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ORIGINAL ARTICLE

Who runs the show in digitalized manufacturing? Data, digital platforms and the restructuring of global value chains

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Abstract

This article explores the position of industrial Internet platforms (IIPs) 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 33 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.

KEYWORDS

digitalization, global value chains, industry, Internet of things, platform

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 start 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", IIPs) 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 et al., 2018).

The effects of such transformations on GVCs and the specific roles that IIPs 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 shop floor (Briken et al., 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, 2022; Zuboff, 2015). The industrial Internet and platforms as its infrastructural backbone are still at an early stage of implementation. 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, forthcoming; Ziegler, 2020) and possible effects on the governance of industries (Butollo, 2020; Lüthje, 2019; Thun & Sturgeon, 2019).

Our contribution adds to the emerging literature on the subject by focusing on the relationship between industrial companies and IIPs. By means of a qualitative study on the business practices of IIPs in Germany, we aim to answer the question of whether IIPs 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) whether it is the platforms that capture most of the gains derived from higher productivity or lower transaction costs and (2) whether there are tendencies of oligopolization that lead to an accumulation of power on the side of the platforms.

To answer these questions, we first develop a theoretical understanding of the role of IIPs 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 platforms that focus on process optimization through the collection and analysis of manufacturing data and distribution-centred platforms that reorganize the sourcing process in the mechanical parts industry (Sections 4 and 5). In Sections 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 IIPs 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.

INTANGIBLE ASSETS AND VALUE DISTRIBUTION IN GVCS

The strategic role of IIPs 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 interfirm 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, interorganizational 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, that is, 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', that is, easily exchanged by other suppliers in off-the-shelf transactions, and are exposed to price pressures. Pre- and postproduction 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 et al., 2011; Timmer et al., 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).

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 (Fagerberg et al., 2006; Lema et al., 2019). 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 (Porter & Millar, 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 et al., 1990). As supply chains disintegrated and became more complex, rationalization became a matter of 'systemic rationalization' of the supply chain (Altmann et al., 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, that is, data on consumer behaviour (Pfeiffer, 2021; Rikap, 2020). Digital data thus has played an ever-increasing role for firms' abilities of product design and process innovation.[1]

The technological progress toward the IoT, that is, 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. IIPs are needed to integrate this data in order to use software applications and to improve the matchmaking between industrial customers and suppliers.

PLATFORMS AS AGENTS IN VALUE CHAINS: ANALYTICAL CORNERSTONES FOR THE EMPIRICAL ANALYSIS

As there is 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 constitute 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 et al., 2019; Cusumano et al., 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:

(i) Do platforms capture most of the gains derived from higher productivity or lower transaction costs?
(ii) Are there tendencies of oligopolization that lead to an accumulation of power on the side of the platforms?

We hypothesize that both questions are related. In case a general tendency toward oligopolization prevails, the succeeding platform providers will be in a good position to set the terms vis-à-vis their industrial customers, that is, to capture significant gains from data-based intangibles. If, however, a fragmented market structure prevails, IIPs 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.

Platforms and their functions in industry

In order to develop analytical categories for the empirical analysis, a refined understanding of the role of platforms in industry 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 IIPs. 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 character of interactions within a platform's ecosystem differs according to its core function. Cusumano 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 of applications that extend the functionalities of the platform-mediated ecosystem beyond what could be provided by each single partner or through conventional cooperation between partners. Platforms therefore function as mediators 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, that is, they facilitate transactions while reducing transaction costs.[2] The main function of this type of platform is the matchmaking between suitable transaction partners.

This distinction between these platform functions roughly corresponds to the divergent trajectories of IIPs that can be observed in recent empirical studies on the subject (Butollo & Schneidemesser, 2021, 2022; 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 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 as follows: 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 subindustry and its specific requirements do exist as well. *Distribution-centred platforms* are transaction platforms that act as matchmakers between manufacturers 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'). Similarly, 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).

Platform business models

Our empirical analysis of the IPPs business models is organized according to a categorization that is derived from studies on business models in the B2C segment (Fleisch et al., 2014; Timmers, 1998) and adapted by Ziegler (2020, p. 92) for the analysis of IIPs. It distinguishes between *value proposition*, *platform architecture* and *revenue model* in order to analyse the relationship between platforms and the participants in the ecosystem and their ability to capture value. This distinction provides vital instruments for a refined analysis of the empirical material addressing the precise utility of platforms in the industrial realm and the relationship of actors within their ecosystems.

The *value proposition* of platforms describes the potential benefits that customers can have through the application of platform solutions. It crucially depends on the quality and range of the software applications sourced through the platform that are (to a great extent) provided by complementors, not by the platforms themselves. The utility of a platform to its customers accordingly depends on its ability to build and curate an ecosystem of developers that contribute functionalities to the platform. The precondition to provide services that matter to manufacturers is the ability to merge skills of generic IT service programming with the specific know-how of production processes. Hence, production-centred platforms need to combine and integrate skills from the field of IoT software development with an intimate knowledge of the processes of their customers, as several interview partners emphasized (PC2a, PC4a)[3]. This requires the ability to integrate different types of equipment and to ensure the interoperability of data in a heterogeneous and application-specific context. 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, our interviewees explained that 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 (DC1a, DC2a. DC3a).

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 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 et al., 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), that is, 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 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, that is, the generation of revenues from additional sources than the primary users of the platform (Fleisch et al., 2014).

RESEARCH DESIGN AND METHODS

In the following empirical analysis, we relate the theoretical concepts on platform types (innovation and transaction platform/production- and distribution-centred platforms) and platform business models (value proposition, platform architecture, revenue model) to the empirical data. 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 with industrial companies and/or might facilitate 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 (2020) inductively developed notion of 'points of control'. These 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.

The empirical material consists of 33 interviews gathered between January 2020 and November 2021 with three groups of actors in the field of the industrial Internet: representatives of IIPs, platform complementors, and experts. IIP cases encompass six production- and four distribution-centred platforms active in Germany. All interview partners are involved in developing and executing business strategies within those companies and have an intimate knowledge of the industrial platform economy. In addition, we talked to representatives of complementors to the platforms'

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).

ecosystems—seven manufacturing partners of distribution-centred platforms and four software companies that contribute applications to production-centred platforms. The interviewed industry experts include representatives of industry associations, trade unions and research institutions (a detailed list of the empirical material is provided in Table A1 in the Appendix).

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. 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 subject matters: 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. The precise focus 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 with these co-operations and the question of how they affected their business development.

The data from the interviews were transcribed and analysed according to the method of qualitative content analysis using a mainly deductive, that is, 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.

PRODUCTION-CENTRED PLATFORMS: INFRASTRUCTURE OLIGOPOLIES OR SERVICE PROVIDERS?

The value proposition: Facilitating the use of data to increase productivity

Production-centred platforms facilitate a broad range of process improvements through the use of industrial data, a phenomenon that is often summarized under the term "Industry" 4.0″ (Platform Industrie 4.0, n.d.). Customers can choose from a variety of software applications that can be accessed according to the specific needs of their enterprise. Software that can be flexibly sourced from a cloud infrastructure according to the customers' needs is called Software as a Service (SaaS). Typical applications include tools to monitor and optimize the production flow, for instance, by detecting deviations in real time and rearranging the process sequence, so that bottlenecks can be avoided, and resource usage minimized. Another prominent focus is on (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 monitoring the condition 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 is comprised of various layers with different functionalities (see Figure A1 in the Appendix for a illustration of the production-centred platform ecosystem) (Graff et al., 2018; Lechowski & Krzywdzinski, forthcoming). IoT platforms (or 'Platform-as-a-service' [PaaS]) deal with the integration of software applications (SaaS) that are either self-produced by platform providers or sourced from third parties. Hence, the value proposition of the platform depends on its ability to provide or source SaaS elements that enlarge the range of functionalities customers can access. As in other areas of the platform economy, the physical computing power is mostly not provided by the PaaS operators, but outsourced to 'Infrastructure-as-a-Service' (IaaS) providers, most prominently to Amazon Web Services (AWS) and Microsoft Azure. These also offer generic data analysis and data structuring services to their customers. According to a company spokesperson of one major IaaS provider, the company currently does not pursue the strategy of moving beyond its role as infrastructure service providers, as it does not possess the domain-specific knowledge on industrial processes that would be necessary to do so (IP1)—a view that is widely shared in the industry. However, the boundary between PaaS and IaaS is fluid, which raises concerns about whether companies such as AWS will crowd out genuine PaaS approaches in the future (Lechowski & Krzywdzinski, forthcoming).

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 testbeds. Accordingly, the business models of platforms are still evolving (PC5a_1). The same applies to the composition of the field: many firms have become active in the industrial Internet. A consolidation is likely in the medium term and the boundaries, and the division of labour and the value distribution is in flux (Graff et al., 2018). This also concerns the questions of the relationship between platforms, complementors and industrial customers. The various players in production-centred platforms' ecosystems compete with each other to capture value, but they also need to cooperate for the sake of the joint interest in creating value from data (PC2b_1; PC5a_2; PC4c).

Platform architectures: Balancing relationships with customers and complementors

The most important architectural decisions that affect the relationship between participants in production-centred platforms' ecosystems concern questions of openness and interoperability. Most manufacturing firms operate diverse equipment with regard to machine types, generations and brands; this results in a heterogeneous landscape of controlling software. Under such circumstances, platform strategies that would aim at proprietary and closed solutions, that is, 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 sets of machinery, controlling software and data. A manager at a production-centred platform describes this requirement for openness, which was emphasized in many interviews of our study (PC2b_1; PC4c; PC5a_1), as follows:

> On the one hand, everyone is aware that […] 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." (PC1a)[4]

Therefore, the openness and compatibility of platforms with software from various equipment producers is a precondition for production-centred platforms to attract customers on a larger scale. However, the 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 customers' needs in order to maximize their utility. The result is a delicate balancing game in which the platform providers need to strike the right balance between keeping the services offered on their platform diverse (by cooperating with other actors in the field) and simultaneously navigating between their own and complementors' goals of generating 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 platforms also depends on their abilities to exploit network effects. In order to benefit from same-side network effects, a platform would need to be able to provide functionalities that offer increasing user utility as the number of users grows. Indeed, some software applications (e.g., for predictive maintenance or for optical quality control) would benefit from a higher number of users given their data could be shared, especially if they are built on machine learning approaches, which could result in same-side network effects.

However, in contrast to private consumers who have tended to submit their data willingly (or unknowingly) to platforms in the consumer-oriented Internet, industrial companies are highly sceptical about sharing their data with platforms. This is shown in a recent survey by the German Economic Institute and the Foundation of German Industries (Röhl et al., 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 give certain feedback, etc. (com1PC)

The concerns over the sharing of data are a constraint to the establishment of platforms' business models (com2PC; PC2b_2). For the production-centred platforms in this sample, it is common business practice to ensure that the data stays with the customers and is not appropriated by the platforms or transmitted to third parties. At the same time, so-called data cooperatives and test bed projects explore negotiated sharing of data between ecosystem participants on an experimental basis in order to explore its benefits (Werling et al., 2020).

While same-side network effects thus are difficult to incorporate into the platforms' business models, *cross-side network effects* matter. These would mean that a platform with a growing number of users would become more attractive to complementors and the other way around (Cusumano et al., 2019, p. 17). Cross-side network affects primarily concern the relationship between SaaS complementors and the industrial customers of a platform. 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 (PC2b_1):

> [O]f course there are many third parties out there who […] 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. […] (PC1a)

This need for compatibility also pushes the platforms towards openness with regard to their interfaces and 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 maximize its compatibility and integration with SaaS complementors.

The need to attract a vibrant ecosystem of SaaS providers around the platforms' core affects the competitiveness of platforms. Ideally, they can offer a broad range of SaaS applications to its industrial customers. Yet relationships with complementors are fluid. Unlike with Google Play or the Apple App Store, which act as monopolies with regard to the distribution of smartphone apps in the consumer-oriented Internet, software developers can distribute their apps through different channels and end the relationship with a platform altogether if 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 is distributed.

Revenue models: Benefitting 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). The interviewed representatives of production-centred platforms stressed the high requirements for 'domain-specific' manufacturing knowledge (PC4c; PC5a_2). Standardized and generic data-analysis tools have to be adjusted to meet the needs 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 depending on whether it is to be integrated into public transport vehicles or production machinery (IP1). Production-centred platforms therefore typically combine the function of software distribution with consulting services (PC2b_2; PC4c): they assist with adjustments between production equipment and software elements since customers often lack the specific knowledge of how to benefit from data analytics in their specific context.

Most platforms (PC2, PC4, PC5) offer *off-the-shelf* monthly subscription plans to get access to platform functions. These can be complemented by customized packages of apps and services. However, platforms can find additional sources of revenue as well, as the case of Siemens Mindsphere demonstrates where fees are not only collected from customers, but also from complementors that want to access the platform's developer tools. Furthermore, Siemens with a long history in industrial automation sells complementary hardware components—the so-called Mind Connect elements—that facilitate the 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 is strong resistance among manufacturers to pay for services and equipment without having any certainty 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 proof 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.

Discussion: Constraints to oligopolization

Production-centred IIPs are acquiring a position in industrial GVCs that is of growing importance: they enable corporate customers to take advantage of data to improve processes and boost productivity. Unlike their peers in the consumer-oriented Internet, however, the digital platforms of the industrial realm face greater obstacles to acquiring a dominant position that would enhance their bargaining power vis-à-vis other ecosystem participants. Especially the constraints to sharing data and thus unleashing same-side network effects, obstruct an easy road towards market control in 'winner-takes-it-all' markets. It also is a barrier to revenue models that focus on the secondary usage of data (advertising, for instance), one of the main sources of revenue in the consumer-oriented Internet.

Several interview partners nonetheless expected the market segment to consolidate, with only a handful of large players remaining (IP1; Exp1; com2PC). 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 would fragment along industry boundaries, with only one platform becoming the main beneficiary per segment (PC2a). However, due to the need to ensure interoperability with a heterogeneous hardware landscape and the obstacles to locking in SaaS complementors to one 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_1).

Crucially, the success of production-centred platforms depends on the capacity of their customers to increase their productivity based on the provision of SaaS elements. The primary objective of production-centred platforms is not to grow *at the expense of* their customers but to acquire a share of the productivity increase. In the long term, however, the strongest production-centred platforms could gain bargaining power vis-à-vis other ecosystem participants because complementors and industrial customers alike would depend on the superior range of their ecosystems.

DISTRIBUTION-CENTRED PLATFORMS: INTRODUCING E-COMMERCE TO INDUSTRY

Value proposition: Reducing transaction costs

Distribution-centred platforms function as B2B e-commerce marketplaces and position themselves as matchmakers between industrial customers looking for supply products and the manufacturers that provide them (see Figure A2 in the Appendix for a illustration of the distribution-centred platform ecosystem). One industry in which the distribution-centred platform model is expanding fast is mechanical component manufacturing. In Europe and the United States, 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 partner ecosystems of the three platforms investigated in this study range in size between 240 and 6,000 companies. The manufacturing services offered by complementors include laser, plasma and waterjet cutting, computerized numerical control (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 straightforward: 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 digital platform that acts as an 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 1a). Furthermore, the network of complementors allows for more flexibility, especially at time-sensitive orders because a suitable and responsive supplier can easily be found among the manufacturing partner ecosystem. The disruptions to GVCs during the outbreak of COVID-19 in the beginning of 2020 have accordingly given these platforms a boost, as lead firms had to reorganize their supply chains and often sought for short-term solutions for supply bottlenecks.

Platform architectures: Curating the manufacturing network

Distribution-centred platforms curate their network of manufacturing partners by imposing access rules and continuously evaluating their performance. To become part of a platform's network of manufacturing partners, firms have to provide detailed information on the production processes they offer and successfully complete a trial phase during which orders are closely monitored and evaluated based on dimensions such as product quality, punctuality and fast communication. The mechanisms of monitoring and evaluation are institutionalized and become permanent, and they affect the likelihood that the company will receive orders in the future (DC2c, DC3a). The factors that determine whether a particular manufacturer is chosen, however, remain opaque for manufacturers (com4DC; com2DC).

To create and expand their network, distribution-centred platforms make use of cross-side network effects. The platforms' attractiveness to customers is mainly due to the range and flexibility of the manufacturing services they offer. Both are rooted in the size and diversity of the ecosystem rather than in the flexibility of individual manufacturing partners (Butollo & Schneidemesser, 2021). Viewed from the manufacturing partners' perspective, a platform is most relevant if it has a solid base of industrial buyers that generates a steady flow of orders. Therefore, as the platform expands, it needs to achieve a good balance for 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 manufacturing partners manually and allocates orders via email and telephone (DC2b). Other platforms are particularly active in developing software elements such as instant pricing tools, which automate aspects of the business relationship (in this case, by calculating a binding price for a certain product). Such AI-based tools record the requested materials, required processing techniques, lead time, batch size and the properties of a technical drawing and compare them with automatically generated benchmarks from its vast database. One platform representative claimed that their machine learning algorithm had already analysed more than one million computer-aided design (CAD) files to automatically calculate prizes (DC3a). 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' (DC1a). 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 may particularly be the case when platforms involve firms from low-wage and high-wage countries that are put into direct competition with each other. Manufacturers are then effectively benchmarked against the market participants that are globally most efficient, fastest and cheapest. The same applies to 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. (DC1a)

However, according to our interviews with the platforms' manufacturing partners, the platforms' pricing strategies show contradictory effects. There is no unequivocal race to the bottom. Some of the manufacturers in our sample report no differences in the price level between orders that were transmitted through the platforms and orders that were received directly from customers without the involvement of platforms (com1DC, com2DC). Yet, others reported that revenues on some platform-mediated orders are significantly lower (com3DC, com4DC).

Another facet of the power relation between platforms and complementors concerns the relationship between component manufacturers and industrial customers since the platforms intercept any direct interactions between them. They mediate these transactions and are careful not to enable direct transactions between the two sides of their ecosystem. Manufacturers thereby loose the benefits of a direct customer relationship that can provide a certain stability of business relationships and opportunities for lucrative consulting activities that concern the pre-production processes (com3DC). As the platforms obstruct a direct interaction between manufacturing partners and customers they monopolize such services while manufacturers only perform core manufacturing tasks, a functional impoverishment for the involved firms. Conversely, the platforms can enrich their transactions by pre-production services. One platform in our sample, for instance, was aiming to develop services such as the automated testing of the manufacturability of designs or lead-time calculation (DC3a), which it hoped to achieve by utilizing the vast amount of data on machine-part designs and CAD drawings that is uploaded to the platforms by their customers. This shows how—unlike production-centred platforms—distribution-centred platforms can benefit from secondary use of data (CAD designs, information on manufacturers). This provides a range of opportunities for distribution-centred platforms to capture value from intangible assets.

Revenue model: Fees on transactions

All three distribution-centred platforms of our sample earn a commission on every order that is placed with them. They charge for the matchmaking between industrial buyers and suitable suppliers 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 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 component manufacturers and industrial customers.

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, relying on cross-side network effects. 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 lower transaction costs. For manufacturing partners, this is a double-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 face enhanced competitive pressures.

While effects on manufacturing partners thus are mixed, distribution-centred platforms will likely emerge as the main beneficiaries in the process, capturing large shares of revenues from the savings in transaction costs by collecting fees. If distribution-centred business models turn out to be scalable and diversify across industries, an oligopolization that resembles developments in B2C e-commerce may emerge with a similar implication: a growing dependency of sellers and customers. However, it is not clear that market developments will automatically result in oligopolistic structures (i.e., a fragmented landscape of specialized platforms could be an alternative scenario), and it cannot 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 are often 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.

CONCLUSION

Our discussion of the role of IIPs in GVCs took as its point of departure reflections on the enhanced role of data in industrial processes and the observation that data often is 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 which 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 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 study help to better understand the position that IIPs acquire in GVCs. The analysed platform business models do not mainly aim to capture industrial data with the goal of monopolizing intangible assets, that is, 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, that is, enhanced productivity of manufacturing processes or lower transaction costs through efficient matchmaking. The success of both types of platform business models essentially depends on the capacity of their customers to generate increased revenue from using the IPP’s services.

Hence the issue at stake is not whether industrial platforms will outcompete or replace industrial companies but whether they will emerge as strong service providers that maximise their revenues vis-à-vis traditional manufacturers. Their ability to do so depends on the platforms’ ability to acquire bargaining power based on network effects. In this sense, the trajectories of both platform types are different: *Production-centred* platforms cannot utilize same-side network effects as long as there are still 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 possibility 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, exhibit 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 higher fees for transaction services. What is more, these platforms do record the data from transaction processes, which implies an "information asymmetry" (Staab, 2022) vis-à-vis their complementors that allows them to improve and expand their match making qualities and their pre-production services.

In both of the fields we considered, oligopolization eventually might occur. This mainly means that IIPs 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 affects 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 aiming at more flexible and versatile production processes by applying advanced digital technologies. Distribution-centred platforms thus could emerge as an alternative path to the engineering-heavy strategy of Industry 4.0: they embrace the flexibility of the network to deliver what Industry 4.0 promises by other means (Butollo & Schneidemesser, 2021).

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Notes

[1] What is more, product markets are characterized by an increasing number 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 et al., 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 (Butollo & Schneidemesser, 2021).

[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 et al., 2019).

[3] A description of the data sample and method of analysis is provided in section five and a table that presents the empirical material in detail is provided in the Appendix.

[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 (Butollo & Schneidemesser, 2022).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

Abdelkafi, N., Raasch, C., Roth, A., & Srinivasan, R. (2019). Multi-sided platforms. *Electronic Markets*, *29*(4), 553–559. https://doi.org/10.1007/s12525-019-00385-4

Acatech. (2015). *Smart service welt: Recommendations for the strategic initiative web-based services for businesses. Final report.* Acatech. https://en.acatech.de/publication/recommendations-for-the-strategic-initiative-web-based-services-for-businesses-final-report-of-the-smart-service-working-group/

Ali-Yrkkö, J., Rouvinen, P., Seppälä, T., & Ylä-Anttila, P. (2011). Who captures value in global supply chains? Case Nokia N95 smartphone. *Journal of Industry, Competition and Trade*, *11*(3), 263–278. https://doi.org/10.1007/s10842-011-0107-4

Alsamawi, A., Cadestin, C., Jaax, A., Guilhoto, J., Miroudot, S., & Zurcher, C. (2020). *Returns to intangible capital in global value chains: New evidence on trends and policy determinants*. OECD Trade Policy Papers, (240). https://www.ilo.org/public/english/revue/

Altmann, N., Deiß, M., Döhl, V., & Sauer, D. (1986). Ein „Neuer Rationalisierungstyp'—Neue Anforderungen an Die Industriesoziologie. *Soziale Welt*, *37*(2/3), 191–207.

Baukrowitz, A., Berker, T., Boes, A., Pfeiffer, S., Schmiede, R., & Will-Zocholl, M. (2006). *Informatisierung der Arbeit—Gesellschaft im Umbruch* (1st ed.). Edition Sigma.

BDI. (2019). *Deutsche digitale B2B plattformen* https://bdi.eu/publikation/news/deutsche-digitale-b2b-plattformen/

Briken, K., Chillas, S., Krzywdzinski, M., & Marks, A. (Eds.). (2017). *The new digital workplace: How new technologies revolutionise work*. Palgrave Macmillan.

Brynjolfsson, E., & McAfee, A. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies* (1st ed.). W. W. Norton & Company.

Butollo, F. (2020). Digitalization and the geographies of production: Towards reshoring or global fragmentation? *Competition & Change*, *25*(2), 259–278. https://doi.org/10.1177/1024529420918160

Butollo, F., & Schneidemesser, L. (2021). Beyond "Industry 4.0": B2B factory networks as an alternative path towards the digital transformation of manufacturing and work. *International Labour Review*, *160*(4), 537–552. https://doi.org/10.1111/ilr.12211

Butollo, F., & Schneidemesser, L. (2022). Alibaba's distribution-driven approach towards the industrial internet: A Chinese version of Industry 4.0? In G. Gereffi, P. Bamber & K. Fernandez-Stark (Eds.) *China's new development strategies: Moving up and moving abroad in global value chains*. Palgrave-Macmillan.

Chesbrough, H. W. (2003). *Open innovation: The new imperative for creating and profiting from technology (First trade paper edition)*. Harvard Business Review Press.

Cusumano, M. A., Gawer, A., & Yoffie, D. B. (2019). *The business of platforms: Strategy in the age of digital competition, innovation, and power* (1st ed.). Harper Business.

Dolata, U. (2015). Volatile Monopole. Konzentration, Konkurrenz und Innovationsstrategien der Internetkonzerne. *Berliner Journal für Soziologie*, *24*(4), 505–529. https://doi.org/10.1007/s11609-014-0261-8

Durand, C., & Milberg, W. (2020). Intellectual monopoly in global value chains. *Review of International Political Economy*, *27*(2), 404–429. https://doi.org/10.1080/09692290.2019.1660703

Fagerberg, J., Mowery, D. C., & Nelson, R. R. (2006). *The Oxford handbook of innovation* (Illustrated ed.). Oxford University Press.

Fleisch, E., Weinberger, M., & Wortmann, F. (2014). *Geschäftsmodelle im Internet der Dinge*. BOSCH, Universität St. Gallen. https://www.iot-lab.ch/wp-content/uploads/2014/09/GM-im-IOT_Bosch-Lab-White-Paper.pdf

Ford, M. (2016). *Rise of the robots: Technology and the threat of a jobless future* (Reprint). Basic Books.

Foster, C., & Graham, M. (2017). Reconsidering the role of the digital in global production networks. *Global Networks*, *17*(1), 68–88. https://doi.org/10.1111/glob.12142

Gawer, A., & Cusumano, M. A. (2014). Industry platforms and ecosystem innovation. *Journal of Product Innovation Management*, *31*(3), 417–433. https://doi.org/10.1111/jpim.12105

Gereffi, G. (1994). The organization of buyer-driven global commodity chains: How U.S. retailers shape overseas production networks. In G. Gereffi & M. Korzeniewicz (Eds.), *Commodity chains and global capitalism* (pp. 95–122). Praeger.

Graff, J., Krenz, W., & Kronenwett, D. (2018). *IIoT platforms: Sources of profit or inflated hype? How machinery companies should target their investments to maximize benefits.* (p. 9). Oliver Wyman. https://www.oliverwyman.de/content/dam/oliver-wyman/v2/publications/2018/november/perspectives-on-manufacturing-industries-cover-story.pdf

Haskel, J., & Westlake, S. (2017). *Capitalism without capital: Rise of intangible economy*. Princeton Univers. Press.

Herrigel, G. (2018). Experimentalist systems in manufacturing multinationals: German automobile and machinery examples. *Critical Perspectives on International Business*, *14*(4), 362–382. https://doi.org/10.1108/cpoib-10-2017-0063

Herrigel, G., & Zeitlin, J. (2010). Inter-firm relations in global manufacturing: Disintegrated production and its globalization. In G. Morgan, J. L. Campbell, C. Crouch, O. K. Pedersen, & R. Whitley (Eds.), *The Oxford handbook of comparative institutional analysis*. (pp. 527–561). Oxford University Press. https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199233762.001.0001/oxfordhb-9780199233762-e-19

Hirsch-Kreinsen, H. (2016). Digitization of industrial work: Development paths and prospects. *Journal for Labour Market Research*, *49*(1), 1–14. https://doi.org/10.1007/s12651-016-0200-6

Humphrey, J. (2018). *Value chain governance in the age of platforms*. IDE Discussion Papers 714. Institute of Developing Economies, Japan External Trade Organization.

Kaplinsky, R. (2020). Rents and inequality in global value chains. In S. Ponte, G. Gereffi, & G. Raj-Reichert (Eds.), *Handbook on global value chains* (pp. 153–168). Edward Elgar Publishing.

Kenney, M., Rouvinen, P., Seppälä, T., & Zysman, J. (2019). Platforms and industrial change. *Industry and Innovation*, *26*, 871–879. https://doi.org/10.1080/13662716.2019.1602514

Kenney, M., & Zysman, J. (2016). The rise of the platform economy. *Issues in Science and Technology*, *32*, 61–69.

Lechowski, G. & Krzywdzinski, M. (forthcoming). Emerging positions of German firms in the industrial internet of things: a global technological ecosystem perspective. *Global Networks*.

Lema, R., Pietrobelli, C., & Rabellotti, R. (2019). Innovation in global value chains. In S. Ponte, G. Gereffi, & G. Raj-Reichert (Eds.), *Handbook on global value chains* (pp. 370–384). Edward Elgar Publishing. https://doi.org/10.4337/9781788113779.00032

Lev, B. (2001). *Intangibles: Management, measurement, and reporting*. Brookings Institution Press.

Lüthje, B. (2019). Platform capitalism 'Made in China'? Intelligent manufacturing, Taobao villages, and the restructuring of work. *Science, Technology and Society*, *24*(2), 199–217. https://doi.org/10.1177/0971721819841985

Mayring, P. (2015). *Qualitative inhaltsanalyse: Grundlagen und techniken* (Neuausgabe, 12., aktualisierte). Beltz.

McAfee, A., & Brynjolfsson, E. (2017). *Machine, platform, crowd: Harnessing our digital future*. Norton & Company.

Mudambi, R. (2008). Location, control and innovation in knowledge-intensive industries. *Journal of Economic Geography*, *8*(5), 699–725. https://doi.org/10.1093/jeg/lbn024

Nahm, J., & Steinfeld, E. S. (2014). Scale-up nation: China's specialization in innovative manufacturing. *World Development*, *54*, 288–300. https://doi.org/10.1016/j.worlddev.2013.09.003

Pfeiffer, S. (2021). *Digitalisierung als Distributivkraft: Über das Neue am digitalen Kapitalismus*. Transcript.

Platform Industrie 4.0. (n.d.). What is industrie 4.0? https://www.plattform-i40.de/PI40/Navigation/EN/Industrie40/WhatIsIndustrie40/what-is-industrie40.html

Porter, M. E., & Millar, V. E. (1985, July 1). How information gives you competitive advantage. *Harvard Business Review*. https://hbr.org/1985/07/how-information-gives-you-competitive-advantage

Rikap, C. (2020). Amazon: A story of accumulation through intellectual rentiership and predation. *Competition & Change*. https://doi.org/10.1177/1024529420932418

Röhl, K.-H., Bolwin, L., & Hüttl, P. (2021). *Datenwirtschaft in Deutschland. Wo stehen die Unternehmen in der Datennutzung und was sind ihre größten Hemmnisse?* [Expert opinion on behalf of Bundesverbands der Deutschen Industrie e.V. (BDI)]. Käln. https://www.iwkoeln.de/studien/klaus-heiner-roehl-lennart-bolwin-wo-stehen-die-unternehmen-in-der-datennutzung-und-was-sind-ihre-groessten-hemmnisse.html

Siemens. (2017). *MindSphere. The cloud-based, open IoT operating system for digital transformation*. https://new.siemens.com/uk/en/products/software/mindsphere/mindsphere-white-paper.html

Srnicek, N. (2016). *Platform capitalism*. Press.

Staab, P. (2022). *Digital capitalism: Markets and power in the digital age*. Manchester University Press.

Sturgeon, T. J. (2019). Upgrading strategies for the digital economy. *Global Strategy Journal*, *41*(1), 34–57. https://doi.org/10.1002/gsj.1364

Thun, E., & Sturgeon, T. (2019). When global technology meets local standards: Reassessing the China's mobile telecom policy in the age of platform innovation. In T. Rawski & L. Brandt (Eds.), *Policy, regulation and innovation in China's electricity and telecom industries* (pp. 177–220). Cambridge University Press. http://eureka.sbs.ox.ac.uk/7168/

Timmer, M. P., Erumban, A. A., Los, B., Stehrer, R., & de Vries, G. J. (2014). Slicing up global value chains. *Journal of Economic Perspectives*, *28*(2), 99–118. https://doi.org/10.1257/jep.28.2.99

Timmers, P. (1998). Business models for electronic markets. *EM - Electronic Markets*, *28*(2), 3–8. https://doi.org/10.1080/10196789800000016

Werling, M., Weber, P., & Lasi, H. (2020). *Partizipation. Im Spannungsfeld von Plattform-Giganten, staatlicher Datentreuhand und genossenschaftlich-kooperativen Ansätzen*. (p. 6) [Arbeitsbericht]. Ferdinand-Steinbeis-Institut. https://steinbeis-fsti.de/wp-content/uploads/20-09-15-Arbeitsbericht_Datengenossenschaften.pdf

Womack, J. P., Jones, D. T., & Roos, D. (1990). *The machine that changed the world: Based on the Massachusetts institute of technology 5-million dollar 5-year study on the future of the automobile*. Rawson Associates.

Ziegler, A. (2020). *Der Aufstieg des Internet der Dinge: Wie sich Industrieunternehmen zu Tech-Unternehmen entwickeln*. Campus.

Zuboff, S. (2015). Big other: Surveillance capitalism and the prospects of an information civilization. *Journal of Information Technology*, *30*(1), 75–89. https://doi.org/10.1057/jit.2015.5

Zysman, J., Murray, J., Feldman, S., Nielsen, N., & Kushida, K. (2011). Services with everything: The ICT-enabled digital transformation of services. BRIE Working Paper No. 187a. https://doi.org/10.2139/ssrn.1863550

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APPENDIX

Table (A1)

TABLE A1 Overview of interviewed companies and experts

Category	Characterization	Date	ID[i]	Interview partner
Production-centred platforms and complementors	IaaS, cloud infrastructure provider	27/01/2020	IP1a	Executive, Head of Public Policy DACH
	PaaS, coalition of industrial companies and software providers	27/04/2020	PC1a	Executive, Head of Products (AI)
	PaaS, a major IIoT platform integrating a broad range of self-and externally produced software	24/02/2020	PC2a	Chief expert software IIoT and distinguished research scientist
		30/11/2020	PC2b_1	Senior Management (external cooperation)
		16/02/2021	PC2b_2	Senior Management (external cooperation)
	Industrial software provider	29/01/2020	PC3a_1	Senior Director, Industry 4.0 & Artificial Intelligence
		29/04/2020	PC3a_2	Senior Director, Industry 4.0 & Artificial Intelligence
	IaaS, SaaS, major software company that provides cloud services and software applications to industrial customers	16/04/2020	PC4a	Technical Executive Software Sales
		06/11/2020	PC4b	Executive Architect AI Applications
		13/01/2021	PC4d	Project manager, Cloud computing division (hybrid clouds)
		20/11/2020	PC4c	Project manager, Cloud computing division
		18/01/2021	PC4e	Senior manager software development
	IaaS, PaaS, SaaS. Software division of an industrial company venturing in the field of IIoT	07/12/2020	PC5a_1	Senior Management (Digitalization Engineering & Manufacturing)
		20/01/2021	PC5a_2	Senior Management (Digitalization Engineering & Manufacturing)
	PaaS, specialized in product platforms	26/02/2020	PC6a	Managing Director, Chief Sales & Marketing Officer
	SaaS, mechanical engineering company	27/01/2020	com1PC	Executive, Head of Product Management and Business Center Automation and Factory Control
	SaaS, mechanical engineering company	17/11/2021	com2PC	Manager Production

(Continues)

TABLE A1 (Continued)

Category	Characterization	Date	ID[i]	Interview partner
	SaaS, software provider and consultant	24/02/2020	com3PCa	Executive, CMO & Senior VP Strategy
	SaaS, mechanical engineering company	26/02/2020	com4PC	Executive, Digitalization & Innovation
Distribution-centred platforms and manufacturing partners	Distribution-centred platform (mechanical components)	23/07/2020	DC1a	Executive, Co-Founder
	Distribution-centred platform (mechanical components)	02/04/2020	DC2a	Executive, Co-Founder & CMO
		09/06/2020	DC2b	Executive, Head of Purchase
		18/02/2021	DC2c	Executive, Co-Founder & CMO and Executive, Head of Purchase
	Distribution-centred platform (mechanical components)	10/09/2020	DC3a	Managing Director
	Distribution-centred platform (mechanical components)	27/11/2021	DC4a	Country Manager

[i]We use the following labelling system for quoting interviews and for referring to desk research on the platforms: Each interviewee group has an abbreviation (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. Each interviewee/interviewee group is assigned a lower-case character (a,b,c,…) after the number. If more than one interview was conducted with the same interviewee/interviewee group this is indicated by a number after the lower-case character E.g. the code PC2b_2 refers to the second interview we had with representative b of production-centred platform number 2 in our sample. If we refer to the ID of platforms (DC1, PC4 etc.) without the identifier for the interviewee (lower-case character) the reference is to our desk research on the platform.

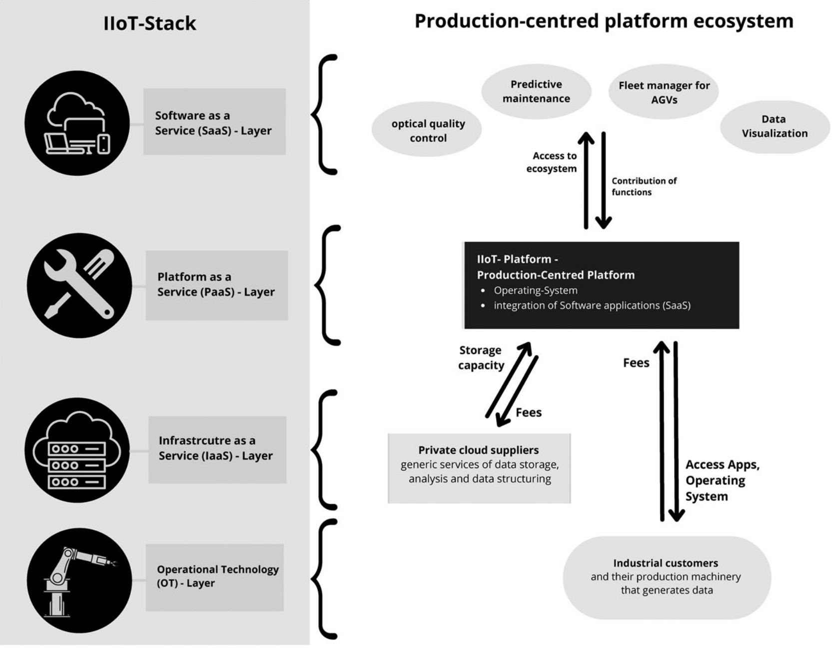

FIGURE A1 Production-centred platform ecosystem

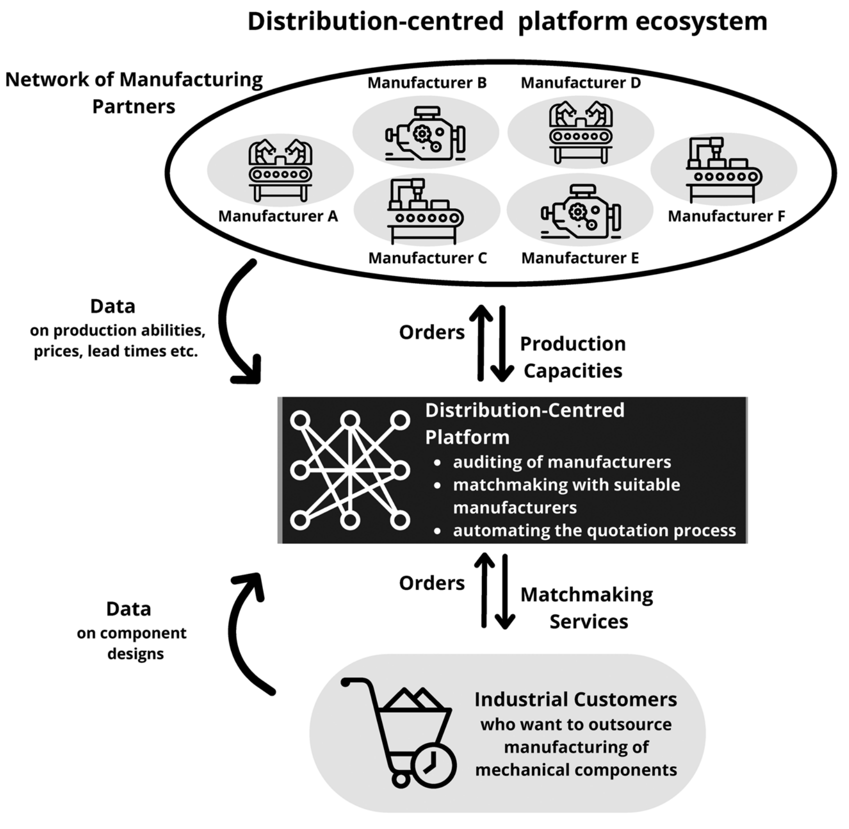

FIGURE A2 Distribution-centred platform ecosystem