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Data and Digital Platforms in Industry

Implication for enterprises strategies and governance

Data and Digital Platforms in Industry

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Abstract

This article explores the position of industrial internet platforms (IIP) in manufacturing value chains. We develop an understanding of the role of data in global value chains (GVCs), referring to literature on intangible assets and theories on platform business models. We use data from a qualitative empirical study based on 45 interviews on platforms active on the German market to answer (1) whether there are tendencies of oligopolization that lead to an accumulation of power on the side of the platforms, and (2) whether it is the platforms that capture most of the gains derived from higher productivity or lower transaction costs. The analysis shows that platforms mainly act as service providers and/or intermediaries that support manufacturing companies in reaping benefits from data. While the relationship between platforms and manufacturers currently corresponds to a symbiosis, a stronger power imbalance could evolve in the future since processes of oligopolization are likely.

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1 Introduction

New digital technologies are about to transform the economy as we know it. By combining steep increases in computing power, the abundance of data from all sorts of transactions and new methods of analysing and learning from such data (Brynjolfsson & McAfee, 2014), equipment manufacturers and software providers are able to offer a broad variety of 'new digital technologies' (Sturgeon, 2019) which promise to enhance the capacities of their (industrial) customers. Partly this is about new technological artefacts. There is significant technological progress in the fields of collaborative robotics, modularized automation lines, digital assistance systems, 3D printers and other types of material equipment. In this contribution, however, we depart from the hypothesis that the more fundamental changes for industrial organization rest on developments that one cannot touch or see: the recursive processes of data generation, analysis and usage that increasingly shape business models and enterprise organization in global value chains (GVCs).

The term 'industrial internet' describes such new possibilities for process rationalization and business model innovation related to the analysis of data in the industrial context. Such options concern the optimization of processes (e.g. production scheduling, maintenance, quality control), the improvement of products by making use of life-cycle data (i.e. connected car, smart home, etc.), and the data-based match making in business-to-business (B2B) transactions. Digital platforms (henceforth: "Industrial Internet- platforms", IIP) are important facilitators of such approaches. Just like in the field of the consumer-oriented internet, they take on the position as *infrastructures* of digitized transactions and enable manufacturers to take advantage of software applications to analyse industry-related data (Acatech, 2015; BDI, 2019; Graff, Krenz, & Kronenwett, 2018).

The effects of such transformations on GVCs and the specific roles that IIP take on within them are virtually unknown. Most of the research on the digitalization of manufacturing has focused on technological artefacts like robots or digital assistance systems and their implications on the shopfloor (Briken, Chillas, Krzywdzinski, & Marks, 2017; Ford, 2016; Hirsch-Kreinsen, 2016). Debates on the impact of digital platforms on economic organization, on the contrary, have focused on the role of large tech companies of the consumer-oriented internet that have disrupted the field of media, communication and retail (Dolata, 2015; Kenney & Zysman, 2016; Staab, 2019; Zuboff, 2015). The industrial internet and platforms as its infrastructural backbone are still at an early stage of implementation as they become only meaningful with their diffusion in enterprises, which has just begun to take off. Correspondingly, empirical research that traces the possible outcomes of the platformization of industries on GVCs is scarce. First contributions have outlined possible trajectories with regard to the opportunities for industrial upgrading of suppliers (Humphrey, 2018; Sturgeon, 2019), the competition between tech companies and manufacturers in the field (Lechowski & Krzywdzinski, 2019; Ziegler, 2020), and possible effects on the governance of industries (Lüthje, 2019; Thun & Sturgeon, 2019, Author).

Our contribution adds to the emerging literature on the subject by focusing on the relationship between industrial companies and IIP. By means of a qualitative study on the business practices of IIP in Germany, we aim to answer the question of whether IIP as economic agents will assume an equally powerful position in the industrial field as their peers in the consumer-oriented internet. More specifically we ask: (1) Do IIP emerge as agents that capture most of the gains from higher productivity and/or lower transaction costs, or does the relationship between IIP and industrial customers amount to a symbiosis with shared benefits? (2) Are there tendencies of oligopolization in the field of IIP?

To answer these questions, we first develop a theoretical understanding of the role of IIP in GVCs by discussing the relationship between 'intangible assets', data, and platforms (sections 2 and 3). We then operationalize these insights and introduce the subject-matter and the methods of our investigation, focusing on two types of platforms: production-centred and distribution-centred platforms (sections 4 and 5). In section 6 and 7 the empirical material is presented with a focus on platform business models and the variables that define their position in GVCs. In the final section we conclude that due to significant differences between business models in the consumer-oriented and the industrial internet, the position of IIP rather resembles one of strategically important service providers and/or intermediaries that participate in the value creation networks of digitalized manufacturing than that of an oligopoly that expands its reach on cost of manufacturers. However, tendencies of an oligopolization could evolve in the future, especially in the field of distribution-centred platforms.

2 Intangible assets and value distribution in GVCs

The strategic role of IIP is linked to the increasing significance of data in fragmented production networks. The application of the Internet of Things (IoT) as a means of generating and connecting data from industrial processes radically enhances the volumes and accuracy of up-to-date (or even real-time) data (Brynjolfsson & McAfee, 2014; Sturgeon, 2019). Artificial Intelligence provides new possibilities to make economic use of this data by detecting patterns, making predictions and improving processes based on the sheer amount of available data and distributed computing power.

Even though the economic significance of data, often dubbed the 'new oil', is widely recognized, their role for inter-firm relations in GVCs is not theoretically explored sufficiently with few exceptions (Foster & Graham, 2017; Sturgeon, 2019). The role of knowledge-intensive production factors described as 'intangible assets', however, lies at the core of theory building on GVCs (Durand & Milberg, 2020; Kaplinsky, 2020; Mudambi, 2008). In what follows, we will first review the existing insights on intangibles as they were taken up in GVC theory and then discuss the role of data in this context, which we interpret as an increasingly important resource for the *production* of intangibles.

The term 'intangibles' refers to intellectual or knowledge assets (Lev, 2001). These can comprise of legally defensible titles such as patents, copyrights and brands but also consist of organizational structures, inter-organizational relationships and human creativity (Mudambi, 2008). It has been empirically shown that intangible assets, in spite of some inherent problems regarding their monetarization, are generating an increasing share of returns, roughly a third of all production factors (Alsamawi et al., 2020; Mudambi, 2008). According to Haskel and Westlake (2017) the measurable impact of intangibles is only partially represented in its de-facto impact on business models and competition. In a knowledge-intensive 'capitalism without capital', the generation of rents through the capture and monetarization of intangibles plays an ever more prominent role.

Crucially, intangibles are allocated unevenly in disintegrated value chains. Intangible assets tend to be concentrated in activities that are allocated prior or after the actual manufacturing process, i.e. in R&D or design activities on the one hand and in marketing, advertising and after-sales services on the other (Mudambi, 2008). This polarization is often explained in alignment to Vernon's product life cycle model: pure-play manufacturing activities can easily be replicated (especially by firms in emerging economies). They hence become 'commoditized', i.e. easily exchanged by other suppliers in off-the-shelf transactions, and are exposed to price pressures. Pre- and post-production activities, on the contrary, are more difficult to copy and often include a service dimension that is customized according to users' preferences (Kaplinsky, 2020; Mudambi, 2008). While empirical studies on some industries confirmed this pattern (e.g. Ali-Yrkkö, Rouvinen, Seppälä, & Ylä-Anttila, 2011; Timmer, Erumban, Los, Stehrer, & de Vries, 2014), the equation of low-value added activities with manufacturing is oversimplified. Especially in innovation-intensive producer-driven commodity chains (Gereffi, 1994), value creation crucially depends on the permanent adjustment of processes in recursive innovation processes that are partly related to practical shop floor knowledge (Herrigel & Zeitlin, 2010; Nahm & Steinfeld, 2014).

3 Intangibles and data

The question of whether or not a firm can develop intangibles touches a great variety of questions from the general characteristics of a region's innovation system, the innovative capabilities of a firm, the conditions for technology transfer to the availability of a suitably trained workforce and the specific company cultures. While some of these factors rely on the general institutional and political context in which GVCs are embedded and some remain the domain of proper lab-level basic innovation, others rely on incremental improvements of products and processes based on information that is gathered from customers or shop floor experiences (Herrigel, 2018; Herrigel & Zeitlin, 2010). This requires feedback loops from customers' user experience to product developers (product innovation) or from shop floor performance to process design (process innovation). As Michael Porter and Victor Miller (1985) argue, '[e]very value activity has both a physical and an information-processing component. The physical component includes all the physical tasks required to perform the activity. The information-processing component encompasses the steps required to capture, manipulate, and channel the data necessary to perform the activity.' The information-processing component can be used to manipulate and improve the physical component.

The history of industrial organization to a significant degree revolves around the question of how to make use of information derived from manufacturing processes and markets (Baukrowitz et al., 2006). Taylorist scientific management, for instance, rested on a detailed mapping of the work process by taking the time of each production step manually and using this data to comprehensively redesign the workflow. The organizational revolution of lean production in the 1990s increased flexibilization by improving the way information was transmitted along the supply chain based on Kanban and Kaizen techniques (Womack, Jones, & Roos, 1990). As supply chains disintegrated and became more complex, rationalization became a matter of 'systemic rationalization' of the supply chain (Altmann, Deiß, Döhl, & Sauer, 1986), resulting in the rise of supply chain management as a separate management discipline and systematic supply chain monitoring as one of its major instruments. All of these processes were accompanied by the intensification of 'codification, standardization and monitoring of the workflow' (Durand & Milberg, 2020, p. 408).

The growing need for the coordination of processes in complex value chains and the possibilities to use software to facilitate the monitoring and recursive adaptation of processes gave rise to industrial information systems, in particular systems for supply chain management, Enterprise Resource Planning (ERP) and Manufacturing Execution (MES). Such software facilitated the adjustment of production processes to market demand based on production-related data. In addition, social media data and data on B2C transactions also began to play an important role in detecting consumers' preferences and developing appropriate marketing and product design strategies. Brand building, a prerequisite for rent generation in consumer industries, increasingly relied on market intelligence, i.e. data on consumer behaviour (Pfeiffer, 2021; Rikap, 2020). Digital data thus has played an ever increasing role for firms' abilities of product design and (dynamic) process innovation. [1]

The technological progress towards the IoT, i.e. the ability to generate high-resolution data from real-life processes and to connect this data from different devices at a unitary data layer, enhances the possibility to support key enterprise functions through data-based intangibles (Ziegler, 2020, pp. 27–52). Progress in Machine Learning but also more traditional methods of data analysis can help to utilize large data sets in order to detect patterns, predict future developments and integrate automated decision making in management functions. IIP are needed to integrate and use this data in order to use software applications and to improve the matchmaking between industrial customers and suppliers.

4 Platforms as agents in value chains: analytical cornerstones for the empirical analysis

As there's an enhanced importance of data that can be utilized in order to generate value, the question of how it can be used and who benefits from it becomes paramount. For this end, firms need to rely on a cloud infrastructure and on platform solutions that can connect different sets of data and integrate software applications to analyse it. This provides industrial customers with advantages of enhanced productivity and/or reduced transaction costs, but it also puts the owners of cloud and platform services in a potentially powerful position, particularly if IIP owners can acquire and monetarize customers' data. Such strategies have been a cornerstone of platform business models in the consumer-oriented internet, where platforms sell user data for advertising purposes (Srnicek, 2016; Zuboff, 2015). However, it can be expected that tighter requirements for the secrecy of the data by industrial customers constitutes a limitation to replicate such strategies in the field of the industrial internet. Thus the conditions under which platform business models can expand and the potential effects on the relationship between platforms and manufacturers need to be investigated in order to arrive at a concrete analysis of power relations in this emerging field.

A related question concerns the oligopolization of platforms. In the consumer-oriented internet, digital platforms in the field of e-commerce (Amazon), social media (Facebook), and web services (Google) soon reached a market-dominating position. Their success rests on the creation of ecosystems that offer customers attractive options through network effects and other distinct features of platform-based business models (Abdelkafi, Raasch, Roth, & Srinivasan, 2019; Cusumano, Gawer, & Yoffie, 2019; Dolata, 2015). As platforms in the industrial realm replicate some of the strategies of their peers in the consumer-oriented internet, similar processes of oligopolization might emerge.

Based on these considerations, we pursue the following research questions in our empirical study:

(1) Are there tendencies of oligopolization in the field of IIP?

(2) Do IIP emerge as agents that capture most of the gains from higher productivity and/or lower transaction costs, or does the relationship between IIP and industrial customers amount to a symbiosis with shared benefits?

We hypothesize that both questions are related. In case a general tendency towards oligopolization prevails, the succeeding platform providers will be in a good position to set the terms vis-à-vis their industrial customers, i.e. to capture significant gains from data-based intangibles. If, however, a fragmented market structure prevails, IIP will rather take on the role of specialized service providers. Customers would find it easy to switch providers who would be chosen according to the specificity and quality of their services in a more equitable relationship.

4.1 Platforms and their functions

In order to tackle the research questions, a refined understanding of platform business models is needed. In what follows, we relate the theoretical literature on platform business models in general (Cusumano et al., 2019; Gawer & Cusumano, 2014; McAfee & Brynjolfsson, 2017) to the field of IIP. We follow the definition by Cusumano et al. (2019) who state that *industry platforms* 'bring together individuals and organizations so they can innovate or interact in ways not otherwise possible, with the potential for nonlinear increases in utility and value' (Cusumano et al., 2019, p. 13).

The ability to enhance the benefits for users by drawing on the resources of the entire ecosystem takes on different forms according to the core functions of a platform. Cusomano et al., (2019, pp. 18–21) distinguish between *innovation platforms* and *transaction platforms*. The former aim at the extension of a platform's functions through complementary contributions by ecosystem partners (henceforth: complementors). Platforms thus act as integrators in open innovation systems with a multiplicity of contributors (Chesbrough, 2003). *Transaction platforms* pursue a different strategy as they take on the role as intermediaries by setting up online marketplaces, i.e. they facilitate transactions while reducing transaction costs*[2]*. This distinction between ideal types of platforms roughly corresponds to the divergent trajectories of IIP that can be observed in recent empirical studies on the subject (Lüthje, 2019):

Production-centred platforms are integrators of software applications (apps), which industrial customers can adjust according to their needs. We interpret production-centred platforms as a type of innovation platform as their core rationale concerns the supply of a software ecosystem through the add-ons by complementors (or self-developed apps). Such platforms are established by firms that have experience with prior generations of production-related information systems and/or are large manufacturers themselves. Prominent platforms of this type are: Siemens Mindsphere, Bosch IoT-Suite and IBM's Watson IoT. These enterprises offer services to a large variety of industries from mechanical engineering to automotive and chemical products and the energy or mobility sector. Niche-solutions that specialize on one industry or sub-industry and its specific requirements do exist as well.

Distribution-centred platforms are transaction platforms that act as matchmakers between manufacturers of supply products and industrial customers. They take the task of finding reliable suppliers off a company's hands by curating and auditing a diverse and far-flung network of manufacturers specialized in different processes. Such platforms can be observed in heterogeneous industries such as consumer goods manufacturing in China and the mechanical component manufacturing industry worldwide.

As described in the theoretical literature (Cusumano et al., 2019, pp. 19–21), a hybridization of platform approaches can be observed in the industrial field as well. Production-centred platforms also serve as transaction platforms since software applications are traded on their marketplaces ('app stores'). Likewise, distribution-centred platforms can complement their transaction features by add-on software functionalities that facilitate these transactions. However, the distinction between innovation and transaction platforms is a useful point of departure for the analysis of business models in the respective fields, as they show different characteristics according to the main type of platform under consideration (Cusumano et al., 2019, pp. 77–104).

4.2 Platform business models

The analysis of the platforms' business models is organized according to a categorization that is derived from studies on business models in the B2C segment (Fleisch, Weinberger, & Wortmann, 2014; Timmers, 1998) and adapted by Ziegler (2020, p. 92) for the analysis of IIP. It distinguishes between *value proposition*, *platform architecture*, and *revenue model* in order to analyse the relationship of platforms towards the participants in the ecosystem and its ability to capture value.

The *value proposition* crucially depends on the ability to integrate software services according to the domain-specific requirements of manufacturers. Hence, platform owners need to combine skills from the field of IoT software development with an intimate knowledge of the processes of their customers. Production-centred platforms in particular need to master the challenges of integrating different types of equipment and ensuring the interoperability of data in a heterogeneous and application-specific context (PC2, PC4a)[3]. Distribution-centred platforms face less challenges of integrating the data from ecosystems participants as they mostly do not monitor production processes but just the transaction processes. However, they need to possess a good knowledge of the products traded through their platforms in order to engage in matchmaking successfully and to provide effective quality control (DC1, DC2. DC3). As in the consumer-oriented internet, the utility of a platform's services depends on the richness of an ecosystem around it. Hence, the success of a platform's *value proposition* significantly depends on architectural decisions with regard to their ecosystems through which network effects can be achieved.

Platform architectures concern the ecosystem rules for the various actors that are involved in platform business models, affecting the power relation between them and the economic prospects of the business models as a whole. Transaction platforms curate the networks of service providers or sellers through various activities including the definition of rules of access, user-generated evaluation schemes, insurance and fraud prevention measures and the monitoring of service provision (Cusumano et al., 2019; Dolata, 2015; Kenney, Rouvinen, Seppälä, & Zysman, 2019). Innovation platforms need to manage their network of co-inventors to ensure their productive interactions with the platform and avoid possible frictions. What is more, they need to decide upon the degree of openness of their platforms on a continuum between proprietary models in which the control by the platform owners is tight and more open models of governance (Cusumano et al., 2019, pp. 88–90).

The character and strength of *network effects* depend on these decisions. *Same-side network effects* happen when the utility for each user rises with the number of users that take advantage of the same service. *Cross-side network effects*, on the contrary, concern different groups of platform users (Cusumano et al., 2019, p. 17), i.e. when a customer of a transaction platform benefits from a far-flung network of producers of goods or services that are attached to such a platform. In order to benefit from network effects, platform providers need to gain enough weight by attracting a sufficient number of users on all sides of the platform..

The *revenue model* concerns the different ways by which platforms generate income through various kinds of subscription models or direct fees on transactions. There is a tension between the monetary business interests of platform owners and their business strategy that aims at a rapid expansion of a platform's reach and the exploitation of network effects. Freemium models, in which premium users pay for add-on services that go beyond the basic free services offered to everyone, are one way of dealing with this tension. Another prominent strategy aims at the monetarization of user data for advertising purposes, i.e. the generation of revenues from additional sources than the primary users of the platform (Fleisch et al., 2014).

5 Research design and methods

In the following empirical analysis, we will relate the above reviewed theoretical insights on platforms' business models and the concerns about increasing platform power vis-à-vis other ecosystem participants to the field of IIP. By this approach, we gain insights into the characteristics of an *industrial* platform economy, a section of the platform economy which has barely been subject to empirical research. By systematically analysing the platforms' business models at the level of 'value proposition', 'platform architecture' and 'revenue model', and identifying possible sources of power that affect the platforms' relationship to industrial companies and processes of oligopolization, we provide a differentiated perspective on the dynamics of the platform economy in the industrial realm. In order to identify potential sources of power of the emerging platforms, we follow Ziegler's inductively developed notion of 'points of control', which are strategically important aspects of a business model that can enable a platform to exercise some degree of control over other ecosystem participants, while simultaneously harvesting the benefits of collaboration with partners in their ecosystems. As a synthesis of the conducted expert interviews as well as an evaluation of the literature on platform business models, Table 1 provides an overview of such points of control that are associated with the three dimensions of a platforms' business model.

Table 1: Analytical dimensions and 'points of control'

Dimensions of business model	Points of control
Value proposition	Domain-specific competences in IT Domain-specific competences in Manufacturing
Platform architecture	Proprietary/de facto standards Openness/closure of interfaces Rule setting vis-à-vis complementors Prescriptions with regard to data governance Performance monitoring of other agents
Revenue model	Direct fees Pay-per-use Advertising of third parties Sale of complementary services & products

Source: Authors, based on Timmers (1998) and Ziegler (2020).

The analysis is based on 45 interviews gathered between January 2020 and May 2021 with three groups of actors in the field of the industrial internet: representatives of IIP, platform complementors and experts. IIP cases encompass five production- and three distribution-centred platforms active in Germany. All interview partners are involved in strategy building within those companies and have an intimate knowledge of the industrial platform economy. In addition, we talked to representatives of seven complementors of distribution-centred platforms, i.e. manufacturing partners, and to four complementors of production-centred platforms that contribute Software applications. The interviewed experts include representatives of industry associations, trade unions and research institutions.

The selection of platforms is based on a mapping of the production- and distribution-centred platform-landscape in Germany identifying the most relevant players and highlighting the variety of approaches. The five production-centred platforms included in this study can be considered the most relevant platforms in Germany concerning size and recent growth trajectory. They have varying backgrounds in manufacturing and/or industrial and enterprise software. The selection of distribution-centred platforms likewise was conducted according to economic relevance. The case studies focus on the field of on-demand manufacturing of mechanical parts, an industrial segment where such approaches are prominently explored and practised.

Interviews with platform operators and experts were designed as semi-structured interviews and covered three topics: platforms functionalities and architecture, the platform's business model and strategy, and its relationship to other actors in the field, particularly to industrial customers or complementors. Emphasis was adjusted depending on the interviewee group: While questions were focused on industry-level developments and broader trends in expert interviews, the interviews with platform operators focused on the details of the platforms' business models. In the case of platform complementors, the focus of the interviews lay on their relationship with platform operators, their experiences in the cooperation and the question of how it affected their business development.

The data from the interviews was transcribed and analysed according to the method of qualitative content analysis using a mainly deductive, i.e. theory-oriented, method of coding and an analytical method that aims at the summarization of findings (Mayring, 2015). The following sections entail brief descriptions of the main findings that are structured according to the above-mentioned analytical categories.

6 Production-centred platforms: infrastructure oligopolies or service providers?

6.1 Value proposition: facilitating the use of data for enhanced productivity

Production-centred platforms promise the facilitation of a broad range of process improvements through the use of industrial data, often summarized under the term "Industry 4.0" (Platform Industrie 4.0, n.d.). Customers can choose from a variety of software applications (Software as a Service – SaaS) that can be accessed according to the specific needs of their enterprise. Typical applications include tools to monitor and optimize the production flow, for instance by the real time detection of deviances and the rearrangement of the process sequence, through which bottlenecks can be avoided and resource usage minimized. Another prominent focus is (predictive) equipment maintenance, through the provision of data-based forecasts about when certain types of equipment typically wear out. Yet another issue is the virtual modelling of physical assets as *digital twins* that can be used for controlling the state of equipment, processes and products as well as for their simulation and virtual manipulation.

The platform ecosystem in the emerging field of production-centred platforms comprises of various layers with different functionalities (Graff et al., 2018; Lechowski & Krzywdzinski, 2019). The IoT platforms as such (or "Platform-as-a-service", PaaS) deal with the integration of Software applications (SaaS) that are either self-produced or sourced from third parties. Hence, the value proposition of the platform depends on the ability to provide or source SaaS elements that enlarge the scope of functionalities customers can access. As in other areas of the platform economy, the physical computing power is mostly not provided by the platform operators, but outsourced to "Infrastructure-as-a-Service" (IaaS) providers, most prominently to Amazon Web Services (AWS) and Microsoft Azure. These also offer generic services of data analysis and structuring to their customers, but as of yet do neither possess the domain-specific knowledge nor the ambition to move beyond their role as infrastructure service providers (IP1). However, the boundary between PaaS and IaaS is fluid, which raises concerns of whether companies such as AWS will crowd out genuine PaaS approaches in the future (Lechowski & Krzywdzinski, 2019).

While the conviction that the IoT provides great opportunities to generate revenues from industrial data is widespread among the participants in the field, the implementation of IIoT solutions is still at an early stage. There is a great deal of experimentation with few applications exceeding the trial phase of use cases or test-beds. Accordingly, the business models of platforms are still evolving. The same applies to the composition of the field as such: many firms have become active in the field of the industrial internet. A consolidation is likely in mid-term and the boundaries, the division of labour and the value distribution between different players is in flux (Graff et al., 2018). This also concerns the questions of the relationship between platforms, complementors and customers. The various players of production-centred platforms' ecosystems compete with each other for capturing value, but they also need to cooperate for the sake of the joint interest in creating value from data.

6.2 Platform architectures: balancing relationships to customers and complementors

The most important architectural decisions that affect the relationship between participants in the production-centred platforms' ecosystems concern questions of openness and interoperability. Most manufacturing firms operate a variety of equipment types, generations and brands that often result in a heterogeneous landscape of controlling software. Under such circumstances, platform strategies that would aim at proprietary and closed solutions, i.e. software infrastructures that only connect a certain type of machines and cannot be modified by third parties, are not feasible. Instead, platforms need to provide an open infrastructure for manufacturers to connect their heterogeneous machine parks, corresponding machine software and data. A manager at a production-centred platform describes this requirement for openness, that was emphasized in many interview of our study, as follows:

> On the one hand, everyone is aware that such platforms only work if they have a certain relevance. If a certain share of market participants is involved there, and that probably doesn't work if I say: "that's exclusive and only works with my machines". Then customers would say: "wait a minute, this is a silo solution after all! I don't want that." That means it's a game, where you say: "yes I know, I have to open up to competitors." (PC1) [4]

Therefore, openness and compatibility of platforms with multiple equipment producers' software and with applications of other third party developers is a precondition for production-centred platforms to attract customers on a larger scale. However, openness comes with a price: it is not possible to single-handedly define the technological standards of the operating systems and require other agents to adhere to them (as for instance Microsoft could do in closed PC architectures). Instead, all platforms need to demonstrate their openness towards software developers' and customers' needs in order to maximize their utility. The result is a delicate balancing game in which the platform providers need to find the right approach of keeping the services offered on their platform diverse (by cooperating with other actors in the field) while simultaneously navigating between their own and complementors' goals to generate revenues from such services.

While openness and interoperability are the architectural foundations for platforms to generate use value for customers, the success of production-centred platform business models depends on the abilities to exploit network effects as well. In order to benefit from same-side network effects, a platform would need to be able to provide functionalities that proportionally increase their utility with the number of users. There is a potential for such approaches as software packages (e.g. for predictive maintenance or for optical quality control) could be continuously improved by incorporating data from an increasing number of users, especially if they are built on machine learning approaches.

However, in contrast to private consumers who have tended to submit their data willingly (or unknowingly) to platforms of the consumer-oriented internet, industrial companies are highly sceptical about sharing their data with platforms. This is confirmed in a recent survey by the German Economic Institute and the Foundation of German Industries has shown (IW & DBI, 2021) and was also emphasized by our interview partners:

> Well, we do have a certain data hysteria [...], so that in some cases we are even discussing about machine running times with customers. That means data is transmitted to us that says: yesterday the machine ran 28 percent – and it doesn't even say which machine it is, it's anonymized. And I think, a rethinking will have to take place to a certain extent there [...]. Nobody can do anything with it [the data], but we can use it to make benchmarks, to play back a certain feedback, etc. (com1PC)

The concerns over the sharing of data are a constraint to the establishment of platforms' business models. It is common business practice among all production-centred platforms of this sample to ensure that the data stays with the customers and is not appropriated by the platforms or transmitted to third parties (Siemens, 2017, p. 9). At the same time, the experimental and negotiated sharing of data is explored in so-called data cooperatives and test bed projects with temporal data-sharing agreements (Werling, Weber, & Lasi, 2020).

While same-side network effects thus are difficult to incorporate into the platforms' business models, *cross-side network effects* – the more users, the more attractive the platform becomes to complementors and the other way around (Cusumano et al., 2019, p. 17) – are important and could contribute to a consolidation of the platform landscape. These primarily concern the relationship between SaaS complementors and manufacturing companies that take advantage of the applications offered by them. The broader the software ecosystem a platform offers, the higher its attractiveness for customers and vice-versa: SaaS providers can only be attracted if a platform can guarantee access to many customers who can be charged for the use of their software. In order to establish itself successfully on the market, a platform thus needs to engage in cooperation and ecosystem-building with complementors:

> One thing is we develop the infrastructure in the first place. […]. But then of course there are many third parties out there who then develop compatible solutions. And here we are doing our best to promote the largest possible ecosystem, because that's what will decide success or failure at the end of the day. Nobody at [platform name] can do that him- or herself. [...] (PC1)

This need for compatibility also pushes the platforms towards openness with regard to their core software elements. This is described by Ziegler (2020, pp. 247–254) in his case study of a IIP run by an industrial company that progressively opened up its software development until fully turning Open Source in order to maximise its compatibility and integration with SaaS complementors.

The need to attract a vibrant ecosystem of SaaS providers around the platforms' core affects the bargaining position of platforms. Ideally, they can offer access to a large number of potential customers by integrating SaaS elements into their platform ecosystem. Unlike with the app stores Google Play or Apple App Store in the consumer-oriented internet that monopolize the distribution of smart phone apps, software developers can distribute their apps through different channels and quit the relationship with a platform altogether in case their interests are not met. The platforms need to negotiate and cooperate with their complementors on an equal footing, at least as long as the platform landscape remains fragmented and no single platform emerges as a dominant channel through which software applications are distributed.

6.3 Revenue models: participating from productivity gains through services provision

The integration of generic software elements into industrial processes requires a great amount of adaptation and specification. Often this also involves the installation of infrastructure (sensors, hardware hubs, edge computing devices and the like). All interviewed representatives of production-centred platforms stressed the high requirements on domain-specific knowledge. Standardized and generic data-analysis tools have to be adjusted to the requirements of each specific domain including the fine-tuning between the software and the specific machinery or equipment it is integrated with. A generic visual recognition tool, for instance, needs to be adjusted, according to whether it is integrated into public transport vehicles or production machinery (IP1). The revenue model of all surveyed production-centred platforms therefore aims at the sale (or leasing) of SaaS applications in combination with consulting services that concern the implementation of IoT-projects. Production-centred platforms therefore typically combine the function of a software distributor with consulting services: they provide assistance with adjustments between production equipment and software elements to customers that lack the specific knowledge of how to capitalize on the data generated through new digital devices.

Most platforms (PC2, PC4, PC5) offer *off-the-shelf* monthly subscription plans to get access to more or less comprehensive platform functions. These can be complemented by more customized packages of apps and services. However, platforms can find additional sources of revenue as well, as the case of Siemens Mindsphere demonstrates. On the Mindsphere platform also complementors have to subscribe to access the platforms developer tools. Furthermore, Siemens as a company with a background in automation equipment, offers hardware components – the Mind Connect Elements – that facilitate a frictionless integration of devices by any manufacturer with the Mindsphere platform. (Siemens, 2017, pp. 8–9)

The service-centred character of the platforms' business models means that the revenues of platforms are highly dependent on the success of their customers. There are strong reservations among manufacturers against paying for services and equipment without having any security about the concrete economic gains that can be achieved.

Some platform representatives reported that their customers enter the business relationship with a very pragmatic stance and that many were still waiting for proofs of concrete benefits (PC2a, PC2b, PC4a). The platforms' business models thus depend on the fate of their customers: only if productivity gains actually materialize, they will be able to benefit from such progress.

6.4 Discussion: constraints to oligopolization

Production-centred IIP are acquiring a position in industrial GVCs that is of increasing importance: the function of enabling corporate customers to take advantage of data in order to improve processes and raise productivity. Unlike their peers in the consumer-oriented internet, however, the digital platforms of the industrial realm face stronger obstacles to acquire a dominant position which would enhance their bargaining power vis-à-vis other network participants. Especially the constraints for unleashing same-side network effects, that are rooted in the unwillingness of corporate customers to share their data, makes an easy road towards market dominance in 'winner-takes-it-all' markets impossible. It also is a barrier to revenue models that focus on the secondary usage of data, one of the main sources of revenue in the consumer-oriented internet.

Several interview partners nonetheless expected a consolidation of the market segment to a handful of large players. According to this perspective, only some platforms will manage to build vibrant software ecosystems while attracting a large number of industrial customers. One representative of a prominent platform assumed that the field will be fragmented along industry boundaries, whereas one platform might turn out as the main beneficiary in each segment (PC2a). However, due to the need to ensure interoperability with a heterogeneous hardware landscape and to attract SaaS complementors to the platform, production-centred platforms have to balance their monetary self-interest with the need to cooperate with complementors and customers on an equal footing. Or, in the words of one interviewee: "A platform is not by itself relevant. It is relevant in combination with its apps" (PC2b).

Crucially, the success of production-centred platforms depends on the capacity of their customers to raise productivity based on the provision of SaaS elements. The primary objective of production-centred platforms is not to grow *on cost of* their customers, but to acquire a share of the prospected productivity. In a long-term perspective, however, the strongest production-centred platforms could gain bargaining power vis-à-vis other market participants in case they evolve towards oligopolies that could implement de facto standards. Even if the platforms' ecosystems remained open, such a scenario would increase switching costs for customers and thus create lock-in effects.

7 Distribution-centred platforms: introducing e-commerce to industry

7.1 Value Proposition: reducing transaction costs

Distribution-centred platforms function as B2B-marketplaces by positioning themselves as matchmakers between manufacturers of supply products and their industrial customers. The platforms do not operate any manufacturing facilities by themselves but instead cooperate with networks of manufacturers. For the three platforms we studied these partner-networks range between 240–6,000 companies.

One industry in which the distribution-centred platform model is expanding fast is mechanical component manufacturing. In Europe and the US, platform owners, usually start-ups that combine IT capabilities with a good knowledge of their target industries, act as intermediaries between mechanical component manufacturers and their customers.[5] The manufacturing services offered by complementors include laser, plasma and waterjet cutting, CNC turning, milling and drilling, and 3D printing for different kinds of metals and synthetic materials. The manufacturers offer their production capacities via the platform to customers in industries such as machine tools, aerospace, robotics, automotive and medical devices.

The platforms value proposition is very straight forward: they reduce transaction costs for their customers. They do so by reducing the time traditionally invested in finding and auditing suppliers and by simplifying interactions through a platform as digital interface, thus automating and standardizing the handling of orders, payment and contracts. One representative claimed that his platform reduces the time traditionally needed to fulfil an order by 50% (DC 1). Furthermore, the network of complementors allows for more flexibility especially at delivering time-sensitive orders. The disruptions to GVCs during the outbreak of Covid19 in the beginning of 2020 accordingly have given these platforms a boost, as lead firms had to reorganize their supply chains and often looked for short-term replacements for failed transactions.

7.2 Platform Architectures: curating the manufacturing network

Distribution-centred platforms curate their network of manufacturing partners through rules of access and continuous performance-evaluation. As we will show, they can take advantage of cross-side network effects and some of the more advanced platforms utilize data to improve their services. This has significant consequences for manufacturers.

To become part of a platform's network of manufacturing partners, firms have to provide detailed information on the production processes they offer and they have to pass a trial phase during which orders are closely monitored and evaluated along dimensions such as product quality, punctuality and fast communication. The mechanisms of monitoring and evaluation are institutionalized and become permanent over the course of the cooperation and they affect the likelihood to receive orders in the future. The factors that determine whether a particular manufacturer is chosen, however, remain opaque for manufacturers (DC2c, DC3).

To create and expand their network, distribution-centred platforms make use of cross-side network effects. The platforms attractiveness to customers mainly rests on the range and flexibility of the manufacturing services offered. Both are largely rooted in the size and diversity of the – in some cases global – network itself rather than in the flexibility of individual manufacturing partners (Butollo & Schneidemesser, 2021). Seen from the complementors' side, a platform is most relevant if it has a solid base of industrial buyers which generates a steady flow of orders. Therefore, the expansion of the platform needs to achieve a good balance towards both user groups.

The three distribution-centred platforms we studied utilize the data they gather from transactions with customers and manufacturing partners in order to improve their services, but the extent to which they do so varies. One platform curates its network of manufacturers manually and allocates orders via email and telephone (DC2). Other platforms are particularly active in developing software elements such as instant pricing tools that automate aspects of the business relationship (in this case by calculating a binding price for a certain product). Such AI-based tools record the properties of a technical drawing, requested materials, required processing techniques, lead time and batch size and compare them with automatically-generated benchmarks from its vast database. One platform representative claimed that their self-learning algorithm has already analysed more than one million CAD-files to automatically calculate prizes (DC3). Another interviewee expressed the vision to establish a 'universally agreed price for manufacturing that reflects supply and demand in the global market place' based on the recorded data (DC1). Such approaches could tilt the bargaining relationship in favour of the platforms and result in enhanced competitive pressures for the manufacturing partners because the conditions become non-negotiable. This is particularly the case when platforms encompass firms from low-wage and high-wage countries that are put into direct competition with each other. Manufacturers then effectively are benchmarked against the globally most efficient, fastest and cheapest participants in the market. The same accounts for delivery lead times. The manager of one distribution-centred platform explains:

> One of the things that we're doing is kind of levelling standards across the globe. So, for example […] normally, the lead time in Europe is four to six weeks, while in America and Asia one to two weeks is normal. […] And so, when we talk to European CNC suppliers, we tell them like, our standard auction for customers is two weeks. (DC1)

However, according to our interviews with platforms' manufacturing partners, such pricing strategies are not necessarily experienced as a race to the bottom. Some of the manufacturers of our sample report no differences in revenues between orders that were transmitted through the platforms and orders that were received directly from customers without interference of platforms (com1DC, com2DC). Yet others reported that revenues on some orders processed through the platforms are significantly lower (com3DC, com4DC).

Another aspect that concerns the power relation between platforms and complementors is the relationship to customers. Manufacturing partners are cut off from direct interactions with industrial customers as it is the platforms that mediate these interactions, which are careful not to enable direct interactions between the two sides of their ecosystem. Direct relationships of manufacturers to customers, however, not only provide a certain stability in the business relationships, but also provide opportunities for more lucrative consulting activities that concern the pre-production processes. As a direct interaction between manufacturing partners and customers is obstructed through the platforms, such services are monopolized by them while manufacturers only perform core manufacturing tasks, a potential functional impoverishment for the involved firms. Conversely, one platform in our sample was particularly ambitious in developing such pre-production services by utilizing the vast amount of data on machine-part-designs and CAD-drawings that is uploaded to the platforms by their customers for automated testing of the manufacturability of designs or lead-time calculation (DC3). This shows how – unlike the case of production-centred platforms – secondary use of data (CAD-designs as well as log-data) is exercised and provides a range of possibilities for distribution-centred platforms to extend their abilities to capture value from intangible functions.

7.3 Revenue model: fees on transactions

Distribution-centred platforms in the mechanical component industry earn a commission on every order that is handled. They charge for the matchmaking with a suitable supplier and for certain pre-production services. The platforms provide an attractive option for industrial customers to source components as they provide access to a flexible network of producers at very competitive prices. This offer is especially attractive in low volumes/high mix industries in which customers often have the need to order very specific components. In such fields distribution-centred platforms have become relevant supplements to regular supply-chain management practices that rely on direct transactions between producers and customers.

7.4 Discussion: towards e-commerce oligopolies in industry

Distribution-centred platforms enable industrial customers to source components more efficiently. This mainly implies a special kind of supplier governance through rules and evaluations set by the platform, the reliance on cross-side network effects and the charging of commissions on each transaction. As with production-centred platforms, there is a symbiosis between platforms and industrial companies that are involved in the platform ecosystems: manufacturing partners receive steady orders while the platforms benefit from their matchmaking activities. For manufacturing partners this is a two-edged sword: on the one hand they can benefit from additional sales channels and easy access to new customers, on the other hand they might lose opportunities in pre-production functions and become subjected to enhanced competitive pressure.

While effects on manufacturing partners thus are ambivalent, distribution-centred platforms prospectively will emerge as the main beneficiaries in the process, capturing large shares of revenues from the savings in transaction costs. If distribution-centred business models turn out to be scalable and diversify across industries, an oligopolization that resembles developments in B2C e-commerce could be possible with similar implications: a growing dependency of sellers and customers. However, neither is it clear that market developments automatically result in oligopolistic structures (i.e. a fragmented landscape of specialized platforms could be an alternative scenario), nor can it be taken for granted that manufacturing partners (particularly those in low-wage countries) will suffer from the heightened competitive pressures. After all, many small-scale manufacturers choose to participate in the manufacturing networks of distribution-centred platforms because they benefit from the option of flexibly accepting orders that often are supplementary to their regular customer relationships (com3DC, com4DC). This way, they can indirectly access a market that lies beyond their (often regionally confined) reach and improve the utilization of their production capacities.

8 Conclusion

Our discussion of the role of IIP in GVCs departed from reflections on the enhanced role of data in industrial processes and the observation that data often constitutes the raw material for 'intangible assets' that constitute an important variable for the distribution of revenues across firms. In the field of the consumer-oriented internet, digital platforms emerged as infrastructures to take advantage of new data-based business models. They acquired an extraordinarily strong economic role as oligopolies of the digital economy and challenged traditional companies in the sectors they are active in (e.g. retail, media, communication). Our article thus discussed the question of whether there could be similar tendencies at work in the realm of the industrial internet by empirically analysing two prominent platform types, production-centred and distribution-centred platforms.

The results of our investigation help to better understand the position that IIP acquire in GVCs. The analysed business models do not mainly aim at the usurpation of industrial data with the goal of monopolizing intangible assets, i.e. those resources that are paramount to capture value. Rather, they act as service providers and/or intermediaries that support manufacturing companies in reaping benefits from data, i.e. raising productivity of manufacturing processes or lowering transaction costs through efficient matchmaking. The success of both types of platform business models essentially depends on the capacity of their customers to generate revenue to which they contribute capabilities and of which they demand a share.

Hence the issue at stake is not whether industrial platforms will outcompete or replace industrial companies, but whether they emerge as strong service providers that maximise their revenues vis-à-vis traditional manufacturers. Their ability to do so decisively depends on the platforms' ability to acquire power based on network effects. In this sense the trajectories of both platform types are different: *Production-centred* platforms cannot harvest same-side network effects as long as there remain obstacles to the sharing of industrial data. Instead, they need to curate a diverse network of complementors in order to create cross-side network effects, which is only possible if they keep their ecosystems open. Cross-side network effects could result in oligopolization as platforms mature, but there is also the option of a fragmented landscape of more specialized platforms that operate in the niches of their expertise (Sturgeon, 2019, p. 15). *Distribution-centred* platforms, on the contrary, show many similarities with regular e-commerce platforms with potentially strong cross-side network effects. This could enhance their power vis-à-vis industrial complementors and thus their leeway for charging for transaction services. What is more, these platforms do record the data from transaction processes, which implies an information asymmetry vis-à-vis their complementors (Staab, 2019) that allows them to improve and expand their match making qualities and their pre-production services.

In both surveyed fields, oligopolization eventually might preponderate. This mainly means that IIP will stabilize their position in GVCs. As in the consumer-oriented internet this means that they might replace traditional contenders in the field. In the case of *production-centred* platforms this mainly accounts for non-platform software distributers (not manufacturers). In the field of *distribution-centred* platforms this not only accounts for traditional trade intermediaries, but also for single manufacturers that pursue the goal of fast on-demand production of customized products. On a different path that harvests the flexibility of the network, distribution-centred platforms thus could deliver, what the engineering-heavy strategy of Industry 4.0 promises (Butollo & Schneidemesser, 2021).

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Endnotes

[1] What is more, product markets are characterized by an increasing amount of digital services that are based on data. This is most evident in the telecommunication sector where the physical smart phone, merely acts as a carrier for a broad range of apps that can process data from daily interactions recorded through mobile devices (Thun & Sturgeon, 2019). Similar logics of an IoT-driven servitization of the economy are at work in the fields of connected cars, smart homes, smart cities and many other industries. The ability to acquire and process data and to develop digital service applications to this end becomes an important factor that shapes competition in a broad range of product equipment (Zysman, Murray, Feldman, Nielsen, & Kushida, 2011). In the field of mechanical engineering this means that some firms strive to develop software applications related to the steering of manufacturing processes and digital platforms to integrate such applications (Author, forthcoming).

[2] For instance, the primary strategic objective of an innovation platform is the growth of an ecosystem that comprises of diverse complementors that add applications, whereas transaction platforms, while also striving to expand the size of their reach, need to constantly improve their matchmaking techniques in order to reduce frictions in transactions (Cusumano, Gawer, & Yoffie, 2019).

[3] We use the following labelling system for quoting interviews: Each interviewee group has an abbriviation (IP=infrastructure provider, PC=production-centred platform, DC=distribution-centred platform, comPC=complementor of production-centred platform, comDC=complementor of distribution-centred platform). Each platform/complementor is assigned a number. If we refer to more than one interview conducted with the same platform/complementor this is indicated by small letters (a,b,c,…) after the number. E.g. the code PC2b refers to the second interview we had with a representative of production-centred platform number 2 in our sample.

[4] The original German-language quotations are translated by the authors.

[5] In China a similar distribution-centred platform model can be observed in consumer goods manufacturing. There, the e-commerce company Alibaba (along with Pinduoduo and JD.com) is connecting consumer goods manufacturers and e-commerce retailers via a platform (Author).