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# Inhibitors and Enablers of Leverage in Digital Industrial Platform Ecosystems

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**Abstract** Digital platforms have demonstrated their disruptive power across various domains, and an increasing number of manufacturing firms have embarked on establishing digital industrial platforms for emerging technologies like the Industrial Internet of Things. Given the technical and organizational complexity of digital industrial platforms, the ways in which complementors can create value by interacting and engaging with them may differ for these platforms. Drawing on a case study conducted at a large multinational platform provider, the article explores how complementors can use digital industrial platforms to their advantage. To this end, the study adopts the concept of leverage, which refers to the ability of platform ecosystems to exert a significant degree of impact that is disproportionate to the input required. The findings indicate that complementors currently primarily benefit from production leverage, utilizing the platform as a technological foundation for individual solutions. However, the utilization of the platform as a marketplace for

innovative and generically distributable applications that benefit from innovation and transaction leverage is limited. This is due to a variety of inhibitors, which the platform owner tries to mitigate via enablers through deliberate governance in the form of boundary resources. By unveiling domain-specific manifestations, inhibitors, and enablers across different types of leverage, the study contextualizes leverage within the domain of digital industrial platforms and stresses the need for adopting platform and ecosystem thinking and providing relational governance mechanisms. In addition, it extends the notion of architectural leverage by emphasizing the leveraging ecosystem and its governance through the deliberate orchestration of complementor engagement and underscoring ecosystem leverage based on value co-creation and coordination.

**Keywords** Digital platform · Digital industrial platform · Platform ecosystem · Leverage · Complementor · Manufacturing

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## 1 Introduction

As exemplified by firms like Amazon, Microsoft, and Apple, platforms are a major manifestation of digital innovation (Yoo et al. 2012). Their disruptive strength lies in their role as foundations for complementary products, technologies, and services and as market intermediaries between groups of actors (Gawer and Cusumano 2014). Opening the platform to third parties results in ecosystems of complementors (i.e., those who offer products complementary to the service the platform offers). While suppliers enable the production of a good, complementors enhance and sometimes even enable its use (Adner and Kapoor 2010). As a result, business models for digital platforms

depend heavily on an ecosystem of complementors (Parker et al. 2017; Teece 2018).

Platforms thrive when their open and modular architecture allows for 3 types of leverage: production leverage, innovation leverage, and transaction leverage (Thomas et al. 2014). Production leverage refers to increasing the efficient development of solutions through “the use of shared assets and the related interfaces and standards” (Thomas et al. 2014, p. 207). Innovation leverage also refers to the reuse of core platform components but with a focus on a wide variety of novel complements, akin to the notion of generativity (Zittrain 2006). Finally, transaction leverage describes the platform’s role as an intermediary in the ecosystem that facilitates market access, visibility, and the exchange of goods and services. Leverage describes both why complementors may affiliate with a platform and how they can benefit from it, as well as how platform owners benefit from opening the platform to an ecosystem of external partners. To facilitate and direct the ecosystem’s engagement and interaction with the platform, the platform owner typically employs mechanisms that are often summarized under the umbrella term of *platform governance* (Tiwana 2014; Schrieck et al. 2016).

As industrial firms start to tap into platform business models, platform ecosystems in the industrial domain have received considerable attention in information systems (IS) research (e.g., Hanelt et al. 2020; Petrik and Herzwurm 2020a; Hein et al. 2019b). Fueled by the increasing prevalence of the Industrial Internet of Things (IIoT), the creation of digital industrial platforms eases the process of collecting and processing data from industrial assets and facilitates or even enables data-driven services (Hodapp et al. 2019b; Münch et al. 2022). As the platforms open to third parties, an ecosystem of complementors develops software applications and provides consulting and system integration services (Petrik and Herzwurm 2020b). While most studies on platform ecosystems focus on consumer domains like mobile platforms and video game platforms (e.g., Basole and Karla 2011; Cennamo and Santaló 2013; Cennamo et al. 2018; Ghazawneh and Henfridsson 2013), the number of studies that address business-to-business (B2B) or industrial domains is rising (e.g., Hein et al. 2019b; Tian et al. 2021; Wei et al. 2019). In addition, there have been specific studies that focus on enterprise resource planning (ERP) platforms (e.g., Sarker et al. 2012; Huber et al. 2017; Sun et al. 2021).

In industrial B2B environments, the ecosystem’s interactions with a platform tends to be less spontaneous and unsolicited, requiring deliberate organization and facilitation (Blasco-Arcas et al. 2020). Accordingly, initial insights from our problem domain suggest that the technical and organizational complexity of digital industrial platforms (Pauli et al. 2021) affects the manifestation of

platform phenomena, including generativity (e.g., Hein et al. 2019b) and network effects (e.g., Schermuly et al. 2019). Furthermore, digital industrial platforms also tend to be characterized by uncertainty regarding the benefits various actors may derive from engaging with the platform (Hodapp et al. 2019a). These insights point towards a need for a better understanding of the drivers of value creation and competitive advantage, including leverage (Thomas et al. 2014), in an industrial context and, in view of the peculiarities of actors’ interaction with these platforms, moving beyond the prevailing focus on platforms’ architectural aspects to the application of a social or ecosystem perspective (Nambisan 2018; Kapoor et al. 2021).

Consequently, the focus of our study is on *leverage* for digital platforms in industrial B2B environments, in particular linking the leverageable platform to the leveraging ecosystem of complementors. In this context, we ask the research question: *How can complementors effectively leverage digital industrial platform ecosystems?* Specifically, we will address this question by looking at 3 types of leverage and their manifestations, inhibitors, and enablers. To answer this research question, we conducted an exploratory case study that centers on a digital industrial platform ecosystem orchestrated by a large, multinational technology firm that provides, among other things, products and services for factory automation. We included the complementors’ as well as the platform owner’s perspectives through semi-structured interviews with 15 representatives of platform partners that offer complementary solutions and 11 representatives of the platform owner.

Our results show that complementors in digital industrial platform ecosystems face domain-specific inhibitors of all 3 types of leverage. Primarily they benefit from production leverage, that is, using the platform as a technological basis from which to deliver individual customer solutions. Their use of the platform – and especially the ecosystem – for innovation leverage and transaction leverage (serving as a marketplace for innovative and generically distributable applications, respectively) is limited. In addition, contrary to what may be expected in such a technologically complex domain, the focus of the platform owner’s enabling mechanisms lies on facilitating interaction with the ecosystem through platform governance using social boundary resources.

This study makes 3 major contributions to the literature. First, we extend the growing body of literature on digital platform ecosystems in the industrial domain. We show how factors inherent in the domain inhibit manifestations of leverage, which has implications for how platform phenomena and mechanisms in digital industrial platform ecosystems may differ from what we know from other domains. Second, we contribute to the broader literature on digital platform ecosystems by extending the logic of

architectural leverage. We show that a leverageable architecture must be accompanied by a leveraging ecosystem of complementors, both of which are coordinated through leverage-enabling governance to support complementor engagement. Third, we also conceptualize the ecosystem itself not only as an actualizing component for architectural leverage, but as a source for leverage in itself. Our contributions answer calls for an increasing shift in focus from purely architectural to ecosystem-related aspects in the analysis of value creation in platform ecosystems (Nambisan 2018; Kapoor et al. 2021), as well as a specific call for “more complementor-oriented research inclined towards managing this actor group” (Kapoor et al. 2021, p. 103).

The remainder of the paper provides the theoretical background on digital industrial platform ecosystems, the concept of leverage, and platform governance through boundary resources. Subsequently, we explain the method we used for our case study and present our findings. Next, we discuss the insights that emerged from our case study, illustrate the peculiarities of digital industrial platform ecosystems, and describe how our insights extend architectural leverage by strengthening the focus on complementor engagement and ecosystem leverage. The last section contains concluding thoughts, presents implications for research and practice and addresses the study’s limitations as they pertain to avenues for future research.

## 2 Theoretical Background

### 2.1 Digital Industrial Platforms

Technological advances in areas like microprocessors, connectivity, and memory paved the way for the emergence of the Internet of Things (IoT), that is, the connection of physical things via communication technologies (International Communications Union 2012; Wortmann and Flüchter 2015). The literature occasionally uses the terms *IoT* and *IIoT* synonymously in the context of B2B settings (e.g., Xu et al. 2014), but we differentiate between the 2 to highlight industrial applications’ unique characteristics. (Sisinni et al. (2018), p. 4725) describe the IIoT as “about connecting all the industrial assets, including machines and control systems, with the information systems and the business processes.”

To realize the benefits the IIoT offers, industrial firms establish platforms – often cloud-based – that allow for the collection and processing of data from various kinds of industrial assets and are open to third parties that want to develop complementary applications (Hodapp et al. 2019b). While also referred to as IIoT platforms, we use the broader notion of digital industrial platforms following

(Pauli et al. 2021), as IIoT is just one of the technologies used in a broader Industry 4.0 technology landscape – data and its collection and processing play a central role – and it is additionally important to focus on value creation in an industrial (B2B) context alongside technical aspects. These digital industrial platforms come in a range of flavours, depending on their focus on organizational elements (e.g., marketplaces), technical elements (e.g., hyperscalers), or both (e.g., integrated platforms) (Baumann et al. 2022). We currently see a rise of these platforms across the manufacturing industry with both traditional incumbents as well as technology providers entering this space (e.g., BDI 2018).

Digital industrial platforms and the ecosystems of actors around them differ in several ways from most platform ecosystems studied to date due to their technological and organizational complexity (Pauli et al. 2021; Petrik and Herzwurm 2020a). First, they are technologically complex because of the wide variety of underlying industrial assets, which are not tailor-made for a specific platform (Mineraud et al. 2016). Heterogeneous deployment environments and integration into whole smart factories create additional complexity (Hein et al. 2019b; Sandberg et al. 2020). Second, their technological sophistication necessitates complementors in various roles in the ecosystem, from consulting companies to system-integration companies to retrofit companies, requiring them to integrate these diverse stakeholders into a value co-creation process (Hein et al. 2019b; Petrik and Herzwurm 2020b). In addition, digital industrial platforms operate in a B2B environment, which features a wide variety of market structures and relationships between actors (Hein et al. 2019b), more complex, inter-organizational processes (Pauli et al. 2021) and more diverse interests of different actors to manage (Fielt et al. 2008).

In a B2B environment with a variety of actors, including digital industrial platform ecosystems, actor engagement and interaction are subject to challenges that differ from those of business-to-customer (B2C) platforms (Soltani 2022), so “actors in complex business settings may be reluctant to voluntarily engage on a platform in the ways we currently understand” (Blasco-Arcas et al. 2020, p. 81). Initial studies indicate that, in addition to technical complexity, digital industrial platforms’ peculiarities affect the manifestation of key platform phenomena like generativity (Hein et al. 2019b), network effects (Schermuly et al. 2019), and perhaps also leverage (Thomas et al. 2014) that rely heavily on ecosystem interactions.

## 2.2 Platforms and Leverage

The success of platforms can be traced back to the concept of leverage, which fundamentally means “generating an impact that is disproportionately larger than the input required” (Thomas et al. 2014, p. 206). More specifically in a platform context, “leverage is achieved through developing shared assets, designs, and standards that can be recombined, thereby facilitating coordination and governance within and between firms sharing a given platform” (Thomas et al. 2014, p. 206). The premise for platform leverage lies in the platforms’ typically modular architecture (Baldwin and Woodard 2009), which allows for easy extension and adaptation to various purposes of application.

Thomas et al. (2014) derive the theoretical notion of *architectural leverage* from an analysis of similarities and differences in 4 streams of management research: organizational research, product family research, market intermediary research, and platform ecosystem research. They see architectural leverage as a meta-logic that combines platform leverage with architectural openness, which “considers the involvement of third-party suppliers for the production of both components and complements.” (Thomas et al. 2014, p. 208). We see architectural leverage linking platform leverage, that is, a leverageable architecture that is modular and open, and complementors leveraging, that is, a leveraging ecosystem of complementors. Following this logic, architectural leverage can relate to both the benefits for the platform owner, who profits from the platform *being leveraged* and the benefits for complementors, who *leverage* a platform.

The notion of leverage emerged in the early stages of our study, as we were studying how complementors use the technological and business opportunities that digital industrial platforms offer. In this context, the 3 types of leverage that Thomas et al. (2014) define allow for a classification of the value creation and competitive advantage that platforms offer along 3 leverage logics: production, innovation, and transaction. They state that a combination of the 3 leverage logics can typically be found in a platform ecosystem, rather than one leverage logic being dominant, as in organizational, product family, and market intermediary platforms. Therefore, our case study of a digital industrial platform ecosystem can be expected to exhibit all 3 leverage logics.

The notion of production leverage is deeply rooted in the literature on product families, whose internal and supply chain platforms are collections of shared assets (Thomas et al. 2014). Meyer et al. (2010) note that product platforms are particularly beneficial across existing products as well as new market applications by making it possible to create better products at a lower cost. Broadly

speaking, production leverage refers to the reuse of core platform components to achieve economies of scale and scope and to increase efficiency and flexibility in the development of new products and services. This value proposition is central to digital industrial platforms, as they aim to integrate and aggregate data across various assets in smart factories, thus easing the development of data-driven solutions in complex environments (Pauli et al. 2021).

Similar to production leverage, innovation leverage is based on a platform’s role as a technological foundation for complementary modules. Being closely linked to the concept of generativity as a “technology’s overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences” (Zittrain 2006, p. 1980), innovation leverage refers to a platform’s ability to enable third parties’ complementary innovations, resulting in new goods and services. For example, complementors can leverage digital industrial platforms’ often advanced capabilities in areas like artificial intelligence (AI) and edge computing to create innovative solutions that might not have been feasible without the platform’s technical capabilities.<sup>1</sup> Innovation leverage is also in the platform owner’s interest, as it unlocks new capabilities and extends the variety of offerings (Boudreau 2012; Münch et al. 2022), thus helping the platform to cater to the diverging needs of a heterogeneous landscape of customers across industries (Petrik and Herzwurm 2020a; Wareham et al. 2014).

Platform ecosystems also allow for transaction leverage. Based on their role as market intermediaries, platforms reduce the effort of those who are interested in certain transactions to find each other and perform them (Tiwana 2014; Thomas et al. 2014). As many digital industrial platforms offer marketplaces that are akin to app stores on digital B2C platforms (Arnold et al. 2022), they offer complementors easy distribution of the solutions they develop. Simultaneously, the network effects that may be triggered facilitate the growth of the platform’s ecosystem (Katz and Shapiro 1985; Parker and Van Alstyne 2005). In addition to this overall benefit for the platform owner, the platforms’ facilitation of transactions can also be exploited by revenue models like charging for membership in the ecosystem, retaining a fee for every transaction, or sharing revenue with complementors (Hagiu 2006; Rochet and Tirole 2006; Oh et al. 2015).

<sup>1</sup> While production and innovation leverage as Thomas et al. (2014) describe them may refer, to some extent, to the same phenomenon, it is a matter of perspective. From the platform owner’s perspective, any solution produced by a complementor may be regarded as contributing to innovation. However, from a complementor’s perspective, production leverage refers to efficiency-related gains, and innovation leverage refers to the ability to innovate.



Thomas et al. (2014) introduce the concept of architectural leverage for platform ecosystems and distinguish between different types of leverage based on their review of platform literature. Looking at how the debate evolved since Thomas et al. (2014), there has been limited further development of the concept of architectural leverage for platform ecosystems.<sup>2</sup> The notion of leverage is mostly used just generally to refer to the leveraging of the platform architecture of technology (e.g., Cenamor et al. 2017; Schrieck et al. 2021; Wei et al. 2019) or leveraging external actors like complementors, partners or customers (e.g., Jingyao et al. 2022; Kapoor et al. 2021; Schrieck et al. 2021; Tian et al. 2021). There have only been a limited number of papers building on the theoretical notion of architectural leverage and the different types of leverage. A notable exception is Tian et al. (2021) who refer to platform leverage and define 4 theoretical platform leverage logics: production-incremental, production-radical, transaction-incremental, and transaction-radical (integrating innovation leverage into production and transaction leverage). They also emphasize that all platform actors need to be involved to ensure platform leverage. Zhou et al. (2021) build on the work of Tian et al. (2021) and define 3 platform leverage practices (technical, managerial, and service), specifically in the context of digital servitization. In their study of the digitization of ABB's process-automation platform, Sandberg et al. (2020) relate their findings to architectural leverage and the types of leverage – as a sequence from production to innovation to transaction leverage – this was, however, not an explicit part of their research.

Therefore, we conclude that while the notion of leverage is important for platform ecosystems, the theoretical concept of architectural leverage for platform ecosystems and the different types of leverage as introduced by Thomas et al. (2014) have only been limitedly used or advanced and form an interesting and relevant starting-point for our study. The 3 types of leverage are central to the success of platform ecosystems because they offer complementors a rationale for affiliating with a platform, thus enabling the emergence of an ecosystem that drives platform growth and adoption. Consequently, while leverage provides benefits for both complementors and the platform owner, the latter's benefit in terms of overall value creation and capture is often largely a consequence of the former's use of the platform's potential for value creation and capture. Therefore, leverage constitutes a potential for action that

must be actualized by an ecosystem of complementors (Hein et al. 2019a). While architectural openness and modularity are necessary prerequisites for leverage, its actualization may require deliberate facilitation through governance.

### 2.3 Platform Governance Through Boundary Resources

Platform governance can be regarded broadly as “the sum of activities carried out by platform owners that seek to influence the behavior and outcomes of complementors” (Halckenhäusser et al. 2020, p. 4). Platform governance goes beyond the notion of control, as platform owners can also use governance to foster or impede leverage. As the purpose of this study is to determine how platform owners can support complementors in overcoming domain-related barriers to leverage, we focus on the enabling role of governance.

The primary governance instruments for facilitating complementors' engagement with a platform ecosystem are boundary resources. (Ghazawneh and Henfridsson (2013), p. 175) note that “platforms may offer resources with which to facilitate the use of core platform functionality to build applications” and define platform boundary resources as “the software tools and regulations that serve as the interface for the arm's-length relationship between the platform owner and the application developer.” Ghazawneh (2012) differentiates between technical and social boundary resources, and Bianco et al. (2014) define 2 types of technical boundary resources: application boundary resources and development boundary resources. Application boundary resources like application programming interfaces (APIs) and open protocols allow third-party applications and hardware to interact with the platform. Development boundary resources like software development kits (SDKs) support the development and maintenance of complementary solutions. Social boundary resources extend these 2 technological types of resources by promoting (knowledge) exchange between participants in the ecosystem through such efforts as partner programs and workshops. Such boundary resources are means by which complementors can actualize the affordances of digital platforms (Hein et al. 2019a, 2020, 2019b).

By creating and offering boundary resources, platform owners can evolve their platforms and facilitate complementors' ability to engage with and leverage the platform and its ecosystem (Karhu et al. 2018; Petrik and Herzwurm 2020a). Petrik and Herzwurm (2020a) argue that some boundary resources (for example, app stores and APIs), should be viewed as mandatory, while others can be deployed by platform owners at their discretion to cater to individual needs or meet specific purposes. Therefore, the

<sup>2</sup> We searched the Web of Science for papers citing Thomas et al. (2014) and found 244 papers (23 October 2022). We searched the title and abstract of these papers for “lever” and read these titles and abstracts. Then we identified those papers that (1) were about platforms, (2) included leverage as a (theoretical) concept related to platform ecosystems. This resulted in 10 papers in total.

set of boundary resources offered to complementors is not fixed but can evolve over time in response to “emergent, mutual, and interpenetrating processes of resistance and accommodation across heterogeneous and distributed actors and technology artifacts” (Eaton et al. 2015, p. 236). In other words, the complementors and their needs significantly influence the range and design of boundary resources. Similarly, if inhibitors of platform ecosystems’ leverage emerge, the platform owner can mitigate them through governance decisions like providing boundary resources. Initial insights from the industrial domain suggest that platform owners offer a broader set of boundary resources to complementors than is typical for other domains (Petrik and Herzwurm 2019), which may indicate a number of inhibitors of the various affordances that digital industrial platforms provide. This study seeks to identify these domain-specific inhibitors and the governance mechanisms used to address them.

### 3 Method

We conducted an exploratory case study (Yin 2018) to enhance the current literature on digital industrial platforms and answer our research question: *How can complementors effectively leverage digital industrial platform ecosystems?*

We chose case study research because case studies are a viable methodology with which to investigate an emerging domain that is in an exploratory state (Eisenhardt 1989; Walsham 1995). Digital industrial platforms have only recently gained attention from platform scholars. Because their characteristics (e.g., regarding complexity and uncertainty) differ from those of other platforms, knowledge transfer from B2C platform research to digital industrial platforms requires careful judgement. In addition, case study research is an appropriate methodology for studying phenomena in the context in which they occur to gain comprehensive insights into their dynamics (Yin 2018).

#### 3.1 Case Description

We used the following sampling criteria based on our research objective: The case had to be (1) a digital industrial platform that collects and processes data from information systems and industrial assets using a modular architecture and that is open to actors outside the owner-firm, (2) must have already gained acceptance in the industry, resulting in a number of complementors being present, and (3) must have been in operation for some time to allow complementors’ experiences and the measures employed by the platform owner to be collected. We studied the *Connect Platform* provided by *Industry Inc.* as

it fulfilled these criteria and some of the authors had already been in contact with the firm.<sup>3</sup>

Industry Inc. is an internationally operating technology firm that provides, among other things, products and services for factory automation. In 2017, Industry Inc. established its platform, Connect, to collect data from sources like machines and sensors and to transfer and process these data in the edge or in a cloud environment. While Connect was initially meant to serve as central cloud storage, the range of features increased over time until Connect became an open platform that allows complementors to develop and market additional services and products. Industry Inc. provides boundary resources like APIs, SDKs, and an app store to offer third parties the ability to access the data and sell their own applications on the platform.

At the time of this study, Connect has attracted more than 500 complementors that provide offerings, among which the most popular and characteristic is app development. Similar to B2C platforms like iOS, app developers can develop and offer their software on the platform with the tools and specifications it provides. Consultants support customers by evaluating their needs, providing them with use cases, and showing them the return on investment for specific solutions. System integrators ensure data access on the shop floor and that information systems are connected, while connectivity partners provide hardware and software to connect the customers’ industrial assets to the platform. Technology partners ensure the platform’s operability and enhance its capabilities by providing infrastructure as well as knowledge and services to the ecosystem regarding technologies and topics like AI, blockchain, and security. In practice, most complementors perform several roles.

#### 3.2 Data Collection

We collected data through a series of 26 semi-structured interviews with 27 interviewees between July 2019 and July 2020. Each interview lasted between 21 and 60 min, with the median and average durations both at 39 min. On average, interviews with platform owners took a bit longer than those with complementors (45 vs. 35 min). All interviews were recorded, transcribed, and subsequently sent back to the interviewees for amendments and corrections. Table 4 in Online Appendix A (available online via <http://link.springer.com>) provides an overview of the size of each interviewee’s firm, the firm’s role in the ecosystem, the interviewee’s position, and the duration of the interview.

Initially, we conducted 15 interviews with complementors to generate insights into how they engage with the

<sup>3</sup> Both *Connect* as well as *Industry Inc.* are pseudonyms used for reasons of confidentiality.

platform. A prerequisite for complementors' selection was that they were actively using the platform to offer solutions to their customers and that the sample had some diversity in terms of company size and functions.<sup>4</sup> The interview guideline covered 3 categories of questions: the firm's business model and fit with the platform, the offerings the firm has created through the platform, and the firm's interactions with other actors in the ecosystem (Online Appendix B.1).

After initial data analysis revealed the notion of leverage as a fitting conceptual lens with which to categorize our findings (cf. the next section) and guided by a theoretical sampling approach (Glaser and Strauss 1967), we reflected on the additional data we needed to develop our emerging insights. As a result, we interviewed 11 experts on the platform owner side, which gave us an additional perspective on platform leverage and enriched our data set. Because of our theoretical preconceptions, the interview guideline for the platform owner included questions regarding complementors' interactions with the platform and the ecosystem, and measures taken to influence those interactions (Online Appendix B.2).

### 3.3 Data Analysis

We adopted the coding approach that Corbin and Strauss (2015) propose in analyzing the transcripts in several iterative coding cycles that were characterized by a combination of inductive and deductive approaches. The primary goal of this step was to identify the ways in which complementors engage with a platform, along with the associated rationales and influencing factors. First, we analyzed the complementors' interview transcripts inductively and coded them in an open-coding cycle using the qualitative data analysis software MAXQDA. In line with the constant comparative method, we regularly cross-checked new incidents coded in subsequent interviews with incidents in previous interviews (Glaser and Strauss 1967; Corbin and Strauss 2015). Two researchers conducted open coding separately and then consolidated their coding into a common coding scheme through discussion and adjustment until agreement was reached (Harry et al. 2005). As group consensus was our objective, we did not measure inter-coder agreement quantitatively (Saldaña 2013). Next, we applied axial coding to compare and identify relationships between the codes (Corbin and Strauss 2015). Finally, we used selective coding to identify the core categories to

which the sub-categories determined in axial coding were connected (Corbin and Strauss 2015).

To make sense of our emerging insights, we went back to theory and identified the notion of leverage as a fitting conceptual lens with which to categorize our findings. Therefore, we related the findings of our initial interviews with representatives of complementors to production leverage, innovation leverage, and transaction leverage. For instance, we classified how complementors benefit from engaging with the platform as manifestations of leverage. Keeping the concept of leverage in mind, we conducted a second round of interviews, this time with representatives of the platform owner. Again, 2 of the authors coded the additional interviews, using an iterative back-and-forth approach between our emerging theory and the interview data. For example, while we had already identified mechanisms and factors that affect complementors' interactions with the platform, we went back to our data to explore these findings further in view of leverage. This process identified inhibitors of leverage, which we assigned to the previously identified manifestations of leverage. Similarly, we analyzed the interview data for the platform owner's governance actions, which we classified as enablers of leverage and assigned to the respective inhibitors. Figure 2 in Online Appendix C shows our coding scheme with regard to the 3 types of leverage, and Fig. 3 in Online Appendix C illustrates the mapping of inhibitors and enablers to an exemplary manifestation of leverage.

As Yin (2018) suggests, we triangulated the data with secondary data sources provided by Industry Inc., including information on the developer portal, descriptions of use cases, service brochures, training videos, and industry publications. We also conducted further unstructured discussions with Industry Inc. employees during on-site and exhibition visits. This additional data helped us put the interview statements in context and relate them to each other.

## 4 Inhibitors and Enablers of Leverage

Here we present our findings in terms of manifestations of production leverage, innovation leverage and transaction leverage and relate them to inhibitors of complementors and the platform owner's enabling mechanisms. Tables 1, 2 and 3 offer a condensed overview of the manifestations, inhibitors, and enablers of production leverage, innovation leverage, and transaction leverage, respectively.

<sup>4</sup> Most complementors in our sample are firms with fewer than 500 employees. This sample reflects the overall distribution in the ecosystem, as the market for digital industrial platforms is currently in its growth phase, whereas major manufacturing and software companies build and focus on their own platforms.



**Table 1** Inhibitors and enablers of production leverage in digital industrial platform ecosystems

Leverage	Manifestations	Inhibitors	Enablers
Production	Porting of existing solutions	Lack of technical platform capabilities Migration effort	Continual extension of features Integration of self-hosted applications Mix-and-match approach for core platform services Migration workshops
	Development of customer-specific solutions	Regional PaaS/IaaS prevalence Lack of technical platform capabilities Missing complementor capabilities	Support of different infrastructures Continual extension of features Deliberate matchmaking between complementors Software-development kits Low code functionality Joint development events
	Development of generic solutions	Uniqueness and complexity of operational environments High upfront investment Higher profitability of project-based business Adoption uncertainty	Standardized app building blocks Venture capital Standardized app building blocks Flexible pricing based on complementor revenue Development and demonstration events Education through whitepapers, trainings, and workshops Self-application of the platform and solutions Operational and marketing services Flexible pricing based on complementor revenue Trust building through industry experience and certifications Lower entry barriers through <i>freemium</i> price models Communities for exchange

#### 4.1 Production Leverage

Currently, complementors use the platform primarily for production leverage. Our interview data revealed 3 manifestations of production leverage: porting of existing solutions, development of customer-specific solutions, and development of generic solutions.

Many complementors, especially at the beginning of their engagement with the platform, *port existing solutions* to the new platform. Many interviewees on the platform-owner side regard this engagement with the platform as a significant manifestation of production leverage:

“I think at the moment, if it’s about external partners, they primarily use things that have existed before, and which are ported to Connect or docked to Connect.” - PO E

However, inhibitors that impede the transfer of existing solutions include the potentially high *migration effort* and the varying prevalence of *regional PaaS/IaaS* that might not be associated with or compatible with the platform. The complementors evaluated the porting of a solution as feasible if the expected benefits, including access to new customers or improved integration with other solutions, outweigh the effort required. Occasionally, complementors also mentioned a *lack of technical platform capabilities*. For example, complementor K offers an AI-based energy-control solution that optimizes machines’ and buildings’ system settings. As Connect’s edge agent offers only the possibility to collect data from machines but not to control their operations, complementor K could not port its existing solution to Connect. To mitigate such inhibitors, the platform owner adopts measures like *continually extending the platform’s features, supporting different*

**Table 2** Inhibitors and enablers of innovation leverage in digital industrial platform ecosystems

Leverage	Manifestations	Inhibitors	Enablers
Innovation	Realization of innovative solutions	Lack of technical platform capabilities Lack of complementor collaboration  Complex technical and legal requirements  Low digital maturity of market and customers  Difficulty of the customer to determine the added value of innovative platform-based solutions   Customer's risk and change aversion   Lack of generic solutions	Continuous extension of features Joint development and demonstration events Deliberate matchmaking between complementors Communities for exchange Communities for exchange Technical pre-checks Lighthouse reference projects Joint projects with customers Communities for exchange Education through whitepapers, trainings, and workshops Self-application of the platform and solutions Demonstration events Lower entry barriers through <i>freemium</i> price models Lighthouse reference projects Self-application of the platform and solutions Implementation support Joint projects with customers Lower entry barriers through freemium price models [see Table 1 for enablers for the development of generic solutions]
	Realization of new business models	Traditional mindset of complementors and customers	Education through whitepapers, trainings, and workshops Communities for exchange

infrastructures, and the possibility to *integrate self-hosted applications*:

“From a technological perspective, one can say that we offer Connect on three platforms in parallel. This means that you have the infrastructure of AWS, Azure or Alibaba as a basis, to simply offer our customers worldwide scalability. A Connect application can [currently] be transferred quite easily to other infrastructures, which is especially interesting for companies operating in China or simply globally.” - PO C

“We have the possibility of integrating self-hosted applications into Connect as well. That is, the app can already be running anywhere and then use Connect services and data.” - PO E

The platform owner also works to reduce entry barriers by supporting the transfer of solutions through dedicated

*migration workshops* and offering a modular structure that allows for flexible combination of the underlying core platform services (*mix-and-match approach for core platform services*). However, even with these enablers, transferring existing solutions is not always feasible or attractive for complementors.

The primary manifestation of production leverage we found in our interview data and the complementors' main focus is the *development of customer-specific solutions* based on the increased efficiency from using the platform infrastructure instead of developing them from scratch. Complementors especially value the data-collection capabilities the platform offers, as well as the easy access to data and its visualization solutions.

“If I look back with regard to the solutions created on Connect, asking ‘Well, what of it is actually new?’, I realize that many applications could have also been implemented somehow without an IIoT platform.

**Table 3** Inhibitors and enablers of transaction leverage in digital industrial platform ecosystems

Leverage	Manifestations	Inhibitors	Enablers
Transaction	Access to new customers	Supplier restrictions	Re-branding of solutions
	Distribution of solutions	Lack of generic solutions	[see Table 1 for enablers for the development of generic solutions]
		Necessity for holistic and integrated solutions	Deliberate matchmaking between complementors and customers
		Deployment complexity	Implementation support
			Update and maintenance support
		Complexity of B2B sales and purchase processes	Order-processing support
		Necessity for consulting	Education through whitepapers, trainings, and workshops
		Supplier restrictions	Communities for exchange
		Data security and privacy concerns	Re-branding of solutions
			On-premise options
Cooperation with other actors		Regional disparities in legal requirements	Trust-building through industry experience and certifications
			Communities for exchange
		Lack of ecosystem transparency	Communities for exchange
			Deliberate matchmaking between complementors

Broadly speaking, I think that many solutions are just easier to realize with an IIoT platform and that's why they are implemented." - PO I

Complementor H, whose company offers an application for calibrating machines efficiently, added to this discussion. Fed by specific product information from the manufacturer's information systems, the company's algorithm automatically determines the appropriate settings and sends them to the PLC. As complementor H is not familiar with connecting machines and collecting data, the company relies on Connect:

"Connect can help us because we can scale much easier, because if we develop a product for a customer and this customer already uses Connect and the customers of our customer also rely on Connect, it is really easy to get the data available." - CO H

Although we also found inhibitors of this manifestation of production leverage, they are not particularly pronounced. While complementors mentioned a *lack of technical platform capabilities*, experts from the platform owner stated that this lack of technical capabilities was in some cases a deliberate governance decision to ensure security. Complementors also mentioned *missing complementor capabilities*, especially expertise in solution development, as hampering their production leverage of the platform. To address these inhibitors, the platform owner *deliberately matches complementors* with subsidiary capabilities, provides boundary resources like *software-development kits*

and *low code functionalities*, continually extends features considering the complementors' requirements, and initiates *joint development events*.

A third typical manifestation of production leverage in many platform ecosystems is the *development of generic solutions*. This manifestation of production leverage is currently the least frequent use of the Connect platform by far, as only a small number of generic apps have been developed on the platform, primarily because of the *uniqueness and complexity of the operational environment*. Typically, IIoT solutions analyze large amounts of data about industrial assets to monitor or optimize critical business processes, which results in high demand for reliability and requires adaptation to the peculiarities of the customer's application scenario. Therefore, transferring a solution developed for one customer to another is difficult, as an example from one of the interviewees illustrates:

"One use case we already developed on Connect was [...] a maintenance prediction for train doors [...]. The solution was realized with a customized application [...] In principle, the use case and application are transferable to other train operating companies as well, but the pattern recognition algorithm is proprietary which means the data access is different depending on the train manufacturer. This is the reason why we cannot provide a generic platform application, but only a manufacturer model-based or customized application." - CO L

The transferability of solutions across customers is also limited by countries' disparate legal and technical requirements.

As another significant obstacle, both the platform owner and the complementors stressed the current immaturity of the market (i.e., customers' limited experience with advanced IIoT applications). In combination with the *high up-front investment* needed for the development of an industrial application, the *adoption insecurity* in the nascent domain significantly impedes complementors' willingness to develop generic applications. *Project-based development of customer-specific solutions is often financially more profitable* for complementors.

"The financial investment for application development can be a six-digit amount, the lead time for a project is approximately 12 months. This leads to high risk and thus we develop an application only if we see that there's a real customer project." - CO D

"For a software partner, the individual solution business is more interesting, because he makes more revenue that way in the long term, than offering a scalable solution as a small firm in the ecosystem. That can change in the future, but at the moment, it's not profitable from a partner's perspective." - PO C

The platform owner addresses these inhibitors to the development of generic applications in several ways. First, to overcome the inhibitor of high up-front costs, the platform owner provides *venture capital* in some cases, especially to support smaller firms in the first steps of app development. Second, to address both the high development effort and the uniqueness of operational scenarios, the platform owner offers small, *standardized app building blocks* that can be reused across applications. Third, seeing that the incentive to develop applications without a specific customer's demand is low, the platform owner tries to bring together supply and demand through joint *development and demonstration events*, for example, in the form of hackathons. The interviewees mentioned several other approaches, shown in Table 1. Given the initial inhibitors to the development of generic solutions, the individual solutions that result from these efforts are seen as the basis for deriving generic solutions at a later stage:

"Of course, it's always in the interest of an app developer to develop a generic solution that can be sold as broadly as possible, meaning that it is scalable. [...] But we also know that we are not operating in a consumer environment [...] but in an industrial environment. [...] As a result of the requirements of the industrial domain, the project entry point is often an individual solution, and then later, there's a pivot to a generic solution." - PO H

The development of generic solutions is still at a nascent stage, so the measures taken by the platform owner, shown in Table 1, are only part of the plethora of ways to address the significant inhibitors of this type of leverage in digital industrial platform ecosystems.

#### 4.2 Innovation Leverage

Our interviews also revealed evidence of 2 manifestations of innovation leverage. Even though most of the complementors leverage the platform conservatively to create solutions, they offered examples for the *realization of innovative solutions* brought about by the engagement with the platform ecosystem that range from real-time inventory control to predictive maintenance to AI-based optimization of machine calibration. Most of these applications are domain-specific and many are customer-specific, for example, this solution developed by one of the complementors:

"The customer has test stations to test the aging behavior of batteries to analyze the impacts of different load profiles on the batteries. For this, the company needs to determine the state of health in a very accurate way. We use AI-based algorithms to analyze critical sequences in the load profile. The analysis process could be shortened from 80 minutes to under 1 minute with our application." - CO H

Our data also reveal inhibitors of innovation leverage in digital industrial platform ecosystems. While some complementors mentioned the *lack of technical platform capabilities* as an inhibitor of innovation, more significant inhibitors that the interviewees addressed were *complex technical and legal requirements* and a *lack of complementor collaboration*. However, the major impeding factor that both the complementors and the platform owner mentioned is the digital immaturity of the market and its customers, which is connected to *customers' aversion to risk and change* and their *difficulty in determining the added value of innovative platform-based solutions*. In addition, because of the *lack of generic solutions*, competition is reduced, reducing pressure to innovate.

To overcome these inhibitors, the platform owner uses, among other measures, *joint development and demonstration events*; educates the customers and complementors through *whitepapers, training, and workshops*; and stimulates interaction by fostering *communities for exchange* between complementors and customers. A key approach to overcoming customers' risk aversion and insecurity regarding innovative platform-based solutions is the *self-application of the platform and solutions* by the platform owner itself. As customers often have trouble assessing the value of a solution, the platform owner establishes trust by

showcasing how they can use the Connect platform in their own factories (*lighthouse reference projects*). Several more approaches mentioned by the experts are shown in Table 2.

“From a platform owner perspective, what’s important, is to push projects and lead by example. The principle “eat your own dog food” is always really, really good with regard to innovations. A company like Industry Inc. that uses Connect themselves in their factories and can show what they achieve by that. That helps. That definitely helps.” - PO C

Besides the development of innovative solutions in the narrower sense, *new business models*, a second manifestation of innovation leverage, are realized in only a few cases, mainly because the *complementors and customers* are “stuck” in *traditional mindsets*:

“The big barrier is the issue of value, and by that, I mean added value. Often, it’s not obvious to the companies what kind of added value is created by an IoT platform and an IoT solution. [...] It’s very obvious in the [PO country’s] mechanical engineering industry that machines are sold apiece. If you approach them like “just sell your machine as a service in the future”, they stare at you with wide eyes. That’s light years ahead.” - PO C

“From a technical point of view, many think that the concept of pay-per-use is very attractive, because I don’t pay anything when I’m not using the app. On the other hand, depending on the department, you will be met with resistance, because you can’t do budget planning with pay-per-use, because you don’t know what you should allocate for the next 12 months.” - PO B

Again, *education through whitepapers, trainings, and workshops* and *communities for exchange* were mentioned as enabling means to overcome the traditional mindset.

Our analysis of the interview data with regard to innovation leverage revealed differences in the importance representatives of the platform owner assigned to innovative solutions. Since market immaturity is a key inhibitor of innovation, some stressed the importance of innovative reference projects that showcase the platform’s capabilities, but others felt that a solution’s innovativeness is immaterial as long as it creates traffic on the platform. In addition, an interviewee from the platform-owner side opined that most of the offerings on the platform can be regarded as innovative simply because of the domain’s nascent status:

“We don’t need to be innovation leader, because we’re already way ahead of the average customer today. There’s this figure, where we mapped the

maturity level of most of our customers, like a maturity curve. And they’re all in the very early phases. So we don’t need to care about innovation, because we’re ahead of our customers anyway by, I’d say at least ten to fifteen years, with what we have today.” - PO G

#### 4.3 Transaction Leverage

We also found evidence of 3 manifestations of transaction leverage. Solutions offered on a platform are available to a large number of platform users, so complementors benefit from *access to new customers*, a manifestation of transaction leverage. About half of the complementors we interviewed stated that they had acquired new customers since joining Connect, but many customer firms have *supplier restrictions* that prevent them from purchasing apps from new and unfamiliar suppliers, a definite inhibitor of this manifestation of transaction leverage. To overcome this inhibitor, the platform owner sometimes distributes third-party solutions in its own name as white-label solutions (*rebranding of solutions*):

“We already had the concrete case that we developed an application on Connect and already had a specific customer, but in the end the customer said that they wanted to buy directly from Industry Inc. and not via the application store from us as another supplier.” - CO M

“We have the possibility of integrating self-hosted applications into Connect as well. [...] Sometimes we even white-label them and integrate them into Connect.” - PO E

A second manifestation of transaction leverage is the opportunity to *distribute solutions* directly via the platform. Although both complementors and the platform owner seek this manifestation of transaction leverage, it is also where both parties see the greatest challenge. The first inhibitor of this manifestation is the *lack of generic solutions*. The transactional character of platforms can be leveraged primarily by distributing a standardized offering to a large set of customers. However, in technically heterogeneous environments like the IIoT, the feasibility of standardized solutions and the subsequent benefit offered by a platform’s transactional support are significantly diminished (*deployment complexity*). In addition, single applications can often be part of a larger solution only in the context of smart factories, whereas customers want to avoid a patchwork of solutions (*necessity for holistic and integrated solutions*):

“The second difference [to consumer platforms] is, what I said before, that the [industrial] customer does



not have a single solution for a single problem. He doesn't want a single dashboard, but actually needs an interlinked number of solutions. An app solves a single problem. But what all these apps can't do is communicating with each other. [...] A business customer would never accept that. [...] That's something neither iOS nor Android need to care about. Those are basically nice standalone applications for a single, isolated problem. [...] That's something I might achieve in the B2B area with a few select applications maybe. But the bulk will be rather customized and connected, tailored to specific industries [...] and so on." - PO G

A second major impediment to the distribution of solutions on digital industrial platforms is the *complexity of sales and purchasing in a B2B environment*. In line with the high development costs and the significant effort required for implementing a solution at a customer's site, business customers with purchasing departments do not usually simply "click and buy" an application but conduct time-consuming processes that include a market analysis, invitations to tender, contract negotiations, and supplier selection. Several complementors also stressed the *necessity of consulting* in terms of integration into the customer's operations; *supplier restrictions* that limit customers' freedom of choice; *data security and privacy concerns*, which is why potential customers approach new solutions with caution; and *regional disparities in legal requirements*, which makes the transfer of a platform to other regions difficult. Both the platform owner and the complementors addressed these differences between B2C and B2B platforms in our interviews:

"We are quite critical of the current development of selling apps via a platform in the B2B sector because there is a huge difference to the B2B sector where a private customer is open to click and buy an application on the store. In the B2B sector, there is more consulting necessary. A typical customer will not buy the industrial application just via the store without any consulting." - CO M

"There simply are different processes in the background, commercially, legally, and technically. [...] If we sell something, we don't have to just convince a single person, but a whole company or the whole purchasing department [...]. If I see something on the Apple app store that I like, I decide on my own whether I'm going to buy it or not. Someone working for a company and seeing an app in the Connect store that he likes will hardly be the one signing for the payment. The whole process is just way more complex in B2B." - PO B

The platform owner tries to mitigate inhibitors of transaction in several ways. First, while the complexity of sales and purchasing in the B2B domain is an inhibitor of transaction leverage, transaction leverage is also affected when the marketplace does not support the underlying sales process. Initially, the Connect store simply functioned as a storefront that displayed applications, with the traditional bilateral sales process between customer and app provider in the background. As several interviewees mentioned, the platform owner is addressing this issue by doing more to support the underlying processes of *implementation, update and maintenance*, and *order processing* across the solution's life cycle:

"It's not just about a customer or partner seeing which solutions are available on Connect, but about processing of the order, deployment and support for these solutions also being handled via a technical platform. And that's what the marketplace is about. It's not just the store front-end of Connect, but everything in the background [...]. That is, not just the order, but also updates, maintenance, pricing, subscription- and usage-based models, that's all part of a marketplace." - PO B

In addition to creating built-in support for the underlying sales processes, measures that have been successful in production leverage and innovation leverage can be applied to transaction leverage (cf. Table 3). The platform owner can also support the distribution of apps by either *re-branding the solutions* to sell them with the respected name *Industry Inc.* or through marketing and functional checks (*trust-building through industry experience and certifications*):

"What we support actively is if someone says that they'd like to offer this app they developed via the Connect store as well. Then this app is tested by our marketing department and our development department in terms of functionality. The presentation and content are checked collaboratively, and we offer professional consulting. And then, we also provide our global network. This means, if the partner has an app, he knows exactly that with Industry Inc. he has this global visibility and access to a global distribution structure." - PO D

A third manifestation of transaction leverage occurs when complementors leverage the ecosystem by *cooperating with other actors* because the initiating partner lacks the capabilities or resources to realize a particular solution for a customer. For many firms, IIoT is a diverse and highly sophisticated option for which it is difficult to offer solutions on one's own, so companies welcome cooperation with third parties that can provide missing resources

and knowledge. The need for such cooperation also shows the technological complexity that is inherent in implementing solutions on digital industrial platforms:

“[...] we collaborated with [Complementor B] because of their core competencies in a specific connectivity solution for a smart city project. We bring connectivity hardware like sensors and gateways into the solution, [Complementor B] brings the connectivity technology with a focus on near-field-communication. In addition, we contribute our competencies in application development [...]” - CO N

In addition to compensating for missing capabilities, firms are also interested in aligning complementary offerings to increase customer demand, attract new customers, and retain existing customers. While many complementors, especially large firms, prefer to draw on their existing partner networks, rather than partners in the digital industrial platform's ecosystem, smaller firms tend to appreciate the opportunity to find partners within the ecosystem. Only a few interviewees stated that the ecosystem is not of interest at all, as they are interested only in the technical capabilities of the platform, they have all necessary competencies in house, and/or they already maintain a partner network. The remaining majority is at least open to future cooperation, albeit often in a passive position:

“Our focus is doing business - if we can provide a good solution, which meets the requirements of the customer, it does not really matter for us if we provide this with a joint solution or on our own.” - CO B

The complementors considered the main inhibitor of such cooperation within the ecosystem to be the *lack of ecosystem transparency*, as many of the complementors did not have a comprehensive view of other actors in the ecosystem and their capabilities. The platform owner tries to mitigate this issue by *deliberately matching complementors* and creating *communities for exchange* between ecosystem participants, supported by dedicated community managers. Fostering communities and exchange also supports the distribution of solutions, as communities and exchanges offer opportunities to discuss the value of a solution or best practice with regard to legal and other requirements.

## 5 Discussion

We discuss here how our insights help understand the role of leverage in the specific domain of digital industrial platform ecosystems. We also address research implications, highlighting to extend the logic of leverage to

emphasize more equally the architectural and ecosystem elements. In addition, we provide practical implications, stressing the need for platform and ecosystem thinking, relational governance mechanisms, and active ecosystem orchestration. We finalize the discussion with limitations and future research.

### 5.1 Leverage in Digital Industrial Platform Ecosystems

Our study of Industry Inc.'s Connect platform provides domain-specific insights for those who seek to launch digital industrial platforms, particularly platforms for cloud-based IIoT applications. We found manifestations of all 3 types of leverage – production, innovation, and transaction – with production leverage being the most prominent. We generally found significant, domain-specific inhibitors of all types of leverage and governance actions by the platform owner to mitigate them through enablers. In the following, we take a broader perspective and examine the most significant challenges faced by platform owners when establishing digital industrial platforms and complementors when engaging with these platforms. We will consider how the 3 types of leverage in digital industrial platform ecosystems may be affected by the technical and organizational complexity.

#### 5.1.1 Production Leverage in Digital Industrial Platform Ecosystems

In general, production leverage was most prominent in our case of a digital industrial platform, which benefits from the (re)use of assets, interfaces and standards for the development, production and delivery of goods and services. This is in line with the study of the digitization of ABB's process-automation platform by Sandberg et al. (2020) and their conclusion that this transition started mostly with production leverage. In terms of the manifestations of production leverage, we see a focus on porting existing solutions and developing customer-specific solutions, whereas the development of generic solutions is subject to several inhibitors. This difficulty of creating broadly applicable solutions clashes to some extent with platforms' purpose to “create value by facilitating transactions across large, generic markets” (Furr 2016, p. 1). Our findings indicate that developing and providing generic solutions is currently less feasible in digital industrial platform ecosystems, which deal with low market maturity, high complexity, and unique operational environments in the IIoT domain. In addition, high upfront investment in developing generic solutions and high levels of uncertainty about potential customers adopting these solutions may reduce incentives for complementors to develop generic solutions instead of specific customer projects. Such being

the case, the platform owner can, by supporting the development of customer-specific solutions, still leverage the ecosystem of complementors to address a heterogeneous market that could not otherwise be addressed (Ceccagnoli et al. 2012; Wareham et al. 2014), although complementors cannot yet exhaust the potential for additional customer bases efficiently.

### 5.1.2 Innovation Leverage in Digital Industrial Platform Ecosystems

For innovation leverage, which benefits from complementarities, components and extensions for the creation of new goods and services, we identified the manifestations of realizing innovative solutions and new business models. Innovation for digital platforms is often linked to generativity (Eck and Uebernickel 2016), which increases with the heterogeneity of the devices and actors involved in innovation (Yoo et al. 2010), so the generative potential of digital industrial platform ecosystems may in principle be high. However, as Eck and Uebernickel (2016) propose, generativity is a consequence of both a system's design and the actors' interaction with it over time. As a result, it depends heavily on the complementors' willingness and ability to build innovative solutions on the platform (Hurtt and Elie-Dit-Cosaque 2017). While our results indicate that this ability may be restricted by missing (technical) capabilities, a larger inhibiting factor can be found in the currently rather low market maturity. As many industrial customers are still at the beginning of their digitalization efforts, they may have difficulty assessing the value of solutions, especially innovative ones, so many complementors focus on conservative solutions at the beginning of their platform journeys (Sandberg et al. 2020). However, innovation leverage might also not be as critical for digital industrial platforms that target IIoT applications as it is in other B2B or B2C domains, at least not in the short term. For many B2C platforms – for example, mobile operating systems and devices as well as video game platforms – the variety of complements is a key factor in consumers' choice of platforms. For digital industrial platforms, however, Schermuly et al. (2019) found that customers are concerned primarily with their specific use cases' being realized on the platform, without necessarily looking left or right.

### 5.1.3 Transaction Leverage in Digital Industrial Platform Ecosystems

For transaction leverage, which benefits from market access and pricing mechanisms for the efficient buying and selling of goods and services, we identified manifestations related to the access to new customers, distribution of

solutions and cooperation between actors. However, even though these results demonstrate that complementors can use digital industrial platforms for more efficient transactions, they make use of this opportunity only to a limited extent. While most of the complementors we interviewed have benefited from access to a large customer base since joining the platform ecosystem, they still have difficulty fully leveraging this access. In examining the industrial company ABB, Sandberg et al. (2020) likewise observed that transaction leverage occurred late in ABB's transition to a (digital) platform ecosystem and even then only to a limited extent. As our results indicate, this limited use of transaction leverage may in part be due to the lack of generic solutions for digital industrial platforms in a context of high technological and organizational complexity.

Even if generic solutions can be developed, their distribution through the platform faces additional barriers arising from sales and purchasing in a B2B environment. Factors like product complexity and commercial uncertainty often result in a need for cross-functional decision-making that traditionally involves purchasing, finance, administration and engineering functions (Fisher 1970). "Traditional value chain inertia" in moving manufacturing toward digitalization can also play a role here and a move involves working with sales personnel who are accustomed to working in a certain way and may be unwilling or slow to change their ways (Sjödén et al. 2022, p. 59).

When transaction leverage has significant inhibitors, most interactions – even though related to the platform – take place more or less directly between the solution provider and the customer, following the traditional, hierarchically organized supply chains (Pauli et al. 2021). This dyadic approach has several implications for our understanding of digital industrial platform ecosystems. First, it suggests that network effects, where the value a provider can receive depends on reaching a critical mass of users (Shapiro and Varian 1999), may not be pronounced in this domain. This insight aligns with previous research on industrial platforms, which has also noted this phenomenon (Schermuly et al. 2019). Industrial platforms cannot scale as quickly and easily as other platforms can and may, therefore, have few or delayed same-side or cross-side network effects (Parker et al. 2016). Second, the typical model of platform ecosystems, which arranges peripheral actors around the core platform (as the facilitator of transactions and interactions), may have only limited applicability in digital industrial platform ecosystems, so platform owners may have trouble capturing value from transactions in the ecosystem. As a consequence, our insights confirm the suggestion by Hein et al. (2020) that more complex types of platform ecosystems may be difficult for prevailing models to analyze.

## 5.2 Implications for Research

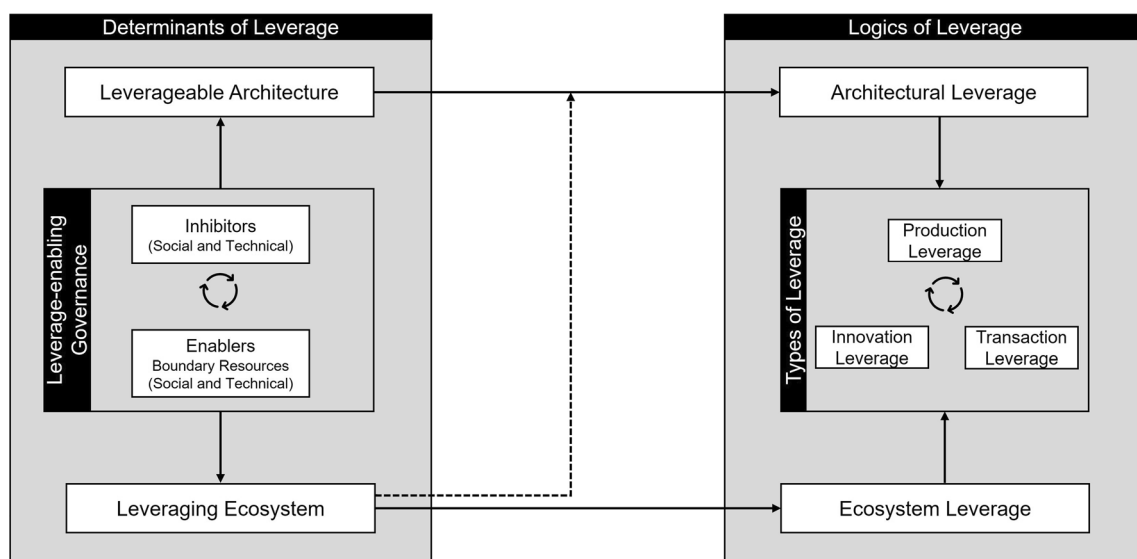
In addition to providing a contextualized assessment of leverage for the domain of digital industrial platforms, our results open up new perspectives on the concept of leverage in the context of platform ecosystems. (Thomas et al. (2014), p. 206) describe the development of “shared assets, designs, and standards” as the foundation of leverage in the context of platforms. To conceptualize *architectural leverage*, they relate the logic of leverage to the notion of architectural openness to explain how a *platform-as-ecosystem* welcomes different types of leverage within an open system. Despite acknowledging in their literature review that the *platform ecosystem* stream is the only stream of platform literature that addresses all 3 types of leverage, Thomas et al. (2014) focus on architecture as the main determinant of leverage, factoring out the ecosystem’s specific role to a large part. While the assessment of a platform’s modular and open architecture as the basis for leverage is supported by others (Chen et al. 2022b), the results of our study regarding manifestations, inhibitors and enablers of leverage encourage us to draw more attention to the importance of the ecosystem of complementors.

Therefore, as depicted in Fig. 1, we provide an integrated perspective that includes both architectural and ecosystem leverage. To illustrate the mechanics of leverage, our model draws the path from the determinants of leverage including the relevant inhibitors and enablers to the resulting meta-logics of leverage that ultimately fuel the 3 types of leverage. In addition, the 3 types of leverage influence each other as (lacking) manifestations of one type of leverage often act as enablers (or inhibitors) of another type. Most importantly, we emphasize the ecosystem

perspective, proposing to extend the notion of architectural leverage, as conceptualized by Thomas et al. (2014), in 2 ways. First, by stressing the importance of the *leveraging ecosystem* and its *leverage-enabling governance* through (purposefully orchestrated) complementor engagement for the realization of architectural leverage, and second, by introducing the meta-logic of *ecosystem leverage* based on value co-creation and coordination and influencing the 3 types of leverage.

### 5.2.1 Leveraging Ecosystem and Leverage-Enabling Governance

To illustrate our first extension of the logic of architectural leverage, we need to look at the prerequisites for leverage. In line with Thomas et al. (2014), the starting point and necessary precondition for leverage is what could be called a *leverageable architecture*, that is, an architecture that is sufficiently modular and open to allow for interactions with third parties through shared assets, designs, and standards. Such a many-to-many architecture creates the potential for complementors to benefit from it in various ways, as described by the 3 types of leverage. However, without complementors actually *leveraging* this potential, leverage itself will not manifest. Therefore, a leverageable architecture is necessary but not sufficient, as the potential for leverage provided by the architecture must be realized by a *leveraging ecosystem*, which requires third-party actors’ motivation and ability to interact with the platform and the surrounding ecosystem. This is of critical importance as in platforms the locus of value creation moves from inside the firm to outside (Parker et al. 2017) and complementors are autonomous actors acting purely out of self-interest and



**Fig. 1** An integrated perspective on architectural and ecosystem leverage



there can be much heterogeneity amongst them (Engert et al. 2022).

Moreover, the leverageable architecture as well as the leveraging ecosystem require a *leverage-enabling governance* with boundary resources as the primary instrument. The realization of a platform's potential for leverage can be subject to inhibitors, which may be in a large part domain-specific, as is the case in our study of IIoT and manufacturing. Therefore, (domain-specific) technical and social boundary resources as enablers can be a deliberate response to (domain-specific) inhibitors. This resonates with the broader literature on complementor engagement in platform ecosystems, where recent studies address the disjointed consideration of architecture and governance in facilitating complementor engagement (Saadatmand et al. 2019) and the importance of boundary resources in the support of complementors' engagement goals (Engert et al. 2022). In addition, one may also expect changes to the set of boundary resources when a new platform becomes more established and advanced, leading to a potentially diminishing importance of some inhibitors, including a lack of technical capabilities of the platform. This aligns with other studies on boundary resources that stress their dynamic nature along a platform's life cycle as they are adapted to the requirements of the surrounding ecosystem (Eaton et al. 2015; Hein et al. 2019b).

### 5.2.2 Ecosystem Leverage as Meta-Logic

Regarding our second extension of the logic of architectural leverage, we look at the logics of leverage. The platform literature, originating from engineering disciplines, connects architectural leverage to “platform thinking” (p. 209) benefiting from creating and sharing assets and systems, leading to concepts like production and innovation leverage (Thomas et al. 2014). As the literature on multi-sided markets emerged, transaction leverage became an advantage addressed by platforms, emphasizing the ecosystem's ability to connect actors on both supply and demand sides for efficiency gains. This ecosystem-focused view is increasingly prominent, as it not only reduces transaction costs but also fosters value co-creation between actors, an area less explored in leverage studies so far (Tian et al. 2021). The need to move beyond an architectural perspective is also highlighted by Nambisan (2018), who warns against overlooking the significance of actors' (inter)actions. Our findings highlight these interactions, presenting the ecosystem not merely as a means for realizing architectural leverage but as an important source of leverage in itself. This *ecosystem leverage* extends beyond the platform's transactional intermediary role, influencing all types of leverage, as illustrated by the inhibitors and enablers of production leverage and

innovation leverage that are tied to the lack of collaboration among complementors.

Architectural leverage and ecosystem leverage can both be seen as meta-logics that encompass and fuel all 3 types of leverage. Architectural leverage enables actors to build on the platform's modular and open, leverageable architecture and thus allows for economies of scale and scope for production and complementarities for innovation. The potential for third-party modules provides an important rationale behind the need for efficient transactions. Ecosystem leverage emanates from the leveraging ecosystem itself and allows for interactions between actors that offer the potential for various ways of value co-creation as actors join forces to increase efficiency and innovation in solution development. Naturally, interaction within the ecosystem also lays the foundation for transactions. The relevance of understanding 2 concurrent meta-logics of leverage is prominent in our case study, where they are perceived differently by the complementors and the platform owner. The complementors primarily focus on leveraging the platform in an architectural sense, often overlooking the opportunities for interaction with other actors in the ecosystem. While the platform owner emphasizes the importance of the ecosystem and its potential for creating manifestations of leverage in various ways, resulting in an increased focus on social boundary resources.

These insights both strengthen as well as initially answer the call for a move beyond considering an ecosystem's role in leverage from a market intermediary perspective to an organizational perspective, resembling what Chen et al. (2022a) refer to in regard to a platform and its actors as a *meta-organization*. Platform ecosystems as meta-organizations require coordination among multiple participants with aligned as well as competing interests posing many interesting and complex strategic challenges (Kretschmer et al. 2022). As Thomas et al. (2014) mention with regard to a potential limitation of their firm-level architectural leverage, there may be merit to such a complementary ecosystem-level, as an integrated perspective may uncover “the subtleties and complexities of [...] platform ecosystem literature[s], such as [...] the complexities of the interaction among modularity, standards, and complementors”.

### 5.3 Implications for Practice

Our research also has practical implications for digital industrial platform owners and complementors, stressing for complementors the need for platform and ecosystem thinking and for owners the use of relational governance mechanisms and the need to be active ecosystem orchestrators. First, complementors may need to advance their *platform and ecosystem thinking* to make sense of and



leverage the new opportunities provided by platform ecosystems as our results indicate that many complementors are still acting as suppliers of solutions to individual customers. Parker et al. (2016) stress that firms have to shift from pipeline thinking (linear value chain) to platform thinking with respect to how value is created and transferred. But doing so may be complicated as platform thinking requires complementors to make complex strategic decisions in a highly dynamic environment (Cenamor 2021). Our study confirms the difficulty industrial firms face with regard to “learning the new rules of platform ecosystem strategies” (Hanelt et al. 2020, p. 12).

Second, the owners of digital industrial platforms could be required to focus more on relational governance mechanisms – like exchange communities and development as well as demonstration events – to stimulate active complementor engagement in the ecosystem as a major enabler of all kinds of leverage. Contrary to what one may expect in a technologically complex domain like the IIoT, our study suggests that many of the inhibiting and enabling factors in our study are of a social or organizational nature, rather than a technical nature. This view is in line with Petrik and Herzwurm (2020a), who find that many technical boundary resources (for example, APIs and SDKs), cover only the basic needs and expectations of complementors, while social boundary resources like partner programs and dedicated events increase complementors’ engagement. However, whether these measures can create the desired impact in a B2B setting remains to be seen. Insights from the ERP domain show that standardized, ecosystem-wide governance mechanisms may fall short in light of heterogeneous customer demands (Huber et al. 2017). So platform owners may have to facilitate leverage and value creation by entering into customized, individual governance interactions with certain complementors and customers (Hein et al. 2019b; Engert et al. 2022).

Third, platform owners need to play an active role as ecosystem orchestrators (Fuller et al. 2019). They are well-advised to monitor complementors’ engagement with the platform (ecosystem) through, for example, dedicated community managers, to identify any significant inhibitors for leverage that may arise. Platform owners also need to evaluate how complementors leverage the platform as well as the surrounding ecosystem in view of their intended strategy or business model with regard to the platform. Depending on the platform’s role for the company’s business (e.g., a minor enhancement of their *physical* products’ functionality or a potential major future revenue stream), certain types and manifestations of leverage may be more beneficial than others. In addition, platform owners should be careful to not misjudge the nature of challenges in such a technologically complex domain. The platforms’ success eventually hinges not just on complementors’ and

customers’ ability to create and use offerings, but also on their willingness to do so. While this may be the case in many other domains as well, in potentially rather *conservative* industries like manufacturing this may require considerable effort in terms of conveying and demonstrating the value and opportunities of platform-based solutions to each actor.

#### 5.4 Limitations and Future Research

This study is subject to several limitations that should be noted. First, while our study took place over the course of one year, it captures only a snapshot in the life cycle of a digital industrial platform ecosystem. Therefore, some of our findings may be related to the platform’s life cycle phase at the time of our study. Second, we examined a digital platform established by an incumbent industrial company, so some of our insights, like the deployment of the platform in the owner’s own factories, may be limited to this kind of platform owner. Start-ups or (large) technology companies, which are also entering the industrial domain, might face different challenges and have other mitigation measures at their disposal. Third, our results provide domain-specific insights for incumbents who are launching digital industrial platforms, particularly integrated platforms based on cloud-based IIoT applications (Baumann et al. 2022), which are of particular interest to established industrial companies transforming to Industry 4.0. However, our findings may not be transferable to other digital platform settings in the industrial domain, including pure marketplaces for buying and selling industrial products.

Notwithstanding these limitations, this study provides valuable insights into the concept of leverage in digital platform ecosystems, especially in the industrial domain, and suggests key areas for further investigation. First, we witnessed that many inhibiting factors impede the development and distribution of generic applications in digital industrial platforms. This contradicts (to an extent) a central rationale behind platform business models (Furr 2016) and questioning the transferability of many established insights about digital platforms to the industrial domain. We call for further research into how insights about how leverage in digital platform ecosystems may vary across different types of technologies, platforms and industries.

Second, future research can examine the more general patterns of interrelationships and logical order between the different types of leverage and their specific manifestations in the industrial domain and beyond. For example, can we assume that production leverage is often a first step for complementor engagement in the industrial domain, followed by innovation leverage as complementors become increasingly familiar both with a platform’s capabilities

and the different ways they can benefit from engaging with it? Will production and innovation leverage necessarily precede transaction leverage when dealing with complex technologies (e.g., IIoT), especially when technological features for solution development provided by a platform appear more tangible for most complementors than potential benefits through cooperation in an ecosystem?

Third, considering the significance of a leveraging ecosystem and the role of leverage-enabling governance, we suggest a further examination of the literature on complementor engagement as a valuable source of insights for exploring leverage in platform ecosystems. This may also be useful for better understanding the role of technical vs. social boundary resources in relation to the inhibitors and enablers of architectural and ecosystem leverage. Specific attention should be paid to the heterogeneity of complementors, for example, differences in motivation and ability, including differences between large vs. small or traditional vs. new to the ecosystem or domain.

## 6 Conclusion

In this paper, we studied digital industrial platforms focusing on 3 types of leverage - production, innovation, and transaction leverage - and their manifestations, inhibitors and enablers. We conducted a case study in the context of IIoT and manufacturing. The results of our case study demonstrate that complementors can leverage digital industrial platform ecosystems in various ways through manifestations of the different types of leverage. However, the extent to which they can do so is affected by a variety of domain-specific inhibitors. Even though the platform owner employs a variety of enabling mechanisms through governance in the form of technical and social boundary resources, mitigating these inhibitors takes significant time and effort and may not always be successful. In addition, our findings enhance the understanding of the concept of architecture leverage (Thomas et al. 2014) for platform ecosystems by extending the ecosystem perspective. This sheds light on the leveraging ecosystem and leverage-enabling governance through (purposefully orchestrated) complementor engagement. It also stresses the role of the ecosystem itself and the actors' interactions for ecosystem leverage as a meta-logic based on coordination and value co-creation.

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