]	Electrical and ICT engineering	[0–200]	[0–10]
70	>10	Electrical and ICT engineering	[0–200]	[0–10]

Table A1. *Cont.*

Case No.	Company Years	Industry	Employees	Sales [in Million Euro]
71	[1–3]	Electrical and ICT engineering	[1000–5000]	>500
72	[3–5]	Electrical and ICT engineering	[0–200]	[0–10]
73	>10	Electrical and ICT engineering	[1000–5000]	[200–500]
74	[3–5]	Electrical and ICT engineering	[0–200]	[50–200]
75	>10	Electrical and ICT engineering	[0–200]	[0–10]
76	>10	Electrical and ICT engineering	[0–200]	>500
77	>10	Wood processing	[0–200]	[200–500]
78	[1–3]	Electrical and ICT engineering	[200–500]	[10–50]
79	[5–10]	Plastics engineering	[0–200]	[0–10]
80	>10	Electrical and ICT engineering	[1000–5000]	>500
81	[5–10]	Electrical and ICT engineering	[200–500]	[50–200]
82	>10	Mechanical and plant engineering	[0–200]	[10–50]
83	>10	Mechanical and plant engineering	[1000–5000]	[200–500]
84	[5–10]	Electrical and ICT engineering	[0–200]	[10–50]
85	>10	Mechanical and plant engineering	[0–200]	[0–10]
86	[1–3]	Plastics engineering	[0–200]	[10–50]
87	>10	Steel and metal processing	[0–200]	[0–10]
88	>10	Mechanical and plant engineering	[0–200]	[10–50]
89	[5–10]	Plastics engineering	[1000–5000]	[50–200]
90	>10	Steel and metal processing	[200–500]	[10–50]
91	>10	Mechanical and plant engineering	[0–200]	[10–50]
92	>10	Mechanical and plant engineering	[0–200]	[0–10]
93	[5–10]	Plastics engineering	[200–500]	[10–50]
94	[1–3]	Mechanical and plant engineering	[500–1000]	[200–500]
95	[0–1]	Wood processing	[200–500]	[50–200]
96	[0–1]	Mechanical and plant engineering	[0–200]	[0–10]
97	[1–3]	Plastics engineering	[500–1000]	[200–500]
98	>10	Mechanical and plant engineering	[200–500]	[50–200]
99	>10	Steel and metal processing	[0–200]	[0–10]
100	>10	Mechanical and plant engineering	[0–200]	[0–10]
101	>10	Mechanical and plant engineering	[500–1000K]	[50–200]
102	[1–3]	Mechanical and plant engineering	[0–200]	[0–10]

References

1. Kagermann, H.; Wahlster, W.; Helbig, J. *Recommendations for Implementing the Strategic Initiative Industrie 4.0—Final Report of the Industrie 4.0 Working Group*; Communication Promoters Group of the Industry-Science Research Alliance, acatech: Frankfurt am Main, Germany, 2013. Available online: https://www.acatech.de/Publikation/recommendations-for-implementing-the-strategic-initiative-industrie-4-0-final-report-of-the-industrie-4-0-working-group/ (accessed on 20 February 2019).
2. Lasi, H.; Fettke, P.; Kemper, H.; Feld, T.; Hoffmann, M. Industry 4.0. *Bus. Inf. Syst. Eng.* **2014**, *6*, 239–242. [CrossRef]
3. Kiel, D.; Müller, J.M.; Arnold, C.; Voigt, K.I. Sustainable Industrial Value Creation: Benefits and Challenges of Industry 4.0. *Int. J. Innov. Manag.* **2017**, *21*, 1740015. [CrossRef]
4. Kenney, M.; Zysman, J. The Rise of the Platform Economy. *Issues Sci. Technol.* **2016**, *32*, 61–69.
5. Gawer, A.; Cusumano, M.A. Industry Platforms and Ecosystem Innovation. *J. Prod. Innovat. Manag.* **2014**, *31*, 417–433. [CrossRef]

6. Hagiu, A.; Wright, J. Multi-Sided Platforms. *Int. J. Ind. Organ.* **2015**, *43*, 162–174. [CrossRef]
7. Müller, J.M.; Buliga, O.; Voigt, K.I. Fortune Favors the Prepared: How SMEs Approach Business Model Innovations in Industry 4.0. *Technol. Forecast. Soc.* **2018**, *132*, 2–17. [CrossRef]
8. Parker, G.; Van Alstyne, M.; Choudary, S.P. *Platform Revolution: How Networked Markets are Transforming the Economy and How to Make Them Work for You*; Norton and Company: New York, NY, USA, 2016; ISBN 978-0393249132.
9. Wiegand, N.; Witt, S.; Steiner, M.; Backhaus, K. Platform Adoption in Network Markets: Selecting Beneficial Partners to Achieve Market Dominance. *Int. J. Innov. Manag.* **2015**, *19*, 1550028. [CrossRef]
10. Müller, J.M.; Pommeranz, B.; Weisser, J.; Voigt, K.I. Digital, Social Media, and Mobile Marketing in industrial buying: Still in need of customer segmentation? Empirical evidence from Poland and Germany. *Ind. Mark. Manag.* **2018**, *73*, 70–83. [CrossRef]
11. Boudreau, K. Open Platform Strategies and Innovation: Granting Access vs. Devolving Control. *Manag. Sci.* **2010**, *56*, 1849–1872. [CrossRef]
12. De Reuver, M.; Sørensen, C.; Basole, R.C. The Digital Platform: A Research Agenda. *J. Inf. Technol.* **2017**, 1–12. [CrossRef]
13. Gawer, A. Bridging differing perspectives on technological platforms: Toward an integrative framework. *Res. Policy* **2014**, *43*, 1239–1249. [CrossRef]
14. McIntyre, D.P.; Srinivasan, A. Networks, Platforms, and Strategy: Emerging Views And Next Steps. *Strateg. Manag. J.* **2017**, *38*, 141–160. [CrossRef]
15. Schuh, G.; Potente, T.; Wesch-Potente, C.; Weber, A.R.; Prote, J.P. Collaboration Mechanisms to Increase Productivity in the Context of Industrie 4.0. *Procedia CIRP* **2014**, *19*, 51–56. [CrossRef]
16. Veza, M.; Mladineo, M.; Gjeldum, N. Managing Innovative Production Network of Smart Factories. *IFAC-Papers OnLine* **2015**, *48*, 555–560. [CrossRef]
17. Lee, J.; Bagheri, B.; Kao, H.A. A Cyber-Physical Systems Architecture for Industry 4.0-Based Manufacturing Systems. *Manuf. Lett.* **2015**, *3*, 18–23. [CrossRef]
18. Schlechtendahl, J.; Keinert, M.; Kretschmer, F.; Lechler, A.; Verl, A. Making Existing Production Systems Industry 4.0-Ready. *Prod. Eng.* **2015**, *9*, 143–148. [CrossRef]
19. Lee, J.; Lapira, E.; Bagheri, B.; Kao, H.A. Recent Advances and Trends in Predictive Manufacturing Systems in Big Data Environment. *Manuf. Lett.* **2013**, *1*, 38–41. [CrossRef]
20. Davis, J.; Edgar, T.; Porter, J.; Bernaden, J.; Sarli, M. Smart Manufacturing, Manufacturing Intelligence and Demand-Dynamic Performance. *Comput. Chem. Eng.* **2012**, *47*, 145–156. [CrossRef]
21. Radziwon, A.; Bilberg, A.; Bogers, M.; Madsen, E.S. The Smart Factory: Exploring Adaptive and Flexible Manufacturing Solutions. *Procedia Eng.* **2014**, *69*, 1184–1190. [CrossRef]
22. Wang, F.; Zhao, J.; Chi, M.; Li, Y. Collaborative Innovation Capability in IT-Enabled Inter-Firm Collaboration. *Ind. Manag. Data Syst.* **2017**, *117*, 2364–2380. [CrossRef]
23. Piccarozzi, M.; Aquilani, B.; Gatti, C. Industry 4.0 in Management Studies: A Systematic Literature Review. *Sustainability* **2018**, *10*, 3821. [CrossRef]
24. Liao, Y.; Deschamps, F.; De Freitas Rocha Loures, F.; Pierin Ramos, L.F. Past, Present and Future of Industry 4.0—A Systematic Literature Review and Research Agenda Proposal. *Int. J. Prod. Res.* **2017**, *55*, 3609–3629. [CrossRef]
25. Müller, J.; Dotzauer, V.; Voigt, K.-I. Industry 4.0 and its Impact on Reshoring Decisions of German Manufacturing Enterprises. In *Supply Management Research: Aktuelle Forschungsergebnisse 2017*; Bode, C., Bogaschewsky, R., Eßig, M., Lasch, R., Stölzle, W., Eds.; Springer Gabler: Wiesbaden, Germany, 2017; pp. 165–179. [CrossRef]
26. Müller, J.M.; Voigt, K.-I. Sustainable Industrial Value Creation in SMEs: A Comparison between Industry 4.0 and Made in China 2025. *Int. J. Precis. Eng. Manuf.-Green Technol.* **2018**, *5*, 659–670. [CrossRef]
27. Kang, H.S.; Lee, J.Y.; Choi, S.; Kim, H.; Park, J.H.; Son, J.Y. Smart Manufacturing: Past Research, Present Findings, and Future Directions. *Int. J. Precis. Eng. Manuf.-Green Technol.* **2016**, *3*, 111–128. [CrossRef]
28. Müller, J.M.; Kiel, D.; Voigt, K.I. What Drives the Implementation of Industry 4.0? The Role of Opportunities and Challenges in the Context of Sustainability. *Sustainability* **2018**, *10*, 247. [CrossRef]
29. Brettel, M.; Friederichsen, N.; Keller, M.; Rosenberg, M. How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective. *Int. J. Mec. Aero Ind. Mech. Eng.* **2014**, *8*, 37–44.

30. Laudien, S.M.; Daxböck, B. The Influence of the Industrial Internet of Things on Business Model Design: A Qualitative-Empirical Analysis. *Int. J. Innov. Manag.* **2016**, *20*, 1640014. [CrossRef]
31. Arnold, C.; Kiel, D.; Voigt, K.I. How the Industrial Internet of Things Changes Business Models in Different Manufacturing Industries. *Int. J. Innov. Manag.* **2016**, *20*, 1640015. [CrossRef]
32. Schallmo, D.; Williams, C.A.; Boardman, L. Digital Transformation Of Business Models—Best Practice, Enablers, And Roadmap. *Int. J. Innov. Manag.* **2017**, *21*, 1740014. [CrossRef]
33. Eisenmann, T.; Parker, G.; Van Alstyne, M.W. Strategies for Two-Sided Markets. *Harv. Bus. Rev.* **2006**, *84*, 92.
34. Sedera, D.; Lokuge, S.; Grover, V.; Sarker, S.; Sarker, S. Innovating with Enterprise Systems and Digital Platforms: A Contingent Resource-Based Theory View. *Inform. Manag.* **2016**, *53*, 366–379. [CrossRef]
35. Xie, K.; Wu, Y.; Xiao, J.; Hu, Q. Value Co-Creation between Firms and Customers: The Role of Big Data-Based Cooperative Assets. *Inform. Manag.* **2016**, *53*, 1034–1048. [CrossRef]
36. Esposito De Falco, S.; Renzi, A.; Orlando, B.; Cucari, N. Open Collaborative Innovation and Digital Platforms. *Prod. Plan. Control.* **2017**, *28*, 1344–1353. [CrossRef]
37. Inoue, Y.; Tsujimoto, M. Genres of Complementary Products in Platform-Based Markets: Changes in Evolutionary Mechanisms by Platform Diffusion Strategies. *Int. J. Innov. Manag.* **2018**, *22*, 1850004. [CrossRef]
38. Gawer, A.; Cusumano, M.A. Platform Leadership: How Intel, Microsoft, and Cisco drive industry innovation. Harvard Business School: Boston, MA, USA, 2002; ISBN 978-1578515141.
39. Tiwana, A.; Bush, A.A. Spotting Lemons in Platform Markets: A Conjoint Experiment on Signaling. *IEEE T. Eng. Manag.* **2014**, *61*, 393–405. [CrossRef]
40. Ravichandran, T. Exploring the Relationships Between IT Competence, Innovation Capacity and Organizational Agility. *J. Strateg. Inf. Syst.* **2017**, *27*, 22–42. [CrossRef]
41. Fatorachian, H.; Kazemi, H. A Critical Investigation of Industry 4.0 in Manufacturing: Theoretical Operationalisation Framework. *Prod. Plan. Control.* **2018**, 1–12. [CrossRef]
42. Kiel, D.; Arnold, C.; Voigt, K.I. The Influence of the Industrial Internet of Things on Business Models of Established Manufacturing Companies–A Business Level Perspective. *Technovation* **2017**, *68*, 4–19. [CrossRef]
43. Martinez, B.; Vilajosana, X.; Kim, I.H.; Zhou, J.; Tuset-Peiró, P.; Xhafa, A.; Poissonnier, D.; Lu, X. I3Mote: An open development platform for the intelligent industrial internet. *Sensors* **2017**, *17*, 986. [CrossRef] [PubMed]
44. Menon, K.; Kärkkäinen, H.; Wuest, T.; Gupta, J.P. Industrial internet platforms: A conceptual evaluation from a product lifecycle management perspective. *Proc. Inst. Mech. Eng. Part B: J. Eng. Manuf.* **2018**. [CrossRef]
45. Silva, M.; Vieira, E.; Signoretti, G.; Silva, I.; Silva, D.; Ferrari, P. A Customer Feedback Platform for Vehicle Manufacturing Compliant with Industry 4.0 Vision. *Sensors* **2018**, *18*, 3298. [CrossRef] [PubMed]
46. Alexopoulos, K.; Sipsas, K.; Xanthakis, E.; Makris, S.; Mourtzis, D. An industrial Internet of things based platform for context-aware information services in manufacturing. *Int. J. Comp. Integ.* **2018**, *31*, 1111–1123. [CrossRef]
47. Edmondson, A.C.; McManus, S.E. Methodological Fit in Management Field Research. *Acad. Manag. Rev.* **2007**, *32*, 1246–1264. [CrossRef]
48. Eisenhardt, K.M.; Graebner, M.E. Theory Building from Cases: Opportunities and Challenges. *Acad. Manag. J.* **2007**, *50*, 25–32. [CrossRef]
49. Benbasat, I.; Goldstein, D.K.; Mead, M. The Case Research Strategy in Studies of Information Systems. *MIS Q.* **1987**, *11*, 369–385. [CrossRef]
50. Yin, R.K. *Case Study Research: Design and Methods*; Sage: Thousand Oaks, CA, USA, 2009; ISBN 978-1506336169.
51. Dubé, L.; Paré, G. Rigor in Information Systems Positivist Case Research: Current Practices, Trends, and Recommendations. *MIS Q.* **2003**, *27*, 597–636. [CrossRef]
52. Mason, J. *Qualitative Researching*; Sage: Thousand Oaks, CA, USA, 2002; ISBN 978-0761974284.
53. Cannell, C.F.; Kahn, R.L. Interviewing. In *The Handbook of Social Psychology*, 2rd ed.; Lindzey, G., Aronson, E., Eds.; Addison-Wesley: Reading, MA, USA, 1968; pp. 525–595, ISBN 978-0201042634.
54. Kasabov, E. Start-Up Difficulties in Early-Stage Peripheral Clusters: The Case of IT in an Emerging Economy. *Entrep. Theory Pract.* **2015**, *39*, 727–761. [CrossRef]
55. Miles, M.B.; Huberman, M.A. *Qualitative Data Analysis*; Sage: Thousand Oaks, CA, USA, 1994; ISBN 978-0803955400.
56. Gioia, D.A.; Corley, K.G.; Hamilton, A.L. Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. *Organ. Res. Methods* **2013**, *16*, 15–31. [CrossRef]

57. Graebner, M.E.; Eisenhardt, K.M. The Seller's Side of the Story: Acquisition as Courtship and Governance as Syndicate in Entrepreneurial Firms. *Admin. Sci. Q.* **2004**, *49*, 366–403. [CrossRef]
58. Krippendorff, K. *Content Analysis*; Sage: Los Angeles, CA, USA, 2013; ISBN 978-1412983150.
59. Maxwell, J.A. *Qualitative Research Design*; Sage: Thousand Oaks, CA, USA, 1996; ISBN 978-0803973282.
60. Weston, C.; Gandell, T.; Beauchamp, J.; McAlpine, L.; Wiseman, C.; Beauchamp, C. Analyzing interview data: The development and evolution of a coding system. *Qual. Sociol.* **2001**, *24*, 381–400. [CrossRef]
61. Holsti, O.R. Content Analysis. In *The Handbook of Social Psychology*; Lindzey, G., Aronson, E., Eds.; McGraw-Hill: New York, NY, USA, 1968; pp. 596–692, ISBN 978-0201042641.
62. Eisenhardt, K.M. Building theories from case study research. *Acad. Manag. J.* **1989**, *14*, 532–551. [CrossRef]
63. Birkel, H.S.; Veile, J.W.; Müller, J.M.; Hartmann, E.; Voigt, K.-I. Development of a risk framework for Industry 4.0 in the context of sustainability for established manufacturers. *Sustainability* **2019**, *11*, 384. [CrossRef]
64. Müller, J.M.; Veile, J.W.; Voigt, K.-I. Cooperation strategies among SMEs for Implementing Industry 4.0. *Proc. Hamburg Int. Conf. Logist.* **2017**, *23*, 301–318. [CrossRef]
65. Seuring, S.; Müller, M. From a literature review to a conceptual framework for sustainable supply chain management. *J. Clean. Prod.* **2008**, *16*, 1699–1710. [CrossRef]
66. Ojala, A.; Evers, N.; Rialp, A. Extending the international new venture phenomenon to digital platform providers: A longitudinal case study. *J. World Bus.* **2018**, *53*, 725–739. [CrossRef]