How Industry Incumbents Establish Internet of Things Platforms for Value Cocreation: Insights into Platform Governance, Growth, and Capabilities

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Papers

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List of Abbreviations

5G	Fifth generation technology standard for broadband cellular networks
API	Application programming interface
B2B	Business-to-business
B2C	Business-to-consumer
CRM	Customer relationship management
DC	Dynamic capability
DCV	Dynamic capability view
E2E	End-to-end
ERP	Enterprise resource planning
HICSS	Hawaii International Conference on System Sciences
IaaS	Infrastructure as a service
ICIS	International Conference on Information Systems
ICT	Information and communication technology
IIoT	Industrial internet of things
IoT	Internet of things
IP	Intellectual property
IS	Information systems
IT	Information technology
KBV	Knowledge-based view
LPN	Low power network
MES	Manufacturing execution system
MISQE	MIS Quarterly Executive
NB	Narrowband
OTT	Over-the-top
PaaS	Platform as a service

PO	Platform owner
RBV	Resource-based view
RQ	Research question
SaaS	Software as a service
S-D logic	Service-dominant logic
SDK	Software development kit
VHB	German Academic Association for Business Research
WI	International Conference on Wirtschaftsinformatik

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Abstract

The uprise of the internet of things (IoT) has stimulated both digital platform natives and industry incumbents to compete for IoT platform leadership. While digital natives, such as Microsoft, Google, or Amazon denote experienced and well-studied platform owners, industry incumbents, such as IBM, General Electric, and AT&T have to learn how to extend their established pipeline businesses with IoT platforms. As socio-technical systems, IoT platforms offer industry incumbents the unique opportunity to profit from value cocreation, i.e., the joint development of products and services with third parties. While scholars have studied multiple mature digital platforms, research on platform establishment and industry incumbents' capabilities to foster value cocreation is scarce. Thus, this thesis asks: *How can industry incumbents successfully establish IoT platforms for value cocreation?*

Drawing on case study research, three pillars answer this overarching research question. Pillar one examines platform governance to understand what strategies support the value cocreation process and how they address specific challenges in enterprise IoT. Pillar two deals with the challenge of platform growth in the establishment phase. On the one hand, third parties' decisions to join IoT platforms are studied. On the other hand, two modes that foster early platform growth are proposed. Pillar three explores how industry incumbents develop platform capabilities in form of organizational routines and how they aid their business transformations to run both pipelines and platforms.

Overall, the results of this dissertation contribute to platform research and its successful establishment from a value cocreation perspective. In that, they extend prior findings on platform governance, growth, and capabilities. While the results are insightful for all stakeholders of complex platforms, such as IoT platforms, they particularly address industry incumbents and the shift in their role, and the capabilities needed to actively foster value cocreation. Thus, managers can act upon the recommendations presented in this thesis when establishing their IoT platforms. However, future research is needed to find additional success factors to thrive for IoT platform leadership.

Keywords: IoT platforms, platform establishment, value cocreation, industry incumbents, platform governance, platform growth, platform capabilities.

Kurzfassung

Der Aufschwung des Internets der Dinge (IoT) hat sowohl native Plattformunternehmen als auch Industrieunternehmen zu Anwärtern für die IoT-Plattformführerschaft erhoben. Während Plattformunternehmen wie Microsoft, Google oder Amazon gut erprobt sind, müssen Industrieunternehmen wie IBM, General Electric und AT&T erst lernen, wie sie ihre traditionellen Wertschöpfungsketten mit IoT-Plattformen erweitern können. Als soziotechnische Systeme bieten IoT-Plattformen den Industrieunternehmen die einzigartige Möglichkeit, von der Value Cocreation zu profitieren, d.h. von der gemeinsamen Entwicklung von Produkten und Dienstleistungen mit Drittanbietern. Während Forscher eine Vielzahl reifer digitaler Plattformen untersucht haben, gibt es nur wenige Erkenntnisse zur Etablierung neuer Plattformgeschäfte und zu den Fähigkeiten, die Industrieunternehmen aufbauen müssen, um die Value Cocreation zu fördern. Daher fragt diese Arbeit: *Wie können Industrieunternehmen IoT-Plattformen erfolgreich für die Value Cocreation etablieren?*

Anhand von Fallstudien wird diese übergreifende Forschungsfrage in drei Säulen beantwortet. Säule eins untersucht die Plattform-Governance, um zu verstehen, welche Strategien die Value Cocreation unterstützen und wie sie spezifische Herausforderungen im Enterprise IoT adressieren. Säule zwei beschäftigt sich mit der Herausforderung des Plattformwachstums in der Etablierungsphase. Einerseits werden die Entscheidungen von Drittanbietern, sich IoT-Plattformen anzuschließen, untersucht. Andererseits werden zwei Modi vorgeschlagen, die das frühe Wachstum der Plattformen fördern. Säule drei erforscht, wie die Industrieunternehmen Plattformfähigkeiten in Form von organisatorischen Routinen entwickeln und wie sie ihre Geschäftstransformationen unterstützen, um sowohl Wertschöpfungsketten als auch Plattformen zu betreiben.

Insgesamt tragen die Ergebnisse dieser Dissertation zur Plattformforschung und ihrer erfolgreichen Etablierung aus der Perspektive der Value Cocreation bei. Dabei erweitern sie frühere Erkenntnisse zu den Themen Governance, Wachstum und Fähigkeiten. Während die Ergebnisse für alle Stakeholder komplexer Plattformen relevant sind, werden insbesondere Industrieunternehmen adressiert. Manager können sich an den Handlungsempfehlungen dieser Arbeit beim Aufbau ihrer IoT-Plattformen orientieren. Zukünftige Forschung ist jedoch notwendig, um zusätzliche Erfolgsfaktoren zu bestimmen.

Stichworte: IoT-Plattformen, Plattform-Etablierung, Value Cocreation, Industrieunternehmen, Plattform-Governance, Plattform-Wachstum, Plattform-Fähigkeiten.

Part A – Summary of the Dissertation

1 Introduction

This section stresses the motivation for studying the establishment of internet of things platforms (1.1), derives the research gaps, questions, and goals that have guided the five paper projects (1.2), and details the structure of the dissertation (1.3).

1.1 Motivation

The uprise of the internet of things (IoT) has stimulated both digital platform natives, such as Microsoft (Azure IoT) or Amazon (Amazon Web Services IoT), and industry incumbents, such as IBM (Watson IoT), AT&T (Control Center), or Siemens (Mind-Sphere), to compete for IoT platform leadership (Marheine, 2020). This battle continues to heat up according to recent market analysis, identifying more than 600 IoT platform offerings worldwide (Lueth, 2019). While IoT offers platform natives the opportunity to enter new markets and increase their power (e.g., Google entered the smart thermostat market), industry incumbents are presented a unique opportunity to extend their business models and value creation logic through IoT platforms (Wortmann & Flüchter, 2015).

Traditionally, industry incumbents conduct pipelines businesses, that is, the purchasing, manufacturing, selling, and maintaining of products and services (Porter, 1985). They "create value by controlling a linear series of activities" (Van Alstyne, Parker, & Paul Choudary, 2016, p. 4). In contrast, IoT platforms, as socio-technical systems, provide generic functions in device, connectivity, data, and application management, connecting physical things with information systems as well as consumers with producers (i.e., third parties) (Marheine & Pauli, 2020). IoT platforms leverage autonomous third parties that develop hardware- (e.g., sensor) and software-based (e.g., applications) solutions, which increase the platform value and, in effect, increase the number of users, a phenomenon known as "network effects" (Katz & Shapiro, 1986). This form of platform-based value creation is referred to as "value cocreation" (Kohli & Grover, 2008; Sarker, Sarker, Sahaym, & Bjørn-Andersen, 2012). To sum up, while pipeline businesses generate value through the volume of products and services sold by a single company, platforms create value through use or size of the network, cocreating or exchanging products and services (Cusumano, Gawer, & Yoffie, 2019; Van Alstyne et al., 2016).

Despite the opposing value creation logic, organizations can operate both pipelines and platform businesses. To seize this opportunity and benefit from value cocreation, industry incumbents can leverage their classic advantages when establishing IoT platforms, such as existing customer relationships, resources, installed base, or knowledge (Leijon,

Svenheden, & Svahn, 2017; Macmillan & Selden, 2008). Yet, despite their strengths vis-à-vis platform natives, little research has reported on industry incumbents' platform establishment journeys (Pauli, Fielt, & Matzner, 2021). For example, Siemens operates a classic pipeline business with multiple product value propositions in domains, such as industrial automation or rail mobility. With MindSphere, Siemens has established an IoT platform business, connecting third parties to its customers. Siemens can use the IoT platform to streamline its internal product portfolio, on the one hand, and leverage external value cocreation on the other hand. This way, Siemens can extend its product business (e.g., controllers) through internally and externally created IoT solutions, such as predictive maintenance (Marheine & Pauli, 2020; Petrik & Herzwurm, 2019b).

However, these business transformations from pipelines to platforms pose challenges to industry incumbents (Van Alstyne et al., 2016). Besides understanding the new value creation logic, industry incumbents, as platform owners, must foster value cocreation to benefit from network effects (Ceccagnoli, Forman, Huang, & Wu, 2012; Karhu & Ritala, 2020; McIntyre & Srinivasan, 2017). To do so, platform owners require new capabilities to foster value cocreation, such as in information technology (IT) (Rai, Pavlou, Im, & Du, 2012), modular design (Schilling, 2000), and partner management (Huber, Kude, & Dibbern, 2017). While the overall aim of the thesis is to explore *how industry incumbents can successfully establish IoT platforms for value cocreation*, this dissertation focuses on three key themes: platform governance, growth, and capabilities. First, it anchors on *platform governance*, as rules that dictate third parties' value creation opportunities (Tiwana, 2014) in enterprise IoT contexts (e.g., manufacturing) (Jayashree & Selvakumar, 2020). Second, it addresses the *platform growth* challenge in the establishment phase (Stummer, Kundisch, & Decker, 2018) in terms of platform adoption and third-party innovation (Cusumano et al., 2019). Third, it scrutinizes the *platform capabilities*, as industry incumbents' internal capabilities, to achieve this goal (Sandebrg, Holmstrom, & Lyytinen, 2020; Svahn, Mathiassen, & Lindgren, 2017). Figure 1 shows this tripartite focus.

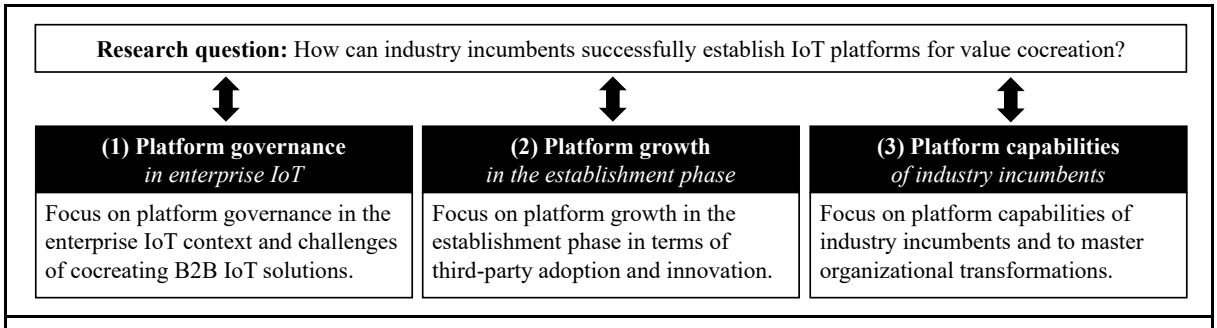


Figure 1: Focus of the Dissertation

1.2 Research Gaps, Questions, and Goals

Although information systems (IS) research has studied how digital platforms can be organized for value cocreation (e.g., Ceccagnoli et al., 2012; Lusch & Nambisan, 2015; Sarker et al., 2012), scholars have called for more contextualization to derive valuable results for both research and practice (Hong, Chan, Thong, Chasalow, & Dhillon, 2014). For example, De Reuver et al. ask for "theories on digital platform architectures that are contextualized based on a deep understanding of the domain in which they are embedded" (2018, p. 128), and Pauli et al. call for analyzing "the differences between industrial incumbents and native platform firms" (2021, p. 185). As depicted in Figure 1, the thesis contributes to these calls, focusing on embedding the three major themes to foster value cocreation in the context of enterprise IoT, the establishment phase, and the capabilities of industry incumbents. The next sections will outline the research gaps, questions, and goals, that are derived from this dissertation's overarching research question (RQ): *How can industry incumbents successfully establish IoT platforms for value cocreation?*

(1) Platform governance. First, much scholarly work studies platform governance in business-to-consumer (B2C) platforms, such as Apple's App Store (Eaton, Elaluf-Calderwood, Sørensen, & Yoo, 2015), Mozilla's Firefox browser (Tiwana, 2015b), or Sony's PlayStation (Cennamo & Santaló, 2019). Platform governance includes platform owner's decisions on platform openness (e.g., Boudreau, 2010, 2017), market entries (e.g., Foerderer, Kude, Mithas, & Heinzl, 2018; Karhu & Ritala, 2020), boundary resources (e.g., Ghazawneh & Henfridsson, 2013; Karhu, Gustafsson, & Lyytinen, 2018), and pricing (e.g., Economides & Katsamakas, 2006; Eisenmann, Parker, & Van Alstyne, 2006). In contrast, research on business-to-business (B2B) platforms is sparse with exceptions in enterprise software (e.g., Huber et al., 2017; Wareham, Fox, & Cano Giner, 2014) and initial studies in the IoT context (e.g., Hein, Weking, et al., 2019; Marheine & Pauli, 2020). The latter empirical studies indicate that not all findings from B2C platforms are generalizable to B2B platforms due to inherent differences (Hein, Weking, et al., 2019; Sarker et al., 2012). In particular, IoT platforms connect not only consumers and third parties, but a wide range of industrial devices. These devices must be compatible with the platform in the sense of sending and receiving data to add value. In addition, IoT platforms link various third-party organizations (e.g., sensor manufacturers) and industries (e.g., heavy equipment) with customers that require end-to-end solutions (Marheine, Pauli, Marx, Back, & Matzner, 2021; Pauli et al., 2021). Pauli et al. (2021) divide the factors of complexity into architectural (e.g., heterogeneity of devices) and organizational dimensions (e.g., lengthy sales processes) that both are impeding value

cocreation. Thus, this thesis seeks to study platform governance in enterprise IoT to explore the differences in value cocreation (Pauli et al., 2021). In that, I intend to contribute to scholarly calls for more research on platform governance and how they can address value cocreation challenges in IoT (Hein, Weking, et al., 2019; Hodapp, Hawlitschek, & Kramer, 2019). Hence, RQ1 asks:

RQ1: *What platform governance strategies are effective in enterprise IoT?*

The aim of answering RQ1 is to understand different platform governance strategies and to explain how industry incumbents can apply (or instantiate) them and why they may or may not aid to overcome IoT-specific value cocreation challenges. In that, we seek to contribute knowledge, in the form of frameworks, that help incumbent managers to organize or design their IoT platforms for value cocreation. While we acknowledge that a "framework is less rigorous than a model" as it often does not specify the relationships between theoretical constructs (Teece, 2007, p. 1320), it allows for the freedom to explore new concepts and relationships. First, an initial framework is expected that reviews relevant governance strategies in the literature on digital platforms, qualitatively testing their use in IoT platforms through multiple cases. Second, building on this knowledge, an in-depth analysis of IoT value cocreation challenges and platform governance to overcome them is aspired, for which an in-depth, single case study is suitable.

(2) Platform growth. Second, platform growth economically refers to the growth of the network of platform users, which confers through the demand and supply of its products and services (Hagiu & Wright, 2015; Stummer et al., 2018). Despite our knowledge of mature platforms (Cusumano et al., 2019; Eaton et al., 2015; Gawer & Henderson, 2007; Ghazawneh & Henfridsson, 2013), we know little about "how" to foster early growth in platforms (Ofe & Sandberg, 2019; Saarikko, Jonsson, & Burström, 2019)—especially in complex platforms, such as in IoT (Pauli et al., 2021). In fact, scholars show that the establishment phase (i.e., the early growth phase of platforms) is the most difficult phase of a platform's life cycle (Edelman, 2015; Evans & Schmalensee, 2010; Pidun, Reeves, & Wesselink, 2021). As a consequence, only 15% of launched platforms and their ecosystems survive (Pidun, Reeves, & Schüssler, 2020). Yet, successful platform establishment can set the course for a dominant market offering and is thus of great relevance (Tiwana, 2014; Tiwana, Konsynski, & Bush, 2010). IoT platforms, a new empirical phenomenon, lend well to exploring how to establish early value cocreation. In particular, platform growth in the establishment phase may require new forms of value cocreation to address the heterogeneity of third-party providers and the complexity of the value creation task. Currently, our body of knowledge lacks in-depth insights into the

governance associated with establishing IoT platforms and achieving early growth in third-party solutions through innovation leverage (Thomas, Autio, & Gann, 2014). I thus ask:

RQ2: *How can platform growth be fostered during the establishment phase?*

The aspired results of RQ2 are twofold. On the one hand, I seek to test and explore motivational factors that drive third parties' decisions to join an IoT platform. In that, the differences in motivations based on the different types of third parties are of interest. In IoT, third parties' value propositions vary on a spectrum from physical (e.g., sensors) to digital solutions (e.g., applications) (Fleisch, Weinberger, & Wortmann, 2015). These findings may help platform owners to foster third-party platform adoption. On the other hand, I aim at understanding how the value cocreation process can be designed to foster early IoT platform growth. A preliminary model with a focus on third-party innovation shall provide guidance.

(3) Platform capabilities. Third, past literature has largely studied native platform owners and their governance decisions to drive value cocreation and third-party innovation (e.g., Foerderer et al., 2018; Gawer & Cusumano, 2002; Tan, Pan, Xianghua, & Huang, 2015). These studies have analyzed how platform natives navigated through their competitive business landscapes (De Reuver et al., 2018; Saarikko et al., 2019). Prominent examples of platform leaders include Microsoft (Casadesus-Masanell & Yoffie, 2007), Intel (Gawer & Cusumano, 2002; Perrons, 2009), SAP (Ceccagnoli et al., 2012), Apple (Ghazawneh & Henfridsson, 2013), or Amazon (F. Zhu & Liu, 2018). Yet, few scholars have studied how non-platform natives, such as industry incumbents, extended their pipelines through platforms (cf. Khanagha, Ansari, Paroutis, & Oviedo, 2020; Svahn et al., 2017). As industry incumbents have spent decades on improving their internal operations and supply chains for efficiency gains, they require new capabilities to build and manage IoT platforms for value cocreation (Teece, 2017; Van Alstyne et al., 2016). In particular, their organizational processes and routines—which are referred to as "platform capabilities"—are little explored (Hanelt, Nischak, Markus, Hodapp, & Schneider, 2020). Hence, the thesis focuses on exploring what organizational routines aid industry incumbents in their journeys from pipelines to platforms; it asks:

RQ3: *How can platform capabilities be developed by industry incumbents?*

To answer RQ3, we must understand the organizational processes and routines that have aided industry incumbents' internal transformations and extensions of business models. With a focus on organizational capabilities in dynamic environments, such as IoT

platforms, the dynamic capabilities view of the firm provides a fruitful lens to address RQ3 (Teece, 2007; Teece, Pisano, & Shuen, 1997). By drawing on multiple case studies, we seek to provide a framework that contributes to research on both IoT platforms and dynamic capabilities. Ideally, the framework presents organizational routines that were developed by different industry incumbents and provides explanations as to how they affect IoT platform establishment. In that, the framework could guide industry incumbents in navigating through the competitive IoT platform business landscape.

In light of the issues outlined above, Figure 2 summarizes the three research pillars that guide this dissertation, presenting its research gaps, questions, and goals for each pillar. Overall, the results shall contribute descriptive, explanatory, and prescriptive knowledge to guide industry incumbent managers in establishing IoT platforms (Gregor, 2006). Moreover, this dissertation contributes to scholarly calls for more contextualization on digital and IoT platforms (De Reuver et al., 2018; Pauli et al., 2021). To do so, the thesis rests and builds on the body of knowledge on digital platforms (e.g., Constantinides, Henfridsson, & Parker, 2018; De Reuver et al., 2018)—viewing IoT platforms as a sub-phenomenon of digital platforms—and value cocreation (e.g., Hein, Weking, et al., 2019; Lusch & Nambisan, 2015; Rai et al., 2012) and acknowledges recent works of scholars that have contributed to related questions on how to successfully build digital platforms as well as IoT platforms (e.g., Hodapp, 2020; Schreieck, 2019).

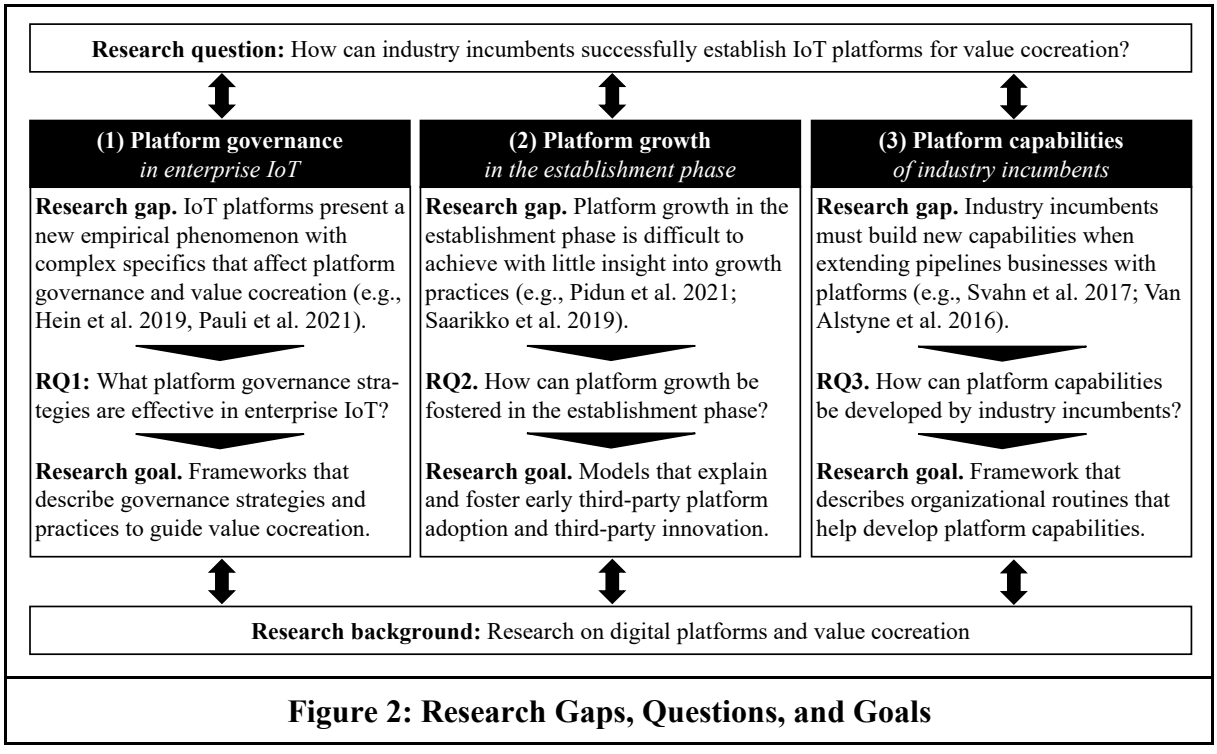


Figure 2: Research Gaps, Questions, and Goals

1.3 Structure

This cumulative dissertation consists of two main parts: the research summary (Part A) and the five papers of this cumulative dissertation (Part B) as depicted in Figure 3.

Part A. Part A summarizes the dissertation, emphasizing the relevance of IoT platforms including the introduction (Section 1), research background (Section 2), research design (Section 3), an overview of results (Section 4), and discussion (Section 5). Section 2 briefly synthesizes the conceptual foundations of IoT platforms (i.e., IoT, digital platforms, and ecosystems) and organizes research on value cocreation in IoT platforms with a focus on the three themes platform governance, growth, and capabilities. Section 3 describes the research design detailing the research epistemology, strategy, and methods. Section 4 summarizes the five papers and demonstrates how they contribute to the three RQs. Finally, Section 5 concludes the thesis by discussing the main contributions to research and practice and describing its limitations and future research opportunities.

Part B. Part B contains the five papers that address the research questions expressed in Section 1.2 and their respective research focus. Each research question is addressed by one or two papers. First, with regards to RQ1 and platform governance, *Paper A* begins with a systematic literature review of governance strategies and demonstrates based on a multiple case study that the dominant meta-strategy in the enterprise IoT environment is cooperation, as opposed to organizing IoT platforms as competitive communities. Building upon this finding, *Paper B* explores the IoT value cocreation challenges of a single industry incumbent in-depth when cocreating IoT solutions with both third parties and customers and offers insights into how to overcome them. Considering RQ2 and the specific challenge of platform growth in the establishment phase, *Paper C* qualitatively tests the factors that led third parties to join an IoT platform. Constituting the only study that focuses on third parties as units of analysis, we propose insights gained into the third-party decision-making that are valuable to IoT platform owners, as they can design or adjust their incentive systems accordingly. *Paper D* elaborates on how and why IoT platform growth in the establishment phase becomes a challenge and proposes a preliminary model to grow platforms by moving back and forth between end-to-end IoT solutions (that are strongly desired by customers) and generic IoT solution components (that serve broad usage regardless of the industry). RQ3 with an emphasis on platform capabilities of industry incumbents is addressed by *Paper E* which examines the organizational routines and processes that three industry incumbents have developed when establishing their IoT platforms. The study focuses on the relationship between dynamic

capabilities (and their instantiations through microfoundations) and the successful establishment of IoT platforms, providing revelatory insights into "how" industry incumbents can build platform capabilities when establishing an IoT platform business.

Figure 3 summarizes the structure of this dissertation showing Part A and B. Within Part B, it shows the three research pillars and questions, as well as the matching of each paper to one of the three pillars. However, it can already be said here that perfect matches are unrealistic, as this dissertation is "cumulative" and has thus evolved. Nevertheless, as previously described, Figure 3 shall also make clear that the findings related to each pillar and research question build upon each other and thus have informed each other sequentially. In addition, the articles presented in Figure 3 include information on the title, outlet (e.g., ICIS), and publication status (i.e., published or accepted). Moreover, all papers in Part B have been reformatted for reasons of consistency throughout the thesis, including the presentation of tables, figures, and references. Furthermore, I use "short titles" for the chapter headings of the papers in Part B (to make them fit into the thesis). Short titles and other bibliographic metadata (e.g., title, authors) precede the chapters on each paper.

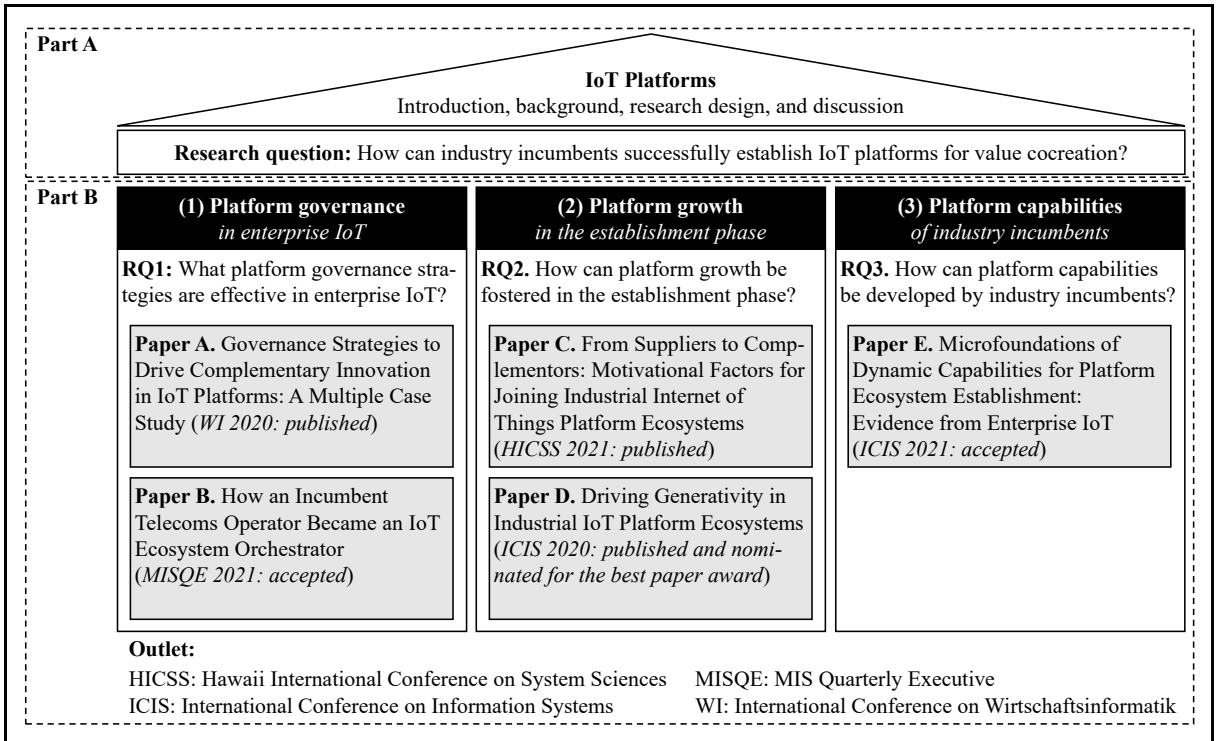


Figure 3: Structure of the Dissertation

2 Research Background

This section introduces the conceptual background of IoT platforms, using the concepts of IoT, digital platforms, and ecosystems (2.1). Then, value cocreation is presented and emphasized as the focal concept for successful platform establishment (2.2). Here, work on platform governance, growth, and capabilities, which industry incumbents require to establish IoT platforms, is presented, as this dissertation contributes to this discourse. A description of all key concepts can be found in the glossary (see Table 27).

2.1 Internet of Things Platforms

Backed by current research, this dissertation views IoT platforms as a sub-phenomenon of digital platforms with a focus on IoT (Marheine, 2020; Marheine & Pauli, 2020; Pauli et al., 2021; Pauli, Marx, & Matzner, 2020; Schermuly, Schreieck, Wiesche, & Krcmar, 2019). *IoT platforms* are socio-technical systems that comprise a central, extendable software base that can be complemented by an ecosystem of third-party organizations (Marheine & Pauli, 2020; Pauli et al., 2021; Tiwana et al., 2010). As a socio-technical system (Bostrom & Heinen, 1977; K. Kapoor et al., 2021), the technical view on IoT platforms is represented through the IoT (as the networking of physical and digital things) and the digital platform (as the core IT system to manage digital resources) (Hein, Böhm, & Krcmar, 2018; Noura, Atiquzzaman, & Gaedke, 2019). The social view on IoT platforms is reflected by the ecosystem—a group of organizations that cocreate value (Adner, 2017; Jacobides, Cennamo, & Gawer, 2018; Marheine & Pauli, 2020). Figure 4 shows the three major concepts behind IoT platforms and some of the key references that detail the individual concepts. The next sections review the literature on the concepts and present definitions that are again summarized in the glossary of this dissertation (see Table 27).

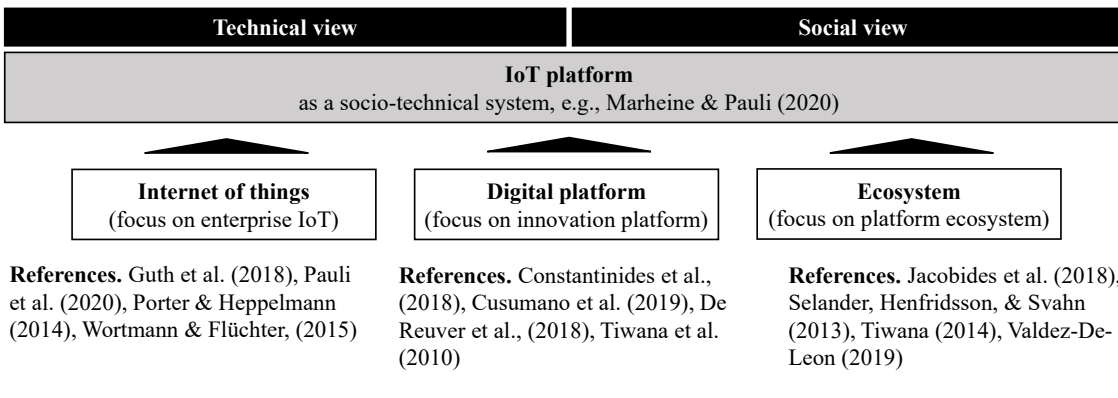


Figure 4: Key Concepts of IoT Platforms

2.1.1 Internet of Things

At its core, the *IoT*, a novel computing paradigm, links physical and digital things with the internet (Guth et al., 2018; Wortmann & Flüchter, 2015). Although the term IoT has been created by Ashton in 1999 in the context of radio-frequency identification technology (Gokhale, Bhat, & Bhat, 2018), it has only recently gained ground due to technical advances in microprocessors, connectivity, memory, and cloud computing (Wortmann & Flüchter, 2015). These advances enable the digitization of products, decoupling their functions from their physical nature (Yoo, Boland, Lyytinen, & Majchrzak, 2012; Yoo, Henfridsson, & Lyytinen, 2010). IoT arms physical devices with sensing, communication, and computing capabilities (Fleisch et al., 2015). These devices are often called "smart products" (Beverungen, Kundisch, & Wünderlich, 2021; Porter & Heppelmann, 2014). Smart products enable their owners to establish new business models, that comply with a service logic, generating recurring revenue streams (Fleisch et al., 2015; Wortmann, Bilgeri, Gebauer, Lamprecht, & Fleisch, 2019).

The term *IoT solution* is used as an umbrella term for all smart products and their digital, data-, or IoT-based services (Yoo et al., 2012). Thus, IoT solutions refer to the physical products and digital services that interface with the IoT platform and leverage its value for users (Marheine, Gruber, & Back, 2019; Marheine & Pauli, 2020). IoT solutions reflect the real value of the IoT with three main goals: *revenue growth* (as digital services can generate new revenue streams), *cost reduction* (as data access can reduce operational costs), and *regulatory compliance* (as data access achieves transparency) (Jayashree & Selvakumar, 2020; Marheine et al., 2019). To attain IoT solutions technically, scholars have put forth the IoT technology stack, that involves four layers, namely, the device, connectivity, platform, and application layer (Guth et al., 2018; Porter & Heppelmann, 2014; Wortmann & Flüchter, 2015; Yoo et al., 2010).

A brief example shows the business and technical potential of an IoT solution. Typically, first aid kits in buildings need to be inspected and replaced regularly. Few firms comply with this requirement and risk violating regulations and the lives of employees. To solve this issue, Flawa AG has created a modular first aid kit called Flawa iQ[1]. The smart first aid kit and its physical modules (e.g., patches) equipped with pressure sensors (device) are connected via Narrowband (NB) IoT (connectivity) to the cloud-based IoT platform (platform) to store, process, analyze, and visualize data (application), guiding its business operations and profiting from different subscription-based service offerings.

[1] https://www.flawa-iq.ch/

The term *enterprise IoT* includes all B2B domains in IoT (Jayashree & Selvakumar, 2020; Marheine et al., 2019) and is ascribed the largest growth rate with industries, such as manufacturing, agriculture, logistics, healthcare, or energy (Atzori, Iera, & Morabito, 2010; Boyes, Hallaq, Cunningham, & Watson, 2018; Jayashree & Selvakumar, 2020; Wortmann & Flüchter, 2015). Even though this thesis and other works use the terms enterprise IoT and industrial IoT (IIoT) interchangeably (e.g., Jayashree & Selvakumar, 2020; Marheine et al., 2019; Petrik & Herzwurm, 2019a), some scholars use the term IIoT to exclusively refer to the smart manufacturing context (e.g., Pauli et al., 2020; Sisinni, Saifullah, Han, Jennehag, & Gidlund, 2018). In contrast to consumer IoT, enterprise IoT solutions have a few particularities. First, enterprise IoT solutions refer to connecting industrial assets, such as machines in manufacturing or tractors in agriculture, as opposed to refrigerators or fitness watches in consumer IoT. The devices must be retrofitted and made compatible with the IoT platform to collect, analyze, and process data, fueling digital services (Fleisch et al., 2015; Marheine & Pauli, 2020; Püschel, Röglinger, & Schlott, 2016). Second, enterprise IoT solutions are often developed end-to-end, involving multiple organizations that bundle their key competencies. Organizations' value propositions range from hardware- to software-oriented offerings, including companies, such as device manufacturers, system integrators, and software developers (Marheine et al., 2021; Petrik & Herzwurm, 2020). The enterprise IoT thus offers an unprecedented environment for studying inter-firm relationships through constellations that span both value creation and industry borders (Porter & Heppelmann, 2014). Third, customers of enterprise IoT solutions have huge security requirements with little fault tolerance (Jayashree & Selvakumar, 2020). Enterprise IoT solutions must be interoperable within the shop floor and compatible with legacy IT systems, such as enterprise resource planning (ERP), manufacturing execution (MES), or customer relationship management (CRM) systems (Jayashree & Selvakumar, 2020), partly reducing the applicability of standard solution components which shall be made accessible through IoT platforms (Marheine & Pauli, 2020). However, IoT platforms can be mainly defined through digital platforms (Pauli et al., 2021), which are detailed in the next section.

Concept	Description and key references
IoT	The linking of physical and digital things with the internet (Guth et al., 2018; Wortmann & Flüchter, 2015).
IoT solution	The physical products and digital services that interface with the IoT platform and leverage its value for users (Marheine et al., 2019; Marheine & Pauli, 2020).
Enterprise IoT	The B2B domains in IoT (Jayashree & Selvakumar, 2020; Marheine et al., 2019).

Table 1: Description of Key IoT Concepts

2.1.2 Digital Platforms

Over the last years, the understanding of platforms has developed from internal product platforms, such as auto bodies, which are expandable through physical modules such as engines (Wilhelm, 1997) to external platforms, such as supply-chain platforms and industry platforms (Gawer, 2014). These external platforms have paved the way for digital platforms. In academia, many terms are used interchangeably to refer to a digital platform, including computer platforms (Bresnahan & Greenstein, 1999), IT platforms (Fichman, 2004), technology platforms (Wareham et al., 2014), or software platforms (Saarikko et al., 2019). Digital platforms have been of interest across multiple research disciplines, such as strategy and management, economics, IS, engineering, and others with different understandings as reported in extensive literature reviews (Constantinides et al., 2018; De Reuver et al., 2018; Thomas et al., 2014). For a detailed description of platform terms and the history, the works of Gawer (2014) and Thomas et al. (2014) are recommended. In this dissertation, *digital platforms* are thus broadly defined as "digital resources—including services and content—that enable value-creating interactions between external producers and consumers" (Constantinides et al., 2018, p. 381). This broad definition is in line with our notion of IoT platforms as a sub-phenomenon.

Today, scholars distinguish two types of digital platforms: transaction and innovation platforms (Cusumano et al., 2019). *Transaction platforms* are matchmakers between supply and demand, facilitating the exchange of data, goods, and services (Cusumano et al., 2019). Transaction platforms represent two- or multi-sided markets (Hagiu, 2006; Hagiu & Wright, 2015; Weyl, 2010). Their value grows as the number of users and transactions increases—yielding network effects (Economides & Katsamakas, 2006; Eisenmann et al., 2006; Eisenmann, Parker, & Van Alstyne, 2011). Network effects reinforce platform growth (Schilling, 2009; Weyl, 2010). Examples include online marketplaces, such as Alibaba, that bring together buyers and sellers or social networks, such as Instagram, that connect influencers with consumers.

In contrast, *innovation platforms*, the closer relative to IoT platforms, are built upon a core product, referring to "the extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it, and the interfaces through which they interoperate" (Tiwana et al., 2010, p. 675). They drive value and network effects through growth in the number of third-party solutions. Innovation platforms often refer to operating systems, such as Siemens's MindSphere (Petrik & Herzwurm, 2019a) Microsoft's Windows (Economides & Katsamakas, 2006), Apple's iOS (Eaton et al., 2015), or Sony's PlayStation (Cennamo, Ozalp, & Kretschmer, 2018).

Innovation platforms consist of three technical elements: the core, boundary resources, and modules (Karhu & Ritala, 2020). The *core* is owned and controlled by the platform owner and represents the actual platform (Tiwana et al., 2010). *Boundary resources* are interfacing digital resources, like application programming interfaces (APIs) or software development kits (SDKs) that let third parties create complementary value (Ghazawneh & Henfridsson, 2013). *Modules* refer to the software-based products or services capable of extending the platform's functionality (Baldwin & Woodard, 2008). For example, Siemens controls MindSphere (core), provides a low-code development environment (boundary resources), and profits from third-party IoT solutions or solution components to, e.g., reduce unplanned machine downtime (module)—thus increasing value.

In addition, digital platforms evolve (Tiwana et al., 2010), as depicted in the platform life cycle (Teece, 2017; Tiwana, 2014). Scholars highlight four phases: birth, expansion, leadership, and renewal (Teece, 2017). *Birth* describes the launch of a platform and the value proposition its digital resources provide. *Expansion* refers to the early platform growth in terms of organizations' platform adoption and innovation. *Leadership* is about keeping users engaged and defending against rivals. *Renewal* addresses the survival of the platform business and reinventing or extending its key value proposition (Isckia, De Reuver, & Lescop, 2020; Pidun et al., 2021; Teece, 2017). In this thesis, we refer to the first two phases—birth and expansion—as platform establishment. *Platform establishment* can be defined as the actions of an organization to launch a platform, establish an ecosystem, and foster value cocreation (Lusch & Nambisan, 2015; Saarikko et al., 2019). This view is consistent with recent IS studies that emphasize value cocreation between organizations in the ecosystem as a key factor for successful platform establishment (e.g., Hein, Weking, et al., 2019; Ofe & Sandberg, 2019; Saarikko et al., 2019; Svahn et al., 2017). Next, the ecosystem concept is defined.

Key concept	Description and key references
Digital platform	The "digital resources—including services and content—that enable value-creating interactions between external producers and consumers" (Constantinides et al., 2018, p. 381).
Innovation platform	The "extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it, and the interfaces through which they interoperate" (Tiwana et al., 2010, p. 675).
Platform establishment	The actions of an organization to launch a platform, establish an ecosystem, and foster value cocreation (Lusch & Nambisan, 2015; Saarikko et al., 2019).

Table 2: Description of Key Digital Platform Concepts

2.1.3 Ecosystems

IS scholars strongly agree that IT in general and digital platforms in particular increase singular and multi-firm performance (Adner & Kapoor, 2010; Kim, Shin, Kim, & Lee, 2011; Ravichandran, 2018; Wang, Zhao, Chi, & Li, 2017). Digital platforms lay the technical foundation for numerous organizations to interact in a shared environment—the ecosystem (Huber et al., 2017; Sarker et al., 2012). Hence, ecosystems often emerge around digital platforms (Jacobides et al., 2018; Selander, Henfridsson, & Svahn, 2013; Tiwana, 2015b; Valdez-De-Leon, 2019). This thesis defines *ecosystems* as a group of organizations, including the platform owner, third parties, and customers, that cocreate value on a platform (Jacobides et al., 2018; Wareham et al., 2014).

Moore (1993, 1996) has transferred the concept of ecosystems from biology to business, referring to an interdependent, interacting organizational group (Adner, 2017; Jacobides et al., 2018). Similar to habitats of living organisms, such as animals and plants, and the non-living environment, such as water or sand, business ecosystems refer to the organizations' interactions in competitive environments of scarce resources (Moore, 1993; Msiska & Nielsen, 2018). Also, ecosystems (and third parties) differ from supply chains (and suppliers) in that "customers can choose among the components (or elements of offering) that are supplied by each participant" (Jacobides et al., 2018, p. 2261).

In their literature review, Jacobides, Cennamo, and Gawer (2018) identify three separate types of ecosystems: business, innovation, and platform ecosystems. First, *business ecosystems* are coined as a "community of organizations, institutions, and individuals that impact the enterprise and the enterprise's customers and supplies" (Teece, 2007, p. 1325). In this research stream, scholars focus on value-creating interactions that are often coordinated by a central firm (Iansiti & Levien, 2004; Jacobides et al., 2018; Nambisan & Sawhney, 2011). *Innovation ecosystems* refer to "collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution" (Adner, 2006, p. 98). Here, scholars research how firms organize innovation activities through cooperation with suppliers (upstream) and third parties (downstream) (Jacobides et al., 2018). *Platform ecosystems* differ from innovation ecosystems in that they focus "on a specific class of technologies—platforms—and the interdependence between platform [owners] and their [third parties]" (Jacobides et al., 2018, p. 2257). The above definition of "ecosystems" as a foundational concept for IoT platforms makes the most conceptual use of platform ecosystems (in terms of conceptual clarity). They drive the value creation and innovation process between various organizations as "actors" in the ecosystem (Isckia et al., 2020; Sandberg, Holmström, & Lyytinen, 2019).

Ecosystems comprise three major groups of actors: platform owners, third parties, and customers (Eisenmann, Parker, & Van Alstyne, 2009; Hein et al., 2020). *Platform owners* establish the digital platform and control its resources (Tiwana, 2015a). They "are increasingly organizing ecosystems to foster innovation by diverse outsiders" (Tiwana, 2015a, p. 266). In addition, this thesis emphasizes industry incumbents as a special type of platform owner as they must master their internal transformations when establishing IoT platforms (Selander et al., 2013; Tian, Vanderstraeten, Matthyssens, & Shen, 2021). This dissertation defines an *industry incumbent* as a large organization with an established pipeline business that has demonstrated industry success through existing value propositions, customer relationships, resources, and knowledge (Macmillan & Selden, 2008; Van Alstyne et al., 2016). Second, *third parties* (or complementors) are the external organizations that leverage the platform to develop and sell third-party solutions (or complements) (Huang, Ceccagnoli, Forman, & Wu, 2013; Marheine & Pauli, 2020). In IoT, third parties can be device providers, system integrators, data analytics providers, or consultancies as long as their product or service extends the platform's modular functions (Marheine et al., 2021; Petrik & Herzwurm, 2020). Third, *customers* use the platform and its modules (Boudreau & Lakhani, 2009; Parker, Van Alstyne, & Jiang, 2017). For example, the German automaker Volkswagen licenses Siemens's MindSphere for various industrial automation use cases and benefits from new technology, constant innovation, individual configuration of modular services, and equipment effectiveness. Table 3 describes the key concepts.

Taken together, this dissertation views an IoT platform as the technical artifact and the social playing field for organizations to cocreate value (Hein, Weking, et al., 2019; Jacobides et al., 2018). The next section focuses on defining value cocreation and reviewing research on fostering it, as the concept represents the key determinant of platform establishment.

Concept	Description and key references
Ecosystem	A group of organizations, including the platform owner, third parties, and customers, that cocreate value on a platform (Jacobides et al., 2018; Wareham et al., 2014).
Platform owner	An organization that establishes and controls a platform (Tiwana, 2015a).
Industry incumbent	A large organization with an established pipeline business that has demonstrated industry success through existing value propositions, customer relationships, resources, and knowledge (Macmillan & Selden, 2008; Van Alstyne et al., 2016).
Third-party	An organization that utilizes the platform to develop and sell products and services compatible with the platform (Gawer, 2014; Huang et al., 2013).
Customer	An organization that uses the platform and its modules (Boudreau & Lakhani, 2009).

Table 3: Description of Key Ecosystem Concepts

2.2 Value Cocreation on Internet of Things Platforms

The concept of value cocreation extends the notion of value creation (Kohli & Grover, 2008; Sarker et al., 2012). Value creation denotes the creation of an output based on an input, covering value systems such as supply chains (Kumar & van Dissel, 1996; Porter, 1985; Zirpoli & Caputo, 2002). Value cocreation refers to the collaborative activities of organizations in which resources, capabilities, and relationships are brought together to generate value, which could not have been generated alone (Grover & Kohli, 2012). This process "is greatly enabled by platforms that provide infrastructure for new value creation and distribution" (Grover & Kohli, 2012, p. 229). "Platforms are viewed as a means to foster actor engagement, combining dispersed resources for value co-creation" (Beverungen et al., 2021, p. 510). Thus, the dissertation defines *value cocreation* as the process and activities of integrating resources into the IoT platform by the organizations affiliated with it (Ceccagnoli et al., 2012; Lusch & Nambisan, 2015; Rai et al., 2012). Both customer and third-party organizations can combine resources of the IoT platform, provided by the platform owner, and create new value on top of the IoT platform. Even though value can take different forms and shapes (Hitt & Brynjolfsson, 1996), this thesis equates *value* with IoT solutions, such as smart products or applications, that are interoperable with and can be operated through the IoT platform (Noura et al., 2019; Tiwana et al., 2010). Hence, the value depicted in Figure 5 can vary from devices (e.g., EnOcean's multi-sensor), to connectivity (e.g., Ericsson's network technologies), to analytics tools (e.g., Microsoft's Azure IoT Edge toolkit), to applications (e.g., Siemens's Asset Performance Monitoring). Although value cocreation raises the issue of capturing an adequate share (Bharadwaj, El Sawy, Pavlou, & Venkatraman, 2013; Morgan, Feller, & Finnegan, 2013; Saraf, Langdon, & Gosain, 2007), this thesis focuses on the platform owners' actions to foster the value cocreation process, which can be assigned to the three pillars of this dissertation, namely, platform governance, growth, and capabilities.

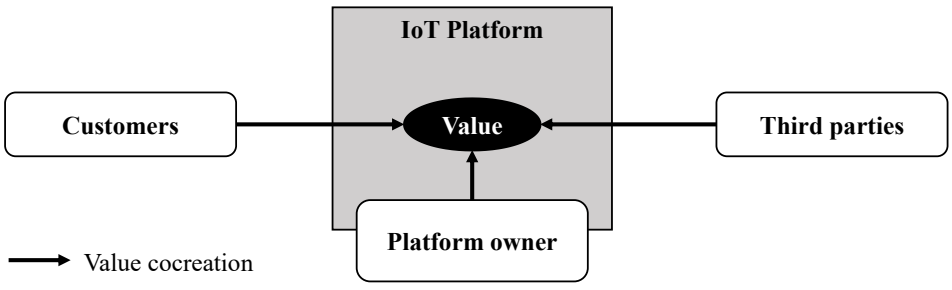


Figure 5: Value Cocreation on IoT Platforms

2.2.1 Platform Governance

To foster value cocreation, scholars study platform governance as its general guardrails (e.g., Foerderer, 2020; Karhu et al., 2018; Tiwana, 2015a). Platform governance extends the concept of IT governance (Sambamurthy & Zmud, 1999, e.g., 2000; Schwarz & Hirschheim, 2003), referring "to the patterns of authority for key IT activities in business firms, including IT infrastructure, IT use, and project management" (Sambamurthy & Zmud, 1999, p. 261). While IT governance emphasizes the rules, policies, and structures of managing the IT function in organizations (Brown, 1997; Schwarz & Hirschheim, 2003), platform governance expands this internal view to an external one involving third parties (Tiwana, Konsynski, & Venkatraman, 2013). Therefore, platform governance determines the relationship and interactions between the platform owner and the third parties (Grover & Kohli, 2012; Tiwana et al., 2010). *Platform governance* thus refers to the rules and mechanisms employed by the platform owner that prescribe the value cocreation opportunities of third parties (Ghazawneh & Henfridsson, 2010; Tiwana, 2015a; Tiwana et al., 2010). The term *mechanism* can be defined as "design actions […] to facilitate structured and unstructured interactions between technology users and technology providers" (Nambisan, Agarwal, & Tanniru, 1999, p. 369). Following Nambisan et al. (1999), governance mechanisms refer to the "structural arrangement", such as contractual agreements (R. Kapoor, 2013), or partner managers (Saraf et al., 2007), and "specific activities", such as training or workshops (Huber et al., 2017).

In line with the socio-technical view on IoT platforms, platform governance can be split into architectural and relational governance (Foerderer, Kude, Schuetz, & Heinzl, 2014; Grover & Kohli, 2012; Tiwana, 2014). *Architectural governance* centers around the platform's technical properties and is thus shaped by its modular design, possibilities to interface with the platform, and evolutionary trajectory (Tiwana et al., 2010). According to the IS and management literature, architectural governance involves decisions about the platform's degree of openness (Boudreau, 2010, 2012), expandability of the platform core (Tiwana et al., 2010; Yoo et al., 2010), and boundary resources (Ghazawneh & Henfridsson, 2013; Karhu et al., 2018). *Relational governance* focuses on the social interactions between platform owners and third parties (Poppo & Zenger, 2002; Wang et al., 2017; Q. Zhong & Sun, 2020). Studies on relationship-oriented governance have focused on alliances and partner management (Ceccagnoli et al., 2012; Huang et al., 2013) knowledge exchange (Foerderer, Kude, Schuetz, & Heinzl, 2019; Morgan et al., 2013), and co-opetition (Gnyawali & Park, 2011; Mantena & Saha, 2012).

2.2.2 Platform Growth

Successful platform establishment requires early platform growth. Platform growth aims at attaining critical mass (Evans & Schmalensee, 2010) and network effects (Eisenmann et al., 2006, 2011), which are fueled by growth in the number of user organizations and third-party solutions (and their quality) (Gawer & Cusumano, 2002; Hagiu & Wright, 2015; Van Alstyne et al., 2016). Hence, this thesis defines *platform growth* as the rapid growth of the IoT platform through third-party platform adoption and innovation (Gawer & Cusumano, 2002, 2008; Parker & Van Alstyne, 2008).

First, *platform adoption* requires "a firm's decision to join an IIoT platform ecosystem as becoming part of a group of firms (i.e., [third parties]) that focus parts of their business activities on developing and commercializing technical artifacts associated and compatible with the platform as the core technology" (Marheine et al., 2021, p. 5955). Besides the incentives that can be provided by platform owners to foster organizations' joining decisions, scholars stress the chicken-or-egg problem (Caillaud & Jullien, 2003; Stummer et al., 2018). The problem deals with making better use of indirect network effects during platform establishment—attracting customers first or third parties. While research on consumer platforms has studied pricing mechanisms of subsidizing either the supply- or the demand-side (Eisenmann et al., 2006; Lin, Li, & Whinston, 2011), IoT platforms price both sides and thus do not offer much guidance (Marheine, 2020). Thus, scholars have studied other mechanisms platform owners can leverage to increase platform adoption, such as access to customers (e.g., Ceccagnoli et al., 2012; Huang et al., 2013), boundary resources (e.g., Karhu & Ritala, 2020; J. Zhong & Nieminen, 2015), or knowledge (e.g., Foerderer et al., 2019; Weiss, Wiesche, Schreieck, & Krcmar, 2020).

Second, *third-party innovation* refers to the outcome of value cocreation in form of IoT solutions developed by third parties. Other outcome-oriented terms that are used interchangeably in this thesis are "generativity" (Marheine & Pauli, 2020) or "complementary innovation" (Marheine, 2020). To foster third-party innovation, platform owners apply governance mechanisms. However, the complexity of the enterprise IoT context (e.g., heterogeneity of devices that must interface) (Pauli et al., 2021) and the difficulty of fully managing the value cocreation process via the platform (e.g., each third-party organization must be managed as a partner) (Huber et al., 2017) requires new approaches to taking the initial hurdle in growing from few resources to many combinable resources that are still valuable for specific domains (Hein, Weking, et al., 2019; Marheine & Pauli, 2020). Thus, platform owners must actively drive value cocreation with customers

and third parties in IoT (Eaton et al., 2015; Ghazawneh & Henfridsson, 2013; Huber et al., 2017).

2.2.3 Platform Capabilities

To establish IoT platforms, industry incumbents not only need a superb understanding of platform governance and platform growth, but need to embrace change (Sebastian et al., 2017; Van Alstyne et al., 2016). To embark on their transformations when establishing IoT platforms, industry incumbents require new, requisite capabilities (Karimi & Walter, 2015; Leijon et al., 2017; Svahn et al., 2017). Platform capabilities can either refer to the platform's capabilities, for example, in data storage and processing (Bonte et al., 2017; Tilson, Lyytinen, & Sørensen, 2010; Yoo et al., 2010), or to the organizational capabilities in establishing and managing platforms and their constituting ecosystems (Grover & Kohli, 2012; Schreieck, Wiesche, & Krcmar, 2021). This thesis follows the latter notion and refers to *platform capabilities* as an organization's internal capabilities to extend a pipeline business with a platform business (Svahn et al., 2017; Teece, 2017; Van Alstyne et al., 2016). The capability building can include: developing new analytics capabilities (Gunther Gust, Philipp Ströhle, Christoph M. Flath, Dirk Neumann, & Tobias Brandt, 2017), orchestrating resources developed internally (by business units) and externally (by third parties) (Linde, Sjödin, Parida, & Wincent, 2021), internalizing the activities, knowledge, or feedback from the ecosystem (Teece, 2017), and adopting innovation routines (Svahn et al., 2017).

In particular, the dynamic capabilities view (DCV) represents a relevant concept to study platform capabilities (Teece, 2007, 2017). Dynamic capabilities refer to a "firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments" (Teece et al., 1997, p. 516). IoT platforms change rapidly and thus require managers to proactively determine the development of their IoT platforms. Since dynamic capabilities represent a rather abstract concept, Teece (2007) offers the concept of "microfoundations" to instantiate dynamic capabilities as organizational routines and processes. However, few scholars have analyzed "how" industry incumbents developed microfoundations, leaving much room for contribution to this research stream (Beverungen et al., 2021; Leijon et al., 2017; Selander et al., 2013; Svahn et al., 2017; Van Alstyne et al., 2016).

Taking the three key themes together, this thesis builds on prior IS and management research in that industry incumbents need guidance to install platform governance, foster

platform growth, and develop platform capabilities to successfully establish their IoT platforms for value cocreation.

3 Research Design

This section shows the research design of the dissertation. It details the guiding research epistemology and chosen research strategy (3.1) and explains the two research methods applied to answer the RQs (3.2).

3.1 Research Epistemology and Strategy

To study IoT platform establishment, this dissertation draws on *soft positivism* in terms of research philosophy, following the approach of multiple IS scholars (e.g., Dawson, Watson, & Boudreau, 2010; Kirsch, 2004; Ravishankar, Pan, & Leidner, 2011). The soft positivism approach (Madill, Jordan, & Shirley, 2000) allows to explore a "preexisting, objective phenomenon (consistent with the positivist view [that assumes that reality is objective and measurable]) while also uncovering potentially relevant, new constructs (consistent with the interpretive view [that accepts reality to be subjective to individual observers and influenced by their experiences and context])" (Dawson et al., 2010, p. 155; Lee, 1991; Myers, 1997b; Orlikowski & Baroudi, 1991). Since the phenomenon studied in this dissertation (i.e., value cocreation on IoT platforms) is objectively studied in digital platforms, but "understudied" in IoT, the soft positivist approach helps to describe, explain, and further explore this new empirical phenomenon. Even though (soft) positivist research epistemology is often used in quantitative studies to test theory, it can also be applied to qualitative research (Benbasat, Goldstein, & Mead, 1987) and is often used in IS research (Chen & Hirschheim, 2004) and in particular in case studies (Dubé & Paré, 2003). In this dissertation, I assume that IoT platforms and their value cocreation dynamics can be objectively described and explained, drawing on existing research and theoretical lenses (Dubé & Paré, 2003; Lee, 1989). However, I also assume that IoT platform establishment—as a new socio-technical phenomenon—might not be covered exhaustively by existing theory (Carroll & Swatman, 2000; Sarker, Xiao, & Beaulieu, 2013) and should thus be studied holistically and in its context. Hence, I seek to explore the emergence of new concepts and differences in value cocreation based on primary data in the manner of interpretivism (Eisenhardt, 1989; Goldkuhl, 2012; Orlikowski & Baroudi, 1991). As a consequence, soft positivism is an appropriate research approach (or view on reality) to scrutinize IoT platforms from a value cocreation (or establishment) perspective as it allows for the required flexibility in research.

As an attempt to contribute to the reality of value cocreation on IoT platforms, this thesis draws on a *qualitative research strategy*. To answer the overarching "how" RQ (how IoT platforms can be successfully established for value cocreation?) qualitative research methods are applied (Myers, 1997b; Yin, 2014). Qualitative research, in particular, helps scholars to create a deep understanding of phenomena in context (Recker, 2013). Other scholars define *context* as "situational opportunities and constraints that affect the occurrence and meaning of organizational behavior as well as functional relationships between variables" (Johns, 2006, p. 386). This thesis emphasizes the enterprise IoT with its industrial complexity as an important contextual factor. Such context allows generating insights into new socio-technical phenomena, that is, phenomena associated with IT, individuals, and organizations and their relationships. This context is therefore not suitable for relying purely on numerical measurements, as the goal is to explore these relationships and interactions holistically and in-depth (Hong et al., 2014; Myers, 1997b; Stebbins, 2001). Thus, both IS and organizational research value contextualization vital for qualitative research (Lee, 1989; Walsham, 1995). Researchers can attain these deep insights through different research methods, such as case study research (e.g., Benbasat et al., 1987; Dubé & Paré, 2003; Eisenhardt, 1989), action research (e.g., Baskerville & Myers, 2004; Baskerville & Wood-Harper, 1996, 1998), or ethnography (e.g., Baskerville & Myers, 2015; Myers, 1997a; Schultze, 2000). In contrast to quantitative research, which focuses on collecting numerical data and testing relationships between independent and dependent variables, qualitative research has a broader scope of data inquiry—leveraging deep insights (Myers, 1997b). *Data collection* in qualitative research relies heavily on textual data (Recker, 2013). The findings of this dissertation rest on 60 semi-structured interviews (see Table 28) and additional data from websites, documents, and informal discussions with practitioners. Qualitative *data analysis* involves coding to create meaningful information of textual data. Coding is the dominant data analysis technique, assigning "labels as units of meaning to pieces or chunks of data collected—words, phrases, paragraphs, or entire documents" (Recker, 2013, p. 92). Hence, coding already includes an interpretation of the data. In general, the three major coding strategies are *open* (i.e., identify concepts), *axial* (i.e., organize concepts in categories or causal relationships), and *selective* (i.e., determine central categories or concepts that relate to others) coding (Corbin & Strauss, 2014; Recker, 2013). All of the coding strategies mentioned have been applied in the papers of this dissertation where more detailed descriptions are found.

3.2 Applied Research Methods

Two research methods are applied in this dissertation: literature reviews and case study research. Five papers address the three RQs. First, Paper A and B aim to answer RQ1 (*what platform governance strategies are effective in enterprise IoT?*). Second, Paper C and D address RQ2 (*how can platform growth be fostered in the establishment phase?*). Third, Paper E responds to RQ3 (*how can platform capabilities be developed by industry incumbents?*). This section explains the methodological choice and reflects how the research methods helped to answer the RQs.

To answer RQ1, a *systematic literature review* was conducted in Paper A. The goal of this study is to review the literature on platform governance strategies that are applied to organize various digital platforms (e.g., Constantinides et al., 2018; De Reuver et al., 2018; Thomas et al., 2014). Literature reviews are typically applied in every study, as every research should be embedded in a research discourse to contribute to our body of knowledge. Yet, systematic reviews are typically more extensive and in some cases allow the researcher to deduce new insights by informing a research topic through combining different research streams or concepts (Webster & Watson, 2002). "Systematic reviews have gained momentum in IS research for offering an explicitly scripted and reproducible review process" (vom Brocke et al., 2015, p. 208). They are thus of great relevance to complex phenomena, such as digital platforms studied by academics across many disciplines (Okoli & Schabram, 2010; Recker, 2013; Webster & Watson, 2002). Among the dominant research disciplines are IS, strategy and management, economics, and engineering (Gawer, 2014). The systematic literature review in *Paper A* reviews research on digital platforms. The goal of this literature review was to understand what platform governance strategies exist and to summarize their positive and negative effects on value cocreation and third-party innovation. Papers were collected based on the search string: ("digital platform") AND ("governance" OR "cooperation" OR "competition" OR "innovation"). The three-step paper selection process focused on the *outlet* (i.e., focus on journals in the AIS Senior Scholars' Basket and journals ranked A or A+ in VHB[2] Jourqual 3), *unit of analysis* (i.e., focus on platform owner perspective), and *topic* (i.e., focus on platform governance) (Marheine, 2020). The final sample included 72 papers that were analyzed in a concept-centric approach, as various concepts or governance mechanisms could be assigned to the strategies (Webster & Watson, 2002).

[2] The complete list of the German Academic Association for Business Research (VHB) Jourqual 3.0 ranking can be found here: https://vhbonline.org/vhb4you/vhb-jourqual/vhb-jourqual-3/gesamtliste.

In addition, all papers—including Paper A—draw on *case study research* with different designs (see Table 4). A case study represents "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-world context" (Yin, 2014, p. 16). This method is particularly appropriate to IS research which has shifted from purely technical to rather organizational issues in which organizational behavior, design, and context matter (Benbasat et al., 1987; Hong et al., 2014). Case studies can be used both for explanatory (or theory testing) (Dubé & Paré, 2003) and for exploratory (or theory building) purposes (Eisenhardt, 1989). To fully address RQ1, RQ2, and RQ3, we set out to acquire insights into industry incumbents' behaviors, processes, and actions regarding their IoT platform establishment journeys as platform owners. While the next paragraph provides an overview of the case designs, detailed descriptions and explanations can be found in the individual articles.

In particular, *Paper A* presents a multiple case study of four industry incumbents, headquartered in the industry nation Germany, to test what platform governance strategies were applied by them and how. *Paper B* conducts a revelatory single case study of an industry incumbent with a retrospective of five years. Their statements regarding value cocreation were triangulated based on interviews with managers from third-party and customer organizations. "Data triangulation refers to perusing, and relating, multiple sources of evidence about a particular phenomenon or topic. Through triangulation of data, researchers can gain a more nuanced picture of the situation, and increase reliability and validity of their findings" (Recker, 2013, p. 91). *Paper C* tests three factors to join an IoT platform based on interviews with 15 third parties that were treated as individual tests (i.e., single, embedded case design). *Paper D* rests on a single case with an industry incumbent and its actions to grow its IoT platform. *Paper E* is based on a multi-case design, seeking to identify the transformational processes and organizational routines that have helped three industry incumbents to establish their IoT platforms.

Papers	**Classification of case study research designs**				
	Main objective	Epistemology	Method	Case design	Unit of analysis
Paper A*	Explanation	Soft positivism	Qualitative	Multiple	Holistic
Paper B	Exploration	Soft positivism	Qualitative	Single	Embedded
Paper C*	Explanation	Soft positivism	Qualitative	Single	Embedded
Paper D	Exploration	Soft positivism	Qualitative	Single	Holistic
Paper E	Exploration	Soft positivism	Qualitative	Multiple	Holistic
Note: *Papers focus on explanations but allow for the discovery of new concepts or relationships.					

Table 4: Overview of Case Study Designs (adapted from Recker, 2013, p. 97)

4 Results

This section summarizes the dissertation's five papers that contribute to the overarching RQ of how industry incumbents can successfully establish their IoT platforms for value cocreation. It outlines each paper's purpose, results, and contribution. The results add to our knowledge on (1) platform governance in enterprise IoT, (2) platform growth in the establishment phase, and (3) platform capabilities of industry incumbents. Overall, the results contribute descriptive, explanatory, and prescriptive knowledge with regards to establishing IoT platforms for value cocreation, and thus answer recent calls for research on digital and IoT platforms (De Reuver et al., 2018; Pauli et al., 2021). Table 5 distills the major results and form (i.e., frameworks, models, or propositions) of each paper and specifies how they address the RQs. Harvey balls indicate the relationship—from no (empty), to partial (half-full), to main contribution (full).

Papers	Results	RQ	RQ1	RQ2	RQ3
Paper A	• A framework of 6 governance strategies: opening, alliancing, coring, entering, pricing, and bundling • 5 governance strategies and 19 mechanisms used in IoT	◑	●	◑	○
Paper B	• A framework of 12 IoT value cocreation challenges and paths to overcome them from an ecosystem perspective • 4 recommendations of how to establish IoT platforms	●	●	◑	◑
Paper C	• A model with 3 factors for third-party IoT platform adoption: financial, technology, and knowledge gain; uncertainty (e.g., platform survival, competition) moderates joining decision	◑	◑	●	○
Paper D	• A model that explains how to drive early IoT platform growth • Mode 1: diversity of end-to-end IoT solutions and abstraction • Mode 2: diversity of modules and concretization	◑	◑	●	○
Paper E	• A framework of 11 microfoundations of dynamic capabilities to guide industry incumbents' IoT platform transformations • 3 propositions that guide IoT platform establishment	●	◑	◑	●
Research Questions					
RQ	How can industry incumbents successfully establish IoT platforms for value cocreation?				
RQ1	What platform governance strategies are effective in enterprise IoT?				
RQ2	How can platform growth be fostered in the establishment phase?				
RQ3	How can platform capabilities be developed by industry incumbents?				

Table 5: Summary of Paper Contributions to Research Questions

4.1 Paper A – Governance Strategies for IoT Platforms

Purpose. Even though platform governance is studied in various digital platform contexts (Constantinides et al., 2018; De Reuver et al., 2018), the concept has not often been transferred to enterprise IoT. In this context, platform natives are competing against digital startups and industry incumbents for successful IoT platform establishment, which requires value cocreation. Platform governance defines the rules for the interactions between platform owners and third parties. These interactions can be of cooperative (i.e., openness) or competitive nature (i.e., third-party market entries). Both meta strategies were found to foster value cocreation, yet, in different contexts and with dissimilar effects. Hence, the purpose of Paper A is to review different platform governance strategies, to analyze whether they are applied in IoT platforms, and to identify through what mechanisms they are applied by industry incumbents.

Results. The first paper rests on a systematic literature review and a multiple case study. Based on a review of 72 papers on digital platforms of information systems (IS), management, and economics research disciplines, six platform governance strategies are identified: *opening*, *alliancing*, *coring*, *entering*, *pricing*, and *bundling*. They are presented in a conceptual framework (see Table 7), guiding the IoT platform analysis. Each strategy is characterized by its fostering or impeding effect on third-party value cocreation and is labeled as cooperative or competitive. For example, opening refers to the strategy to open the platform allowing third parties to develop platform-based solutions. Here, research debates the right degree of openness. While open platforms can foster the quantity, diversity, and quality of complements they can reduce the platform owner's control over the platform (Boudreau, 2010; Wareham et al., 2014). Then, the application of governance strategies (and how they are applied) is tested in a multiple case study of four IoT platforms provided by industry incumbents. The results show that IoT platform owners apply five of the six strategies (i.e., opening, alliancing, coring, entering, pricing) by using 19 different governance mechanisms (e.g., acquisitions). The mechanisms are assigned to the strategies showing that *cooperation* is the dominant meta-level strategy in IoT platforms as opposed to organizing competitive markets.

Contribution. The findings contribute to the understanding of platform governance in digital platforms in general (Constantinides et al., 2018) and B2B or IoT platforms in particular (Hein, Weking, et al., 2019). They inform our knowledge on platform governance as guard rails for value cocreation that can be most effectively applied through cooperative mechanisms to cope with the complexity of IoT solutions.

4.2 Paper B – Cocreation Challenges in Enterprise IoT

Purpose. Informed by the results of Paper A and following other scholars, IoT platforms exhibit value cocreation challenges (Hodapp, Hawlitschek, et al., 2019; Pauli et al., 2021). As value cocreation challenges do not just impede the platform owner from value capture, but the entire ecosystem, the purpose of Paper B is to analyze how value cocreation can be effectively organized, looking at the governance of the platform owner as well as the activities of third parties and customers. This ecosystem perspective seems particularly appropriate to capture the dynamics of IoT platform value cocreation, which requires the synchronous or asynchronous development activities of multiple organizations within the IoT platform's ecosystem.

Results. The second paper presents an in-depth single case study of a large European telecommunication provider, who in addition to its connectivity business, established an IoT platform to capture additional value from its existing business customers. With this study, we seek to study the three phases of establishing an IoT platform: *platform*, *ecosystem*, and *value cocreation*. For each of the three phases, we identify two challenge areas experienced by the industry incumbent platform owner: its *IoT network* and new *digital and physical resources* (platform), *customer centricity* and *partner management* (ecosystem), and *cocreator role* and *business value* (value cocreation) (see Table 13). For example, in addition to expanding its connectivity business with a platform business, the industry incumbent tapped into different verticals, such as heating pumps. Based on the case findings, we derive four recommendations for action that can be applied by all industry incumbents that seek to embark on IoT platform establishment journeys. The recommendations address the *make or buy decision*, the *chicken-or-egg problem*, a *hybrid platform growth approach*, and *value capture options* through IoT data.

Contribution. The results of Paper B contribute to the ongoing scholarly discourse on platform dynamics and value cocreation (Sarker et al., 2012; Wareham et al., 2014). This contribution is enabled in particular by data triangulation and the resulting perspective on the ecosystem (platform owners, third-party providers, and customers) (Tiwana et al., 2010). Moreover, the findings contribute to platform competition in that industry incumbents should not fear a winner-takes-all development in enterprise IoT due to the fragmentation of the market and should thus embrace oligopoly-oriented communities, benefiting from collaboration with digital startups as well as powerful platform natives, such as Microsoft Azure (Cennamo & Santalo, 2013; Gawer, 2014). The results guide industry incumbent managers and IT decision-makers in establishing IoT platforms.

4.3 Paper C – Motivational Factors to Join IoT Platforms

Purpose. When establishing digital platforms in general and IoT platforms in particular, platform owners must attract third parties for platform growth. Once enough third parties have adopted the IoT platform, providing IoT solutions, customers may follow due to indirect network effects (Ceccagnoli et al., 2012). However, little research scrutinizes platform adoption of third parties from their perspective (McIntyre & Srinivasan, 2017; Schreieck, Wiesche, & Krcmar, 2016; Selander et al., 2013) or distinguishes different types of third parties besides the well-studied independent software developers (Huang, Ceccagnoli, Forman, & Wu, 2009; Huang et al., 2013). Paper C focuses on third parties' motivational factors to join IoT platforms and accounts for different types of third parties (Petrik & Herzwurm, 2020)—thus shedding light on early IoT platform growth.

Results. The third paper focuses on understanding why third parties join IoT platforms and analyzing what factors contribute to variances in their joining decision. The findings support the three proposed factors: *financial*, *technology*, and *knowledge gain* that are derived from respective theories. It also explores *uncertainty* as a moderating construct (see Figure 8). The four propositions were qualitatively tested and confirmed in form of a single-case study. Our results emphasize that hardware-focused firms are largely incentivized by financial gain. The reasoning here is that most of these firms operate as suppliers where products are manufactured, sold, installed, and maintained. The platform thus represents a new sales channel to them with network effects. Software-oriented firms are also motivated by technology and knowledge gains. Moreover, our study shows that the three joining factors are moderated by the uncertainty of third parties to join. While we find various uncertainty-related factors and structure them along with a platform, ecosystem, and value cocreation dimension, *platform survival* and *intra-platform competition* (i.e., the competition with the platform owner and among third parties) caused uncertainty that harms third parties' joining decision.

Contribution. The results contribute to our knowledge of the decision-making process of third parties when joining an IoT platform (Ceccagnoli et al., 2012; Tiwana, 2015b). The findings also add to the chicken-or-egg problem, indicating that, on average, third parties are most interested in joining the IoT platforms that have been joined by their customers and are thus motivated by high financial gain potential to commercialize their IoT solutions (Caillaud & Jullien, 2003; Evans & Schmalensee, 2010). Industry incumbents can build on these findings when designing their IoT platform's incentive systems that stimulate the joining decision of third parties (e.g., more transparent ecosystems).

4.4 Paper D – Early Growth of IoT Platforms

Purpose. Resolving the early growth challenge of IoT platforms is of special interest to this dissertation. So far, we know from recent studies that various digital platforms have failed to thrive and survive (Evans & Schmalensee, 2010; Pidun et al., 2020, 2021). In B2B, IoT, and other complex platform contexts, in particular, the problem of successful platform establishment becomes even more severe (Hein, Weking, et al., 2019; Huber et al., 2017; Marheine & Pauli, 2020). Scholars have called for research and designs that explain and prescribe how to foster value cocreation in the establishment phase (Isckia et al., 2020; Saarikko et al., 2019). The purpose of Paper D is thus to develop a preliminary model that explains how IoT platform owners can steer towards early IoT platform growth. In particular, we focus on *generativity* as a platform's ability to create IoT solutions "without any input of the [platform owner]" (Wareham et al., 2014, p. 1195).

Results. The fourth paper proposes two modes platform owners can apply to foster third-party innovation or generativity during early platform establishment. *Mode 1* refers to the *diversity of IoT end-to-end solutions*. *Mode 2* denotes the *diversity of generic IoT modules*. Based on the results of a theory elaboration approach (Ketokivi & Choi, 2014), the two modes were found to result in a virtuous growth cycle by moving from the *abstraction* of end-to-end IoT solutions to the *concretization* of modules (i.e., generic solution components) and vice versa (see Figure 9). In essence, the results emphasize that IoT platforms, despite their huge generative (i.e., innovation) potential due to the heterogeneity of devices in IoT, require end-to-end, project-oriented value cocreation to generate valuable IoT solutions.

Contribution. Paper D contributes to resolving the early growth challenge of complex platforms through the processes of abstracting end-to-end IoT solutions and concretizing generic IoT modules. Our findings contain various contributions. First, while generativity (i.e., the autonomous innovation potential of a platform) has often been understood as a platform's implicit characteristic that must be controlled for by platform owners, we show that it must be deliberately driven in IoT platforms. In that, we contribute to the research stream on generativity (Tilson et al., 2010; Zittrain, 2006). Second, the results also contribute to known governance tensions among platform scholars, such as the "openness vs. control" or the "individual vs. collective" tension (Wareham et al., 2014). Third, we recommend a shift from an architectural design focus on platform governance to a relationship-oriented focus, as IoT platforms, as more complex types, emphasize Mode 1 and the process of abstraction to achieve high customer value.

4.5 Paper E – Industry Incumbent Organizational Routines

Purpose. For industry incumbents, the establishment of IoT platforms and respective business models requires new internal capabilities and transformations besides knowing platform governance mechanisms (Pauli et al., 2021; Teece, 2017). Drawing on dynamic capabilities (Teece, 2007; Teece et al., 1997), that allow to thrive and survive in dynamic environments, such as when establishing IoT platforms, little research has so far looked at how they come to existence. Hence, the purpose of Paper E is to fill this void by using a dynamic capabilities lens and, in particular, employ the concept of microfoundations (Felin, Foss, Heimeriks, & Madsen, 2012; Mahringer & Renzl, 2018) to identify the organizational routines and processes that helped to build dynamic capabilities associated with establishing IoT platforms (Pauli et al. 2021; Teece 2017).

Results. The fifth paper provides insights into how industry incumbents with established business models developed *microfoundations* (i.e., processes, routines) of *dynamic capabilities* (i.e., sensing, seizing, and transforming) that fostered IoT platform establishment. In particular, 11 of the microfoundations (e.g., co-selling, customer success management, adapting sales incentives) were identified that helped a software, telecommunication, and hardware provider in establishing their IoT platforms (see Figure 12). Also, the paper adds a conceptualization of *successful platform establishment* as a function of (1) offering a *platform* with value-adding digital resources, (2) establishing an *ecosystem* of customers and third parties, and (3) fostering *value cocreation* among organizations. Thereby, we contribute to the conceptual clarity of platform establishment and platform life cycles (Saarikko et al., 2019; Teece, 2017; Tiwana et al., 2010). Finally, we derive three propositions that shall guide organizational planning and managerial decisions when establishing IoT platforms.

Contribution. Besides the microfoundations found to instantiate dynamic capabilities, we contribute to theory and practice by shifting the viewpoint from platform owners' external practices, such as platform governance, to internal transformations involving mechanisms, such as changing sales practices or creating customer success management units. Therefore, the results contribute to the literature on platform capabilities in general and in particular to those necessitated by industry incumbents (Svahn et al., 2017; Van Alstyne et al., 2016). Moreover, we contribute to research on dynamic capabilities as a valuable strategic management lens for studying platform ecosystem dynamics in light of organizations' internal transformations (Helfat & Raubitschek, 2018; Linde et al., 2021; Teece, 2017).

5 Discussion

In this section, the implications of this dissertation's results are discussed in light of the research on value cocreation on digital platforms. I then reflect on the contributions to research (5.1) and practice (5.2), explicate the limitations of the work and detail future research opportunities (5.3), and finally conclude this dissertation (5.4).

5.1 Contributions to Research

This dissertation contributes to the literature on *(1) platform governance* in enterprise IoT *(2) platform growth* in the establishment phase and *(3) platform capabilities* of industry incumbents. As pillar one and two contribute largely to platform governance and growth research streams, pillar three adds to the research stream on dynamic capabilities in management research. Yet, insights in all of the three pillars contribute to exploring the opportunities of industry incumbents to foster value cocreation on IoT platforms.

(1) Platform governance. First, we respond to scholarly calls for more contextualization of digital platforms (De Reuver et al., 2018) and IoT platforms (Pauli et al., 2021). In that, this dissertation shows that platform owners' governance strategy to cooperate with third parties trumps competitive interactions in enterprise IoT. This result is in line with the enterprise software context which also contributes to the literature on B2B platforms (e.g., Huang et al., 2013; Huber et al., 2017; Wareham et al., 2014). Since most IoT platform owners have deficit solution offerings, they collaborate with third parties to profit from their complements (Jacobides et al., 2018; Saraf et al., 2007). The case studies of this thesis show that industry incumbents, in particular, require close partnerships with technology providers that complement their weaknesses (Chellappa & Saraf, 2010). For example, telecommunication providers have a strong footprint in connectivity. However, besides their routers or gateways, they do not offer much hardware, nor do they have special application development capabilities. Thus, they require partners, such as sensor manufacturers or software developers, to align parts of their value propositions with the platform strategy. Moreover, we found that all industry incumbent platform owners collaborate with digital infrastructure providers, such as Microsoft Azure or AWS, allowing them to scale their digital offerings. This finding adds to our understanding of platform-based coopetition where the benefits of cooperation outweigh the drawbacks of platform competition (Brandenburger & Nalebuff, 1996; Cozzolino, Corbo, & Aversa, 2021; Gnyawali & Park, 2011).

Second, the dissertation's results add to our knowledge of value cocreation challenges in enterprise IoT. In contrast to various consumer contexts (e.g., mobile phones) where third parties can independently develop applications (e.g., Niantic's Pokémon GO), high degrees of complexity in enterprise IoT impede early value cocreation. This complexity emerges from the technical, business, and domain expertise needed to develop valuable enterprise IoT solutions for business customers. Platform owners thus have to coordinate third parties in a value cocreation process that cannot solely be managed via the platform (Boudreau, 2017; R. Kapoor & Lee, 2013; Marheine & Pauli, 2020). Effective partner management with a shift from single-firm to ecosystem incentives are found to support this task (e.g., co-selling strategy). Hence, the insights of Paper A and B contribute not only to a better understanding of value cocreation in enterprise IoT but provide valuable insights into the governance mechanisms and actions that guide value cocreation.

(2) Platform growth. Third, we contribute to early value cocreation in the establishment phase of IoT platforms (Saarikko et al., 2019; Tiwana et al., 2010). Because scholars have reported network effects to be the main characteristic of successful platform businesses, little work elucidates how they can be achieved in complex contexts. To achieve early platform growth, platforms owners must, on the one hand, attract third parties to join the platform and, on the other hand, foster the cocreation of IoT solutions. Having these intertwined goals in mind, we found that platform owners can motivate third parties to join through financial, technology, and knowledge gains, confirming prior academic findings (e.g., Ceccagnoli et al., 2012; Foerderer et al., 2019; Ghazawneh & Henfridsson, 2013). Yet, we add to the notion of different types of third parties on IoT platforms and call for research that prescribes the best suitable incentives for different third-party groups in IoT, such as hardware-, hybrid-, and software-oriented third parties. Moreover, as opposed to startups, industry incumbents can profit from their existing organizational relationships with customers and suppliers, when achieving their migration onto the platform (e.g., Agarwal, Singh, & Agariya, 2017; Holmberg & Cummings, 2009; Huber et al., 2017; Saraf et al., 2007). In this vein, we explain that attracting business customers onto IoT platforms is of utmost importance as third parties follow value capture opportunities (Schreieck et al., 2021).

Fourth, as opposed to the classic platform governance challenge of balancing openness and control (Boudreau, 2010, 2017; Wareham et al., 2014), our results indicate that value cocreation (process) and third-party innovation (outcome) must be deliberately fostered in early IoT platform establishment. Hence, instead of regulating third-party innovation to control the platform's evolution, IoT platform owners must drive it beyond

guaranteeing high degrees of openness. Opening a platform alone is not enough due to the aforementioned complexity-related reasons. To establish early platform growth, IoT platform owners have to focus on implementing end-to-end IoT solutions with their customers and abstract solution components ex-post as modules on the platform for reuse. Following these prescriptive recommendations can help platform owners to leverage platform growth during establishment. Once a few IoT solutions have been cocreated in different verticals and became abstracted for reuse, third parties can fasten their developments, eventually resulting in network effects (Ceccagnoli et al., 2012; Huber et al., 2017; Isckia et al., 2020).

(3) Platform capabilities. Fifth, the results of this thesis contribute to the discourse on *how industry incumbents can extend their pipeline businesses with IoT platforms* (Svahn et al., 2017; Van Alstyne et al., 2016). Knowing that digital platforms are playing an increasingly important role in the strategic reorientation and digital transformation of established organizations (e.g., Bilgeri, Wortmann, & Fleisch, 2017; Dremel, Herterich, Wulf, Waizmann, & Brenner, 2017; Sebastian et al., 2017), there is little guidance for industry incumbents to conduct these transformations. These firms need to understand how to evolve their linear value chains into value networks and how to properly leverage their strengths in building platform businesses. To contribute to this emerging research stream, we have conceptualized the platform establishment phase along with the three dimensions platform, ecosystem, and value cocreation in Paper E (Lusch & Nambisan, 2015). In particular, industry incumbents must capture all existing initiatives in the company for platform development and orchestrate existing partners in a value cocreation process. Besides focusing solely on platform governance, we stress platform capabilities as organizations' internal capabilities to achieve this goal (Grover & Kohli, 2012; Schreieck et al., 2021). Therefore, we identified *organizational routines of dynamic capabilities needed for effective platform establishment*. Even though dynamic capabilities have been extensively studied by strategy and management scholars, the concept has recently received much attention in IS research with a focus on guiding digital transformations (e.g., Karimi & Walter, 2015; L. Li, Su, Zhang, & Mao, 2018; Ravichandran, 2018). The underlying premise is that to seize digital business opportunities and transform their business models in dynamic business environments, organizations need dynamic capabilities for competitive advantage (Teece, 2007; Teece et al., 1997). Hence, in this dissertation, we contribute an intra-organizational view of the transformational processes to establish IoT platforms (e.g., Helfat & Raubitschek, 2018; Linde et al., 2021; Teece, 2017).

5.2 Contributions to Practice

Although this dissertation yields several contributions for the managerial practice, such as insights on platform governance and cooperation (Paper A) the platform make-or-buy decision and IoT platform competition (Paper B), incentives to join IoT platforms from a third-party perspective (Paper C), insights into resolving the early growth challenge of IoT platforms (Paper D), and organizations' transformational lessons (Paper E), the next section distills three main contributions. The results aim at guiding industry incumbent managers mainly but may also be of interest for decision-makers of third-party or customer organizations since value cocreation represents a multi-firm endeavor.

First, establishing IoT platforms for value cocreation requires industry incumbents to coordinate IoT solutions end-to-end and offer reusable modules via the platform (Paper D). IoT platform growth is impeded by IoT complexity. To overcome this challenge and to provide customer value, platform owners must cooperate with technology, business, and domain experts, orchestrating their activities to solve customer problems end-to-end. Reusable, domain-unspecific solution components can later be offered directly via the platform. Multiple end-to-end solutions and their modular abstractions thus help to expand the platform's resource portfolio, fostering early growth.

Second, industry incumbents should leverage existing business relationships and focus on customer joining decisions (Paper B and C). In contrast to other contexts, in which platform businesses are established on a greenfield, industry incumbents can already draw on established corporate relationships that must be brought onto the platform. They must, however, provide the right incentives for their customers and third parties to adopt their platform. Giving away the platform for free with basic analytics capability and data storage to every product or service sold is one way to increase early growth. They can capture value once the platform reaches a critical mass. Also, incumbents should prioritize customers' joining decisions over those of third parties, who are often followers.

Third, industry incumbents should create more value than capture. Architecturally open platforms and cooperation with friend and foe helps to accelerate platform evolution and value cocreation (Paper A). Also, platform owners must not fear platform competition because of high market fragmentation and many verticals (Paper B). Incumbents should monetize IoT solutions or applications—not the IoT platform itself as a PaaS offering. Following a customer- and value-oriented approach helps industry incumbents to grow their IoT platforms with the digital transformations of their customers. Organizational roles like customer success managers can help to achieve this goal (Paper E).

Lastly, incumbent platform owners should keep in mind that value cocreation rests on multi-firm success with measures, such as shared customer lifetime—not singular firm performance. Establishing appropriate value capture mechanisms is thus essential for sustainable value cocreation on IoT platforms.

5.3 Limitations and Future Research

Limitations. The cumulative dissertation is not free from *limitations*. While each contribution has its limitations, described in each paper, this subsection outlines the three overarching limitations of this thesis—mostly referring to its research design. First, while the *case selection* involves six IoT platforms, offered by incumbents in the enterprise software, telecommunication, industrial technology, mobility technology, and manufacturing industry; thus appropriate given Eisenhardt (1989) proposed a number of four to ten cases to yield robust results. However, the case sample only entails industry incumbent platform owners that are headquartered in Europe. While Europe is known for its various industries and thus predestined for this research, interactions with other technologies and companies must also be considered above all when establishing IoT platforms. As many IoT platforms are built on the underlying infrastructure of Microsoft Azure or AWS— platform natives based in America—closer proximity to these firms could affect important dynamics that exist in the American market and should be taken into account (e.g., Salesforce, Caterpillar). Moreover, successful platform establishment is difficult to claim as the IoT platform market has concentrated but not yet consolidated (Lueth, 2019)—which is both evidence for the relevance of IoT platforms and the difficulty of successful establishment. We addressed this limitation by selecting successful industry incumbents that had the resources to invest appropriately in their IoT platform establishment initiatives, and by viewing "success" in terms of the ability to early cocreate value with third parties and customers in our qualitative analysis.

Second, the *data collection* rests on a limited number of methods, as it is primarily based on interviews (N=60) with and documents from industry incumbents. Yet, quantitative or other qualitative data collection methods, such as focus groups (to study individuals in-depth, not organizations), would have not captured the socio-technical nature of IoT platforms or suited the research design to study industry incumbents' actions. Also, data collection lacks longitudinal designs, which could have yielded in-depth, process-oriented results. Even though Paper B comes close to a longitudinal research design by taking into account a retrospective of five years and triangulating the platform owner's governance actions to guide the value cocreation with those of its customers and third

parties, interviewees still only reported past actions, possibly allowing for the exclusion of important events or decisions made. Even though important details or relevant findings may have remained covered, we have tried to counteract this potential shortcoming by following the guidelines of theoretical saturation and data triangulation (Corbin & Strauss, 2014; Jonsen & Jehn, 2009).

Third, *data analysis* may suffer from bias. For one thing, interviewees may have reported events in a very subjective way and thus already interpreted or presented them rather positively or negatively. Second, even objective descriptions of the case and its context are not free from researchers' bias, interpreting the empirical phenomenon in light of their experiences and perspectives. Therefore, to counteract the *interviewee bias*, we followed a neutral stance and semi-structured interview guidelines when conducting interviews. Moreover, in most cases, the data analysis and coding were performed by more than one researcher. Here, we specifically looked for consistent accounts and codes from the interviewees, which were supported by further research when in doubt (e.g., internal documents, annual reports). Furthermore, data triangulation also helped to reduce the interviewee bias, looking for shared opinions among them. To counteract the *researcher bias*, we followed the logic proposed in the theory-elaboration approach in terms of constantly comparing the new empirical phenomenon with related research on digital platforms and value cocreation (Ketokivi & Choi, 2014), which again was well in line with the soft positivist research philosophy.

Future research. Despite the limitations, this dissertation yields valuable contributions to the IS literature. The findings highlight the need for further exploratory, explanatory, and prescriptive research on establishing IoT platforms for value cocreation. *Future research* can address the above limitations and extend the existing body of knowledge on value cocreation. In the following, I pave the way for scholars, who seek to extend the contributions of this thesis, emphasizing three themes: coopetition, customer role in the value cocreation process, and ambidexterity. First, this work has highlighted the opportunities and risks for value cocreation with IoT platforms, considering the strengths and weaknesses of industry incumbents. We found that all industry incumbents rely on collaboration with partners—whether in the area of devices, connectivity, infrastructure, or software development. Purposefully seeking collaboration with partners—despite potential competition—adds to the research stream of *coopetition* (Brandenburger & Nalebuff, 1996; Cozzolino et al., 2021; Gnyawali & Park, 2011). The coopetition idea claims that the advantages of collaboration trump its disadvantages. Yet, the sustainable, positive impact of coopetition on value cocreation is disputed by one of the fundamental

paradigms in the platform literature: the *winner-takes-all* paradigm which predicts the failure of various IoT platforms in the future. Even though this paradigm arouses great interest in empirical research (Anderson, Parker, & Tan, 2014; Cennamo & Santalo, 2013; Karhu & Ritala, 2020), IoT platforms—as a new empirical phenomenon—provide a unique chance to study the dynamics of coopetition. Hence, scholars might add to the knowledge on platform dynamics and effects on value cocreation (Tiwana et al., 2010; Wareham et al., 2014). It is quite conceivable that there is some sort of "tipping point" that leads to a strategic reorientation from collaboration to competition between platform owners. To pursue this research, scholars should use qualitative, longitudinal, case studies. Case selection seems key, as case organizations should collaborate over an extended period and exhibit competition in existing business fields (e.g., GE vs. Siemens or Bosch vs. Google in the smart home market). Resulting insights could enhance our knowledge of inter-organizational relationships, as called for by researchers and underscored by this dissertation's emphasis on relation-oriented governance (Ceccagnoli et al., 2012; Hein, Weking, et al., 2019; Huang et al., 2013).

Second, future research should build on the results for the early growth of IoT platforms. Specifically, researchers here could contribute to the persistent chicken-or-egg problem by pivoting the focus from third-party providers to *customers* (Caillaud & Jullien, 2003; Stummer et al., 2018). Customer organizations appear to be crucial for both the adoption of third-party platforms and for value cocreation. Their domain expertise cannot be replaced by many third-party providers and is therefore crucial for value with high utility to emerge (Lusch & Nambisan, 2015). Customers seek applications that are aligned with their machines, processes, and IT system—end-to-end. While IoT platforms offer great potential to develop IoT solutions more effectively and efficiently in the medium term, they require a direct project-oriented exchange in the early value cocreation process. As a result, future research looking at IoT platforms from a value cocreation perspective could focus even more on the role of the customer as a "co-producer" of value. Hence, I recommend a closer convergence in the understanding of value cocreation based on the marketing literature (Lusch & Vargo, 2006; Vargo & Lusch, 2004, 2008), where the concept originated—not to narrowly on the IS and service management stream as I have done in this dissertation. Moreover, the value creation of the customer in early platform growth could also be depicted by a process model or process theory as has been done by other IS and management scholars (e.g., Huber et al., 2017; Khanagha et al., 2020; Tan et al., 2015). For example, Tan et al. (2015) develop a process model that explains the platform development of transaction platforms, derived from the single case of Alibaba.

The underlying idea is that there are differences in value cocreation—depending on the platform evolution in the life cycle (Tiwana et al., 2010). While young platforms need to find their target market, grow in users, and create value, the challenges in value cocreation and governance differ from mature B2C platforms. Although the preliminary model developed in the thesis (Paper D) potentially lacks generalizability, it provides a starting point for thinking about the steps needed to grow a platform's digital resources. I believe that design science research could be a feasible research approach as a design science artifact requires careful evaluation (Hevner, March, Park, & Ram, 2004).

Third, insights on platform capabilities in the sense of industry incumbents' abilities to establish platforms could be built upon. The particular challenge of industry incumbents is *ambidexterity*—the task to balance pipeline and platform business (e.g., Andriopoulos & Lewis, 2009; Wan, Cenamor, Parker, & Van Alstyne, 2017). On the one hand, industry incumbents must successfully continue their product or service businesses. On the other hand, they aim at establishing IoT platform businesses. Their internal capabilities needed to achieve this dualism are of great importance and would suitably complement industry incumbents' organizational routines described in this thesis (e.g., adapting sales to subscription sales business). Ambidexterity is thus put forth as a research opportunity with a potentially relevant effect on value cocreation. Findings could go in the following possible direction. If an industry incumbent does not succeed in balancing core business and platform business, the industry incumbent could either lose power in its role as a platform owner or lose performance in its role as an industry leader, both of which could lead to a negative downward spiral, impeding value cocreation. Ways to investigate ambidexterity can be done quantitatively through questionnaires and qualitatively through interview studies.

5.4 Conclusion

To conclude, the thesis aimed at examining how industry incumbents can successfully establish IoT platforms for value cocreation. Therefore, this dissertation partitioned this research question into three pillars, focusing on platform governance in enterprise IoT (Paper A and B), platform growth in the early establishment phase (Paper C and D), and platform capabilities of industry incumbents (Paper E). The results are presented in the form of conceptual frameworks and propositions, helping industry incumbent managers to establish their IoT platforms as well as third-party and customer organizations to engage in value cocreation. Overall, this thesis contributes to a better understanding of platform-based value cocreation and sheds light on the platform establishment phase.

Part B – Papers of the Dissertation

Paper A – Governance Strategies for IoT Platforms

Attribute	Description
Title	Governance Strategies to Drive Complementary Innovation in IoT Platforms: A Multiple Case Study
Short title	Governance Strategies for IoT Platforms
Authors	Christian Marheine
Year	2020
Publication outlet	Proceedings of the 15th International Conference on Wirtschaftsinformatik
Publication type	Conference paper
Ranking	C (VHB Jourqual 3)
Publication status	Published

Table 6: Bibliographical Metadata on Paper A

Abstract. The widespread uptake of the Internet of Things spurred both software and hardware firms to compete for platform leadership. Information systems research has acknowledged that a platform's success depends on the innovational output of its ecosystem of firms. However, the question whether platform owners should coordinate these firms through cooperative or competitive strategies to create complementary applications remains unaddressed. To address this gap, an exploratory, multiple case study of four German companies with IoT platforms was conducted. Five of the six governance strategies derived from the literature were confirmed: opening, alliancing, coring, entering, and pricing. In these strategies, 19 distinct governance mechanisms and their positive or negative effects were identified. The findings contribute to research on business-to-business platforms by demonstrating that cooperation between platform owners and complementors represents the dominant meta-level strategy in IoT platforms.

Keywords. Internet of things, IoT platforms, platform governance strategies, complementary innovation, multiple case study research.

A.1 Introduction

Recently, the concept of platforms has received much attention in the Internet of Things (IoT) (Hodapp, Remane, Kolbe, Hanelt, & Kolbe, 2019; Schreieck, Hakes, Wiesche, & Krcmar, 2017; Wortmann & Flüchter, 2015). To give an example, the cloud-computing company Amazon Web Services (AWS) operates an IoT platform. The platform provides companies the functionality to manage millions of devices. In addition, companies that use the AWS platform can also develop their software-based products and services ranging from small add-ons to domain-specific applications. In addition to global players (e.g., Amazon), enterprise software firms (e.g., SAP), automation firms (e.g., Siemens), startups and joint ventures have launched their IoT platforms competing for platform leadership. Analysts forecast that the IoT platform market, which consists of around 450 companies (Lueth, 2017), will grow and reach a market value of US$1.8 billion by 2022 (Market Research Future, 2018).

So far, information systems (IS) research has acknowledged that the success of a platform depends on the innovative capacity of its ecosystem (Boudreau, 2012; Foerderer et al., 2018; Gawer & Cusumano, 2002). The ecosystem is a network of independent third-party firms—so-called complementors (Gawer & Cusumano, 2002). These firms develop *complementary innovations* on top of the platform—apps in particular. A high quantity and variety of complementors, who develop apps, determine a platform's success in complementary innovation (Boudreau, 2010; Tiwana et al., 2010). In addition, more innovation on top of the platform will, in turn, attract more end-users to the platform—a phenomenon called indirect network effects (Eisenmann et al., 2006). To motivate complementors to join and innovate on top of the platform, owners can apply different *governance strategies* (Tiwana, 2014, 2015a). The two dominant meta-level strategies are cooperation and competition (Karhu et al., 2018). Cooperation focuses on value co-creation (Bharadwaj et al., 2013). Here, platform owners can share technical resources, such as application programming interfaces (APIs) and software development kits (SDKs) with other firms in the ecosystem. This enables complementors to develop upon the platform (Boudreau, 2010; Ghazawneh & Henfridsson, 2013). In contrast, competition seeks to capture more of the value that is co-created (Schreieck, Wiesche, & Krcmar, 2017). Platform owners can, for example, enter complementary markets with similar products. Due to direct competition, platform owners can take larger shares of complementors' revenue decreasing their incentives to innovate (Foerderer et al., 2018; Gawer & Cusumano, 2002). Overall, while cooperation bears on trust and shared goals (Gawer & Cusumano, 2002; Huang et al., 2013; Perrons, 2009), competition often

involves rivalry between platform owners and complementors (Armstrong, 2006; Foerderer et al., 2018; Gawer & Henderson, 2007). Scholars have called for more research on the platform owner's effectiveness of using either of these meta-level strategies for driving complementary innovation (Gawer, 2014; Tiwana et al., 2010; Yoo et al., 2010). Moreover, most insights on governance strategies and their effectiveness in driving complementary innovation are based on business-to-consumer (B2C) platforms. So far, scholars have studied mobile operating systems (e.g., Eaton et al., 2015), video game consoles (e.g., Cennamo et al., 2018), and social networks (e.g., Z. Li & Agarwal, 2017). The purpose of this paper is to advance our understanding of those strategies applied in business-to-business (B2B) platforms—studying the empirical context of IoT platforms. This motivated the following question: *Which cooperative and competitive governance strategies do IoT platform owners apply and how do they affect complementary innovation?*

To address this research question, an exploratory, multiple case study of four IoT platforms was conducted. The analysis is based on 13 interviews with platform managers. To guide the analysis and to structure the results, a conceptual framework was derived by systematically reviewing the literature on digital platforms. The framework comprises three cooperative and three competitive governance strategies. The results illustrate that IoT platform owners apply five of the six strategies by using 19 different governance mechanisms. These mechanisms are assigned to the strategies showing that cooperation is the dominant meta-level strategy in IoT platforms. The findings contribute to the understanding of platform governance in B2B platforms.

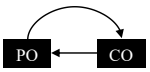
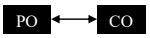
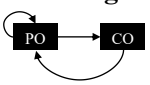
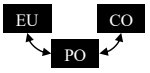
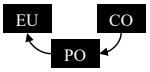
A.2 Background on IoT Platforms and Platform Governance

Following prior work, *IoT platforms* can be defined as central software-based systems that are operated in the cloud connecting different devices, data sources, developers, and end-users (Hodapp, Remane, et al., 2019; Püschel et al., 2016). Compared to digital platforms (Karhu et al., 2018), IoT platforms differ in two things (Guth et al., 2018; Schreieck, Wiesche, et al., 2017). First, its architectural design is more complex. It comprises four distinct connectivity levels including the device layer, the connectivity layer, the middleware layer, and the application layer (Guth et al., 2018). Second, IoT platforms necessitate ecosystems with multiple participants: firms that use the platform and its services (i.e., end-users), firms that develop complementary IoT apps (i.e., complementors), and in addition, firms that build, connect, and maintain devices (Hagiu & Wright, 2015).

Offering an IoT platform requires platform owners to make decisions about the ecosystem of complementors beyond just developing and distributing the platform itself (Schreieck, Hakes, et al., 2017; Tiwana, 2015a). *Platform governance* focuses on the relations between platform owners and complementors (Ghazawneh & Henfridsson, 2013; Tiwana, 2014, 2015a). Whether a platform owner's governance decisions are successful depends on its effectiveness of stimulating complementors to innovate upon the platform (Gawer & Cusumano, 2002). The incentives to innovate can be created through cooperative and competitive governance strategies (Armstrong, 2006; Huang et al., 2013). According to the IS and management literature, cooperative strategies include decisions about the platform's optimal degree of openness (Boudreau, 2010), the formation of strategic partnerships (Huang et al., 2013), and the platform's technical expandability (Bender & Gronau, 2017). In contrast, competitive strategies encompass decisions about the platform owner's entry into complementary markets (Gawer & Henderson, 2007), the pricing structure (Armstrong, 2006), and the bundling of different functions or features (Choi & Stefanadis, 2001). Based on systematically reviewing the platform literature (see Section A.3.1), I derived six governance strategies (i.e., opening, alliancing, coring, entering, pricing, and bundling) and synthesized key aspects in a framework—presented in Table 7. The framework assigns aspects that positively (+) or negatively (−) affect complementary innovation to each strategy with exemplary references. Since these strategies are largely based on research on B2C platforms (i.e., 51 of 72 reviewed papers focus on B2C platforms), this paper seeks to test the framework in the IoT context. Next, each strategy is briefly introduced.

Opening shifts the locus of value creation from within the firm toward the ecosystem of independent third-party firms (Boudreau, 2010, 2012). The debate on this strategy is about choosing the right degree of openness (Karhu et al., 2018). An open platform supports a high quantity and variety of complements (i.e., apps) but reduces the platform owner's control of the ecosystem (Boudreau, 2017). **Alliancing** refers to building strategic partnerships that foster value co-creation and capture (Ceccagnoli et al., 2012; Sarker et al., 2012). While value co-creation can be stimulated through strategic alignment, trust, and contractual agreements, value capture requires strong downstream capabilities (to market complementary apps) and intellectual property rights (IPRs) like patents (Ceccagnoli et al., 2012; Huber et al., 2017). **Coring** aims at extending the platform's own codebase. This provides complementors with the latest features that increase their innovation potential (Gawer & Cusumano, 2008). While too much coring can reduce incentives to innovate, too little coring might cause complementors to switch to

other, technically better-off platforms (Bender & Gronau, 2017). To pursue this strategy, platforms must be built as a modular architecture with standard interfaces so that they are readily expandable (Gawer, 2014; Yoo et al., 2010).

Governance strategies		Implications for complementary innovation		Exemplary references
		(+) Fostering aspects	(−) Impeding aspects	
Cooperative	**Opening** 	**Platform adoption** • Technology access • Complement diversity • Commercialization	**Platform control** • Crowd-out effect • Exploitation • Smaller returns	Boudreau (2010, 2012, 2017), Karhu et al. (2018), Niculescu et al. (2018), West (2003)
	Alliancing 	**Strong partner alignment** • Contractual agreements • IPRs and protection • Downstream capabilities	**Weak partner alignment** • Coordination conflicts • Owner's interest first • Early IP disclosure	Ceccagnoli et al. (2012), Huang et al. (2013), Huber et al. (2017), Sarker et al. (2012)
	Coring 	**Platform development** • Modularity • Standard interfaces • Less coordination effort	**Too little and too much** • Monopoly distortions by coring too little • Crowd-out innovation by coring too much	Bender and Gronau (2017), Gawer (2014), Jacobides et al. (2018), Yoo et al. (2010)
Competitive	**Entering** 	**Efficient competition** • Connector market entries • Attention spillover effect • Market awareness	**Financial incentives** • Power of owner's brand • Price squeezes • Rent appropriation	Foerderer et al. (2018), Gawer and Henderson (2007), Li and Agarwal (2017)
	Pricing 	**Subsidizing 1 or 2 sides** • Small license fees • Much multihoming • Indirect network effects	**Subsidizing no side** • High license fees • Little multihoming • High switching costs	Armstrong (2006), Hagiu (2006, 2009), Rochet and Tirole (2006), Zhu and Zhou (2012)
	Bundling 	**User network growth** • Tying complements • Acquisitions • Envelopment	**Lock-in effect** • Foreclosure of end-users • WTA monopoly effect • Platform complexity	Choi and Stefanadis (2001), Eisenmann et al. (2011), Farrell and Katz (2000), Toppenberg et al. (2016)

Note: The illustrations help to visualize the strategies. The rectangles represent the ecosystem participants: platform owner (PO), complementor (CO), and end-user (EU). The arrows represent governance actions and the flow of innovation.

Table 7: Governance Strategies Framework

Entering is a competitive strategy (Foerderer et al., 2018; Z. Li & Agarwal, 2017). Platform owners enter complementary markets typically to capture a larger portion of the co-created value. On the one hand, the owner's entry can gravitate end-users to the market, stimulating both the sales of platform owners and complementors (Foerderer et al., 2018). On the other hand, a large number of market entries can demotivate complementors to innovate as they could face revenue losses (Gawer & Cusumano, 2002; Gawer & Henderson, 2007). **Pricing** decisions encompass taking homing and switching costs into

account to determine whether end-users (i.e., demand-side) or complementors (i.e., supply-side) should be subsidized (Armstrong, 2006; Rochet & Tirole, 2006). Pricing decisions promote indirect network effects, that is, the subsidized platform-side may attract the other side to the platform (Armstrong, 2006; Eisenmann et al., 2006). **Bundling** also promotes complementary innovation through indirect network effects (Eisenmann et al., 2011). A bundle comprises two or more attractive features offered on a single platform. Bundles can help platform owners to build a monopoly position and deprive others (with just a single key feature) of the opportunity to enter the market with their own platform (Choi & Stefanadis, 2001; Eisenmann et al., 2011). Scholars have also referred to this strategy as "tying of complementary components" (Choi & Stefanadis, 2001, p. 55).

A.3 Research Methodology

To answer the research question, an exploratory, multiple case study was conducted following the "linear but iterative process" defined by Yin (2014, p. 56). A multiple case study was chosen as the appropriate method for conducting this research as the goal was to observe which of the governance strategies have been applied by IoT platform owners, how they have been implemented, and how they affect complementary innovation (Yin, 2014).

A.3.1 Systematic Literature Review

Prior to the case research, the conceptual framework (see Table 7) was developed based on a systematic literature review (vom Brocke et al., 2015; Webster & Watson, 2002). The selection process traversed three steps and commenced based on the search string: ("digital platform") AND ("governance" OR "cooperation" OR "competition" OR "innovation"). First, papers were selected based on their *outlet* with a journal focus—especially those of the AIS Senior Scholars' Basket of Journals[3]—to build a robust fundament. Second, papers were included when their *unit of analysis* was the platform owner focusing on his activities towards complementors. Finally, a *forward* and *backward search* was performed to extend the list with papers whose findings are widely acknowledged among platform experts, e.g., books (Gawer & Cusumano, 2002; Tiwana, 2014) and Gawer's dissertation (2000). Our selection process resulted in a final sample of 72 papers that were analyzed following a concept-centric approach (Webster & Watson, 2002).

[3] https://aisnet.org/page/SeniorScholarBasket

A.3.2 Case Selection

To yield robust findings, Eisenhardt suggests "a number between 4 and 10 cases" (Eisenhardt, 1989, p. 545). To arrive at a manageable sample, the preselection process followed heterogeneous and homogenous sampling (Yin, 2014). The heterogeneous sampling of companies followed three criteria: (1) the traditional business domain (i.e., software or hardware), (2) the platform approach (i.e., horizontal or vertical), and (3) the firm size in terms of annual revenue (i.e., small, medium or large). In addition, the sampling followed two homogenous criteria to ensure the generalizability of results across different cases. First, all IoT platforms had to comply with the definition of an IoT platform (see Section A.2). Second, all IoT platforms had to govern complementors with the goal to drive complementary innovation. The latter criteria were relevant to perform a cross-case analysis (Yin, 2014). Due to this preselection process, many platforms were excluded that did not comply with the two homogenous criteria (e.g., Bsquare) or did not expand the heterogeneous scope of analysis (e.g., IBM Watson IoT). Moreover, the infrastructure as a service (IaaS) IoT platforms of Google, AWS, and Microsoft were excluded, because the focus in this paper was on platform as a service (PaaS) IoT platforms with greater vertical industry focus, such as the industrial IoT. Other platforms were excluded as they did not share their technology with third-party firms (e.g., KONUX). Furthermore, firms situated in Germany were preferred over others in order to facilitate data collection. In addition, IoT platforms were chosen based on literal replication logic, i.e., similar results were expected to be generated from similar platform cases and vice versa (Yin, 2014). The final sample comprised three of the largest German companies from the enterprise software, engineering, and manufacturing domain and one industrial IoT joint venture (see Table 8).

Company	**IoT platform**	**First release**	**Characteristics**								
			Business domain		Platform approach		Firm size			Ownership	
			Software	*Hardware*	*Horizontal*	*Vertical*	*Large*	*Medium*	*Small*	*Single*	*Shared*
PO1	Platform 1	2015	X		X			X		X	
PO2	Platform 2	2016		X	X		X			X	
PO3	Platform 3	2016		X	X		X			X	
PO4	Platform 4	2017	X			X			X		X

Table 8: Overview of the Selected IoT Platform Cases

From now on, the four case firms are referred to as platform owners (POs). **PO1**, a global market leader in enterprise application software, generates an annual revenue of €23 billion. **PO2** is a leader in automation technology with an annual revenue exceeding €80 billion. **PO3** is a global engineering and electronics company with an annual revenue of €78 billion. **PO4** is a joint venture of six large manufacturers and a German software company. PO4 is thus characterized by shared ownership. All POs offer B2B IoT platforms and have the goal to attract more complementors, who develop IoT apps in high quality, to their ecosystem. Both complementors and end-users represent firms.

A.3.3 Data Collection

To collect the material required for the multiple case study analysis, data was retrieved from primary and secondary sources (Yin, 2014). Although the focus of this empirical inquiry laid on primary data, using semi-structured interviews (n=13), the coherent presentation of all cases required secondary data, such as company websites and internal documents, to fill potential knowledge gaps. The interview questions followed a pre-formulated, high-level guideline, which covered information about the IoT platform and the market as well as the cooperative and competitive governance strategies. I conducted all interviews which required me to react to responses given by the respondents, judge the relevance of their statements, and ask further questions if necessary. Each IoT platform case was based on three interviews with platform managers including roles such as vice president and head of IoT.

ID	Role	Length	IoT platform
A1	IoT Consulting Manager	45 min	Platform 1
A2	IoT Product Manager	53 min	
A3	Vice President IoT	25 min	
B1	Head of System & Analytics	41 min	Platform 2
B2	Head of Trend Evangelist	60 min	
B3	IoT Platform Product Manager	47 min	
C1	Senior Manager Field Application	53 min	Platform 3
C2	Director Product & Portfolio IoT	48 min	
C3	IoT Consulting & Partner Manager	35 min	
D1	Senior IoT Sales Manager	78 min	Platform 4
D2	Partner Manager	30 min	
D3	Head of Application Portfolio	47 min	
E1	Independent IoT Platform Market Expert	74 min	
Total	13 Interviews	636 min	4 Cases

Table 9: Overview of the Expert Interviews

All interviews were conducted in German via telephone from October to December in 2018 (see Table 9). The interview with E1, an independent researcher, helped to reflect upon all IoT platforms. On average, the interviews lasted 48.9 minutes (arithmetic mean). Together, they resulted in 636 minutes of audio material, which translated into more than 40,000 words after being transcribed in MAXQDA. Only quotes presented in Section A.4 were translated into English.

A.3.4 Data Analysis

The data collection and analysis process occurred iteratively as suggested by Eisenhardt (1989) and Yin (2014). The focus was on the discovery of governance mechanisms and their effects on complementary innovation across all cases. The coding followed two major phases. In open coding, 521 codes associated with over 600 interview quotes were created. In axial coding, 37 subcategories were identified that summarized open codes related to governance mechanisms and their stimulating or alleviating manifestation. The subcategories were clustered into 19 categories describing distinct governance mechanisms and their positive and negative effects on complementary innovation. Subsequently, the categories were assigned to the governance strategies. During this process, no other governance strategy was identified. Also, none of the mechanisms reported by the interviewees could have been assigned to the bundling strategy.

A.4 Findings

The findings of this paper provide evidence that cooperation with external firms is a major lever for building innovation capabilities in IoT platforms. Table 10 presents the key findings structured in the framework. It illustrates the mechanisms applied by the four POs to govern their complementors and shows their positive (+) and/or negative (−) effects on complementary innovation. Table 10 also highlights the cases that applied specific mechanisms. Since no case applied bundling, the strategy is not presented in this section or Table 10 but discussed later in Section A.5. The next sections present the findings in the form of a cross-case analysis guided along the framework.

A.4.1 Opening

All IoT POs share **technical & social boundary resources** with their complementors to facilitate technological development. Technical resources include open APIs, SDKs, and other knowledge provision forms like video-trainings. Developer communities or

hackathons represent social instruments that are used for co-creating apps and sharing the platform's roadmap with the ecosystem, e.g., to ensure alignment with the PO.

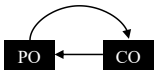
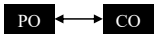
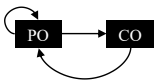
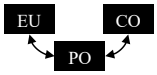
Governance strategies		Implications for complementary innovation (+) Fostering or (−) impeding mechanisms		Case evidence 1	2	3	4
Cooperative	**Opening** 	(+)	Technical & social boundary resources	X	X	X	X
		(+)	Multi-cloud strategy	X	X	X	X
		(+)	App stores for control & commercialization	X	X		
		(+/−)	Open source projects			X	
		(−)	Data control		X		
	Alliancing 	(+)	Partner management programs	X	X	X	X
		(+)	Contractual agreements	X	X	X	X
		(+)	Strategic partnerships	X	X	X	X
		(+/−)	Platform-to-platform partnerships	X	X	X	X
	Coring 	(+)	Modular microservice architecture	X	X	X	X
		(+)	Organic growth	X	X	X	X
		(+/−)	Co-creation projects		X	X	X
		(+/−)	Coring through acquisitions	X	X	X	X
Competitive	**Entering** 	(+)	Market attention		X		
		(+/−)	Monetization model of platform owners	X	X	X	X
		(−)	Cannibalization effect				X
	Pricing 	(+)	Subsidized development tools	X	X	X	X
		(−)	Complex subscription-based pricing models	X	X	X	X
		(−)	High homing & switching costs	X	X	X	X

Table 10: IoT Platform Governance Strategies and Distinct Mechanisms

Moreover, all POs pursue a **multi-cloud strategy**. This way, IoT platforms can run on different cloud infrastructures, such as AWS or Microsoft Azure. Third-party firms benefit from this freedom and must not fear potential vendor lock-ins.

Furthermore, PO1 and PO2 offer **apps stores** (i.e., marketplaces) to commercialize their own and complementary apps. App stores act as an incentive for value capture and equip POs with an instrument to control the quality of complements. PO1, for example, has strict rules that complementary apps must fulfill before they are offered in the store. PO3 promotes third-party marketplaces because of its own smaller range and the costs of building and maintaining the own app store. PO4 does not offer its own marketplace but references the shops of its seven platform sponsors—called a white-label solution.

In addition, while most POs keep their platforms' core functions closed to external developers, PO3 is exceptional. PO3 has established and actively participates in **open source projects**. While its Eclipse community drives innovative ideas, the coordination requires much organizational effort and can result in imitation by others as reported by an interviewee: *"There are good and bad examples [with our open source projects]. [A*

partner] has recently provided essential features. On the other hand, someone took our platform and made his own offering." [C3]

Furthermore, **data** was identified as a control mechanism of PO2. By dictating that data generated by the devices of end-users must be stored to a certain degree inside Platform 2, PO2 exercises power and control over all platform participants. Although platform managers of PO2 emphasized major advantages for end-users, such as central data access, strict rules might curb platform adoption and innovation due to lock-ins.

A.4.2 Alliancing

All POs have **partner management programs** with rules and regulations that partner firms must obey to engage in platform-related value creation and capture activities. They ensure equality among complementors and their seriousness of engagement. Within these programs, **contractual agreements** are often used to reduce value capture risks. For example, partner contracts of PO1 and PO2 define the protection duration of intellectual property (IP) and the terms and conditions for revenue sharing. Based on the interviews, four types of partners were identified: (1) platform resellers, (2) platform integrators, (3) cloud infrastructure providers, and (4) complementors.

Moreover, POs engage in **strategic partnerships** characterized by co-specialization and trust. POs preferably collaborate with companies that complement their traditional capabilities and foster their strengths. For example, PO2 and PO3 illustrate that partner firms benefit from their large installed base and industrial expertise. In return, partners should add strong data processing and analysis capabilities: *"We look for partners who are open and interested in investing in long-term, sustainable collaboration. Ideally, these are companies that complement our industry expertise accordingly." [C1]*

Furthermore, all POs engage in **platform-to-platform partnerships**. Two different types were observed: intra- and inter-platform cooperation. *Intra-platform cooperation* requires two POs to vertically develop a shared technology. For example, PO4's IoT platform is built on top of another company's platform with a horizontal approach, i.e., a platform that serves diverse domains as the technical backbone. Conversely, *inter-platform cooperation* involves two platform providers who are direct competitors and partners at the same time. Their relationship is of coopetitive nature. For example, PO1 and PO2 collaboratively developed PO2's first platform versions helping PO2 to enter the IoT platform market. Yet, the cooperation eventually resulted in a conflict that was impeding third-party firms to join the platform.

A.4.3 Coring

All IoT platforms encompass a **modular microservice architecture**. Microservices are autonomously deployable, modular components, which can be mixed and matched by complementors to rapidly develop new software-based products and services.

When it comes to the extension of the platform, POs pursue three different strategies. First, all POs extend the platform through **organic growth**, which refers to the in-house development of features. Second, besides PO1, all POs have engaged in **co-creation projects** at the core of the platform. In these, POs and complementors jointly develop core services that benefit all platform participants. While co-creation can increase a platform's growth in features, it results in shared ownership or increased dependence. This downside was evident in the case of PO2 which received much support from PO1 in the development of its first platform versions. As the project led to a buggy platform, it was stopped but affected the mutual trust of the two long-standing business partners. Third, all POs engage in **coring through acquisitions**. On the one hand, the absorption of third-party firms may decrease overall incentives to develop apps in the future. On the other hand, a technically advanced platform can attract other third-party firms to the platform, increasing the ecosystem's overall innovation capacity. One of the managers of PO3 argued as follows: *"Our partners and external developers, who are our focus, benefit from it. Of course, the purchase extends our ecosystem. But the bottom line is that with [an acquired technology], we can develop new apps faster and generate different innovation cycles." [B3]* However, managers of PO1 said that the right scope and scale of acquisitions are essential. In 2016, PO1 acquired an Italian cloud provider and a Norwegian company for industrial software solutions. After adding the key IoT features to its platform, PO1 created awareness among industrial business end-users.

A.4.4 Entering

In addition to third-party applications, all POs offer their apps in app stores. If both POs and complementors offer similar apps, there is direct competition. Three possible outcomes were observed based on this initial situation. First, an interviewee from PO2 stated that intra- and inter-platform competition (i.e., within and outside the ecosystem) increases **market attention**. *"[Competition] between different platform and solution providers is also desirable because the market gets so much more attention […] [and] promotes innovation early since no provider is a market leader at this point in time and there are manifold potentials for optimization." [B2]*. However, other platform cases did not report such positive market attention effects based on direct competition.

Second, all POs offer own apps as part of their **monetization model** and to increase the early adoption of business end-users. For example, PO2 has entered the market for machine analytics with its own app. With it, PO2 competes with three complementors who offer similar solutions. Although all apps comprise rather similar features, PO2 profits from the largest number of downloads. This facet shows that end-users prefer apps developed by the platform owner compared to those of third parties. The finding also illustrates that platforms without ready-to-use apps may not convince potential customers to affiliate with it, taking away positive indirect network effects, i.e., growth on one side of the platform leads to growth on the other side of the platform.

Lastly, platform managers of PO4 reported a **cannibalization effect** that occurred when PO4 launched a new industrial messenger app on one of its marketplaces. The new cloud-based product rivaled an on-premises version of one of its sponsors. As sales of the sponsor decreased PO4 decided to stop offering the new app on its marketplace: *"In fact, we have experienced that the [Platform 4] messenger has created more internal and external confusion and absurdly, rivals our own product that we have been selling directly to our customers for many years. We've found that our customers do not understand the difference between the new and our old messenger. Therefore, we are currently very cautious regarding the promotion of the [Platform 4] app" [D4]*.

A.4.5 Pricing

All POs **subsidize** complementors with free development tools, such as SDKs or video-trainings to encourage the development of complementary apps. However, their use of **subscription-based** pricing models results in monthly platform costs based on, e.g., computing power and number of connected devices. This may affect complementors in two ways. First, as both end-users and complementors must pay monthly license fees for platform access, POs create high **homing costs**. As a result, complementors do not affiliate with more than one IoT platform reducing the possibility to scale profits. Second, once connectivity with hundreds of devices is established, enterprise customers face high **switching costs**. They increase lock-in effects and make both complementors and end-users more dependent on the focal platform.

A.5 Discussion

This study yields two major findings. First, it shows that five of the six governance strategies are pursued in IoT platforms. This finding contributes to the literature on B2B platforms (Gawer & Cusumano, 2002; Karhu et al., 2018) and adds particularly to our

knowledge of IoT platforms. Prior work on IoT platforms has examined the importance of different governance mechanisms (Schreieck, Hakes, et al., 2017) and business models (Hodapp, Remane, et al., 2019). However, a comprehensive framework of distinct cooperative and competitive governance strategies used in IoT platforms did not exist.

Second, the findings of this study explain how six governance strategies influence complementary innovation. While the cooperative strategies lead to positive effects, the competitive strategies result in rather negative effects or have not yet been applied. Still, the latter are essential to capture some of the value that is co-created upon the platform. The following sections distill the findings' contributions to research and practice

A.5.1 Contributions to Research

Opening shifts the locus of value creation from within the firm toward the ecosystem. POs execute this strategy by giving complementors access to boundary resources, cloud infrastructures, and app stores. Often-cited papers on digital platforms present tradeoffs coming with high degrees of openness, such as "openness vs. control" (Boudreau, 2010) or "diversity vs. appropriability" (West, 2003). Interestingly, none of these negative effects were associated with open B2B IoT platforms. One argument for the absence of destructive effects lies in the IoT platform market's complexity and fragmentation. As the development of new IoT apps requires technical and contextual know-how, only a few complementors can innovate. Thus, network effects are much weaker compared to B2C platforms.

Alliancing intends to establish close interfirm relationships based on co-specialization and trust. The findings of this study confirm that partner management and contractual agreements have positive effects on value co-creation (Huber et al., 2017; R. Kapoor & Lee, 2013; Sarker et al., 2012). Moreover, the study reveals two types of platform-to-platform partnerships in the IoT context: intra- and inter-platform cooperation. This conceptualization adds to the notion of inter- and intra-platform competition coined by Tiwana (Tiwana, 2015a).

Coring aims at extending the platform core. IS scholars have argued that modular platform architectures equipped with standard interfaces foster external innovation and ensure sustainable platform development (Tiwana, 2015a; Tiwana et al., 2010; Yoo et al., 2010). The evidence of this study is in line with prior findings, that is, microservices function as modular components in IoT platforms. Crucially, POs must improve their capability of rapidly identifying new and promising technologies and integrating them into their own platform—letting the entire ecosystem benefit from them.

Entering is associated with both positive and negative effects on external innovation in academia. While IS and management scholars found predominantly positive effects (Foerderer et al., 2018; Z. Li & Agarwal, 2017), economic scholars suggested destructive effects motivated by capturing higher rents (Choi & Stefanadis, 2001; Farrell & Katz, 2000; Gawer & Cusumano, 2002). In the B2B IoT platform context, entry is often performed accidentally when platform owners offer their own apps in their stores. This is done for two reasons. First, many customers request apps developed by the PO himself—possibly due to trust. Second, these apps are part of the owner's revenue model. Thus, entry decisions should balance short-term financial incentives with the benefits of flourishing ecosystems.

Pricing decisions aim at attracting one side to the platform by low prices in order to increase indirect network effects (Economides & Katsamakas, 2006; Eisenmann et al., 2006; Hagiu, 2006, 2009). However, IoT platforms cash in from both complementors and end-users. Subsidies are only provided through free boundary resources confirming prior findings (Schreieck, Hakes, et al., 2017). High prices and varying pricing models, such as pay-per-use, impede adoption and increase both homing and switching costs.

Bundling seeks to spur complementary innovation through positive indirect network effects. POs can combine two or more key services and offer them together in one set—the bundle. End-users become thus attracted by the extensive set of features by a single PO and, in turn, attract more complementors (Bender & Gronau, 2017; Eisenmann et al., 2011; Karhu et al., 2018). However, no IoT PO applied this strategy. The absence of the strategy can be explained by the IoT platform market's complexity and ongoing expansion (Lueth, 2017; Market Research Future, 2018). Market consolidation and determination of a few leaders may increase the strategy's value in a more competitive and mature market; as then, attracting large quantities of end-users might have a significant effect on overall leadership in the IoT platform market.

A.5.2 Contributions to Practice

The results suggest that POs should coordinate third-party firms through cooperation—the dominant meta-level strategy. This strategy includes three key recommendations for managers. First, platform managers must align the degree of platform openness with their traditional business. Software companies (PO1 and PO4) should open up their platform, but retain control over core functions. This helps to protect their platform core and software skills in data processing and analytics—their competitive advantage. Conversely, hardware firms (PO2 and PO3) must focus on their capabilities in device

management, automation, and engineering. Opening the platform can grow the number of complementors and end-users—without giving away the device-selling business.

Second, POs should build strong partnerships based on co-specialization. Due to the technical complexity and fragmentation of the IoT market (Schreieck, Hakes, et al., 2017), collaboration with strong partners is essential to provide end-to-end IoT solutions. This ensures that most IoT-related needs of enterprise customers can be served by a single firm and its partners. Software firms should build strong partnerships with device integrators. Hardware firms should strengthen their abilities in software development and analytics.

Third, POs should extend the platform through co-creation projects or acquisitions. Cooperation in and across ecosystems can help to accelerate the development of the platform while sharing the costs for the development. Co-creation projects are key to master the technological complexity in the IoT context (Guth et al., 2018; Wortmann & Flüchter, 2015). Moreover, managers should also consider coring new technologies through acquisitions. This instrument, if applied at the right scope and scale, can have positive effects on the technical evolution of the platform and thus drive complementary innovation.

A.6 Conclusion, Limitations, and Future Research

The goal of this study was to understand which cooperative and competitive governance strategies are applied by IoT platform owners and how they influence complementary innovation. This question was answered by conducting a multiple case study of four IoT platforms involving 13 interviews. The findings of this work show that five of the six governance strategies derived from the literature are applied in IoT platforms. In sum, cooperation is the dominant meta-level strategy. It allows platform owners (1) to share the platform and other resources with the ecosystem (opening), (2) to complement own weaknesses utilizing co-specialization with strategic partners (alliancing), and (3) to continuously extend the platform itself (coring). Overall, governing B2B platform ecosystems requires platform owners to balance cooperation for value co-creation and competition for value capture.

This study is not without limitations. First, the empirical inquiry is based on a limited number of IoT platform cases, but appropriate given the complexity of each ecosystem (Eisenhardt, 1989). Second, the case sample does not include companies, which are headquartered outside of Germany, decreasing its potential to compare global differences and to make generalizations for all IoT platforms (Yin, 2014). Yet, all case firms

operate globally. Third, all interviews were conducted within a limited timeframe, which could have possibly reduced the identification of all cooperative and competitive ecosystem dynamics.

Finally, two avenues for future research are provided. First, future studies should test (and extend) the governance strategies framework empirically. Scholars could conduct in-depth case studies of large B2C (e.g., Amazon) or B2B (e.g., Alibaba) platforms that exhibit strong network effects. This might provide more robust findings on cooperative and competitive dynamics. Second, future research should study turnaround conditions that lead to a changed strategic focus from cooperation to competition in IoT platforms. Scholars should use longitudinal studies and factor in the impact of industry standards for this research objective. This might reveal more insights into interfirm relationships as called for by researchers (Ceccagnoli et al., 2012; Huang et al., 2013).

Paper B – Cocreation Challenges in Enterprise IoT

Attribute	Description
Title	How an Incumbent Telecoms Operator Became an IoT Ecosystem Orchestrator
Short title	Cocreation Challenges in Enterprise IoT
Authors	Christian Marheine, Christian Engel, Andrea Back
Year	2021
Publication outlet	MIS Quarterly Executive
Publication type	Journal paper
Ranking	B (Jourqual 3)
Publication status	Accepted

Table 11: Bibliographical Metadata on Paper B

Abstract. The journey to become an ecosystem orchestrator for an Internet of Things (IoT) platform poses considerable strategic challenges for industry incumbents, which arise along three dimensions: platform, ecosystem and value cocreation. We describe how "TelcoCorp," a large European telecoms operator, addressed these challenges as it established its enterprise IoT platform ecosystem. Based on the TelcoCorp case study, we provide recommendations that IT and business executives can use to become orchestrators in the IoT instead of fearing platform competition.

Keywords. Internet of things, platform, ecosystem, value cocreation, B2B.

B.1 Challenges and Opportunities for Industry Incumbents in Enterprise IoT Initiatives

The Internet of Things (IoT), which interconnects the physical and digital worlds, is shifting organizations' value creation from selling traditional products to marketing "smart products" with integrated digital service offerings (Porter & Heppelmann, 2014). Moreover, the digital economy has taught us the power of platform businesses. They connect a plethora of technology providers and users, and profit from "network effects" (Eisenmann et al., 2011; Katz & Shapiro, 1986), which result in ever-more users, data, innovation and transactions. In the business-to-business (B2B) context, the combination of IoT and digital platforms has stimulated a race for technology leadership. Native platform providers such as Amazon's Web Services, Microsoft's Azure and Google's Cloud, all of which can be used as IoT platforms, compete against long-established product and service firms, referred to in this article as "industry incumbents." These incumbents include, for example, AT&T with its IoT Control Center, GE with its Predix platform offering and IBM's Watson IoT platform. According to market researchers, there are now over 600 IoT platform offerings worldwide competing in a market worth $6.7 billion in 2019 (Lueth, 2019).

Industry incumbents have decades of experience of improving their businesses and supply chains, and now have the opportunity to extend their business models and value creation logic through IoT platforms (Van Alstyne et al., 2016). As a collection of software resources, IoT platforms create value by exploiting the generic capabilities in devices, connectivity, data, security and application management, connecting physical things with digital entities, and technology adopters with third-party providers. The latter can leverage a platform through hardware- and software-based "complements," forming an ecosystem of collaborating organizations around the IoT platform. The processes and activities of these collaborating organizations to integrate resources into the IoT platform are referred to as "value cocreation" (Grover & Kohli, 2012). In enterprise IoT, this value comes in various forms, including devices (e.g., the EnOcean multisensor), connectivity (e.g., Cisco's network technologies), analytics tools (e.g., Microsoft's IoT Edge toolkit) and applications (e.g., GE's asset performance management software). All of these forms of value improve customers' business operations.

To benefit from an IoT platform business model, industry incumbents must learn how to establish their IoT ecosystems and orchestrate third-party providers for value cocreation. To date, there has been little investigation of industry incumbents' experiences of

establishing and orchestrating IoT platforms and ecosystems. Prior research, however, hints that they will need to master how to:

1. Provide a platform with a standalone value proposition
2. Establish an ecosystem of third-party IoT providers
3. Foster value cocreation for IoT customers (Hein, Weking, et al., 2019).

In addition to mastering these three dimensions (i.e., platform, ecosystem and value cocreation), senior executives in industry incumbents must ensure their businesses have the competencies needed to meet the challenges specific to the enterprise IoT context. This context includes industries such as manufacturing, logistics, automotive, energy, construction and healthcare, and involves facing challenges in three particular areas: technical (e.g., dealing with a variety of different types of devices), organizational (e.g., negotiating lengthy sales processes) and regulatory (e.g., complying with national or industry standards). These challenges reduce the chances of successfully establishing an IoT platform ecosystem that dominates multiple industries with a "horizontal" market approach (Pauli et al., 2021).

Because of this complexity, companies (even when competing in a different line of business) often join forces to cocreate value in the enterprise IoT space. Thus, successful journeys to establish enterprise IoT platforms and ecosystems differ considerably from those in consumer markets, and increase the need for platform owners to orchestrate the IoT resources and capabilities of organizations that collaborate in the ecosystem to cocreate value.

In this article, we present a case study of a leading European telecoms company, which we refer to anonymously as "TelcoCorp." We describe the major challenges TelcoCorp faced as it established its IoT platform ecosystem between 2015 and 2020, and the strategies it adopted for dealing with the challenges. (Our case study methodology is described in the Appendix.) From our analysis of the TelcoCorp case, we show how industry incumbents in general that want to establish and foster IoT platform ecosystems can adopt early growth strategies that move beyond merely offering a platform. To thrive and survive alongside established IoT platforms or digital entrants, industry incumbents need to learn how to build on their strengths to become ecosystem orchestrators. As such, they will be able to combine customers' domain and partners' technological knowledge to foster growth both as a horizontal platform provider and as a vertical provider serving specific industries.

As well as describing the challenges that industry incumbents face when establishing enterprise IoT platforms, we also provide actionable recommendations based on how TelcoCorp managed and overcame the challenges. These recommendations can be used by industry incumbents, and firms that operate traditional pipeline businesses, that want to become IoT orchestrators and capitalize on digital service opportunities. Our insights from the TelcoCorp case provide IT and business decision makers with strategies to cocreate, deliver and capture value in enterprise IoT initiatives, and guidance on how to embed these strategies in larger transformation journeys from pipeline businesses to platform businesses.

B.2 Dimensions of Orchestrating IoT Platform Ecosystems for Value Cocreation

To successfully establish IoT platform ecosystems, industry incumbents must develop the orchestration capabilities (Schreieck et al., 2021)that will enable them to benefit from value cocreation. In the context of enterprise IoT, the term "orchestration" denotes an organization's ability to enable and organize a platform's digital resources, the customers and third-party providers in the ecosystem, and their collaborative cocreation activities. In line with state-of-the-art information systems research, organizations that seek to become successful orchestrators need to consider the three dimensions mentioned above and now depicted in Figure 6: platform, ecosystem and value cocreation (Lusch & Nambisan, 2015).

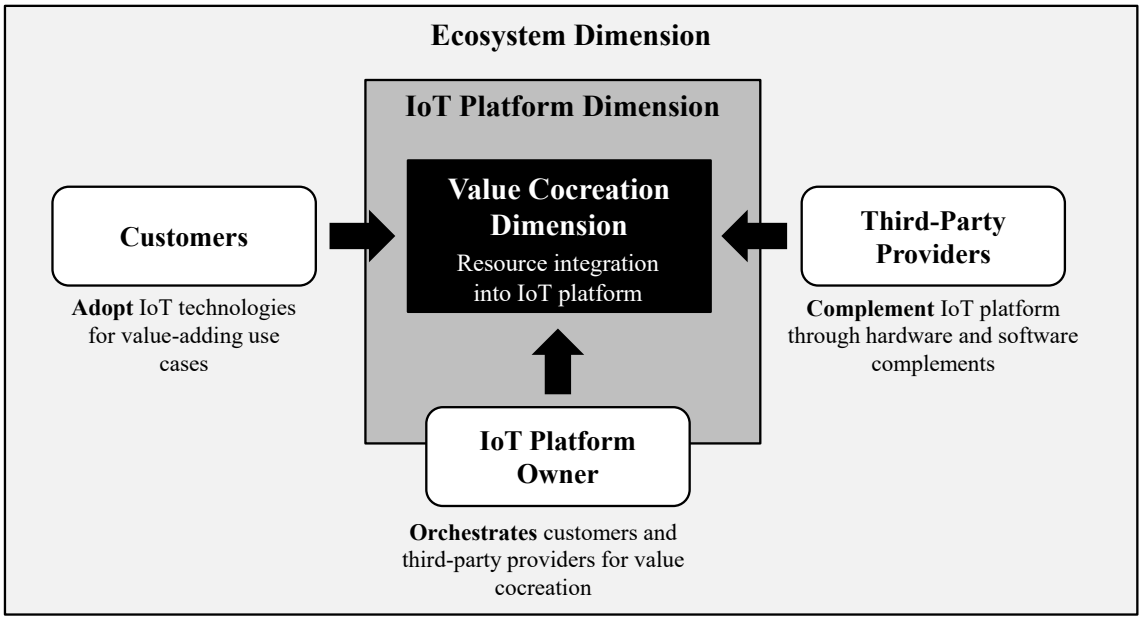


Figure 6: Three Dimensions of Value Cocreation in IoT Platform Ecosystems

First, the IoT platform dimension provides the technological foundation to cocreate value through using openly designed application programming interfaces (APIs) (Karhu, Gustafsson, Eaton, & Sørensen, 2020) that must be generic enough to communicate with heterogeneous hardware and software complements, but specific enough to benefit a single industry. The IoT platform is owned and controlled by the platform owner, which takes on the role of the ecosystem orchestrator. The platform owner's challenge is to manage the diversity of hardware and software on the IoT platform to ensure these elements can connect with heterogeneous industrial assets on the one hand, and to provide applications for different industries and types of customers on the other (Marheine & Pauli, 2020).

Second, on the ecosystem dimension, customers and third-party providers form a non-hierarchal network of collaborating individuals and businesses, including OEMs, systems integrators, device manufacturers and software developers (Jacobides et al., 2018). Ecosystem challenges arise from transforming existing business relationships into partnerships and onboarding new partners that create value-adding complements, as well as managing the customers that consume the solutions provided by complementors. This classic problem of simultaneously growing the supply and demand sides of a platform is known as the chicken-and-egg problem.

Third, the value cocreation dimension refers to the collaborative activities between ecosystem partners to generate customer value, such as enterprise IoT solutions that are integrated, reliable and secure. Complexity emerges from the need to bring together customers and third-party providers to develop value-adding applications. Hence, the orchestrator must bridge knowledge gaps between customers' domains and third-party providers' technologies to enable the creation of usable, value-adding IoT applications. Moreover, platform owners or orchestrators must establish a governance regime for defining the IoT development and commercialization opportunities of third-party providers (Tiwana et al., 2010).

Overall, an IoT platform ecosystem thus forms a socio-technical system that comprises an extendable software base that can be complemented by an ecosystem of third-party providers. The successful establishment of an IoT platform ecosystem requires an organization to launch an IoT platform, nurture an ecosystem of collaborating organizations and foster value cocreation activities among ecosystem partners to develop and market value-adding IoT complements. Industry incumbents require orchestration capabilities to trigger and manage the value cocreation process effectively, and to leverage growth and innovation. However, acquiring the necessary orchestration capabilities to

compete as an IoT platform owner poses a significant challenge to industry incumbents. Despite recent work on the dynamics of ecosystem orchestration (Linde et al., 2021) and evolving technologies (Sandebrg et al., 2020), research in this area is still very limited. To address this gap, in this article we report on the rich empirical findings from our study of TelcoCorp and provide insights into the orchestration capabilities needed to address the novel managerial issues associated with enterprise IoT initiatives.

B.3 TelcoCorp's Recognition of the IoT Business Opportunity

TelcoCorp is a large European provider of information and communication technology (ICT) services, serving consumer and business markets with mobile and broadband connectivity, media entertainment and cloud services. As the national market leader in mobile communications with a market share of about 60% and 19,000 employees, TelcoCorp generated total revenue of $12.3 billion in 2020—40% of which came from business customers. However, since the early 2010s, TelcoCorp had been facing significant challenges with stagnating revenues and, more recently, declining revenues. Like many other European telecoms companies, TelcoCorp has suffered from decreasing price levels in saturated markets (McKinsey & Company, 2019) and competition from over-the-top (OTT) services provided by non-telecoms companies. Examples include WhatsApp, Microsoft Teams and Disney+, which have entered the market with rich content, heavy advertising and direct-to-consumer offerings via the Internet, partially disrupting TelcoCorp's traditional value chains. TelcoCorp's strategic response to these challenges was to radically improve its operations and extend its business by offering novel data-based services.

As industry incumbents, telecoms operators like TelcoCorp are in a good position to extend their value proposition from just providing connectivity to offering IoT platforms and associated digital services—i.e., to providing an "IoT technology stack" (Wortmann & Flüchter, 2015). Given that IoT applications provide connectivity between a physical device and scalable back-end IT systems, telecoms operators have a strong competitive edge. Nick Earle, chief executive of Eseye (an IoT solutions provider), has emphasized the need for reliable and secure connectivity in IoT applications: *"[The] major reason why 80% of IoT projects fail, is the fact that organizations cannot actually connect their devices in order to extract the data they need to support their expected business outcome"* (IoT Now Magazine, 2020). By providing IoT platforms, telecoms operators can not only operate and manage the data running through their networks, but can also harness it to alleviate many of their current challenges, such as stagnating revenues,

structural inflexibility and the large capital investments needed for network rollouts and cloud installations (Wakounig, 2021).

Despite the great potential offered by new network technologies such as 5G mobile networks, telecoms operators must learn how to expand their pipeline business of buying, installing and maintaining connectivity infrastructure into a platform business. This expansion causes new management challenges in each of the three orchestration dimensions—platform, ecosystem and value cocreation—as industry incumbents' IT and business executives steer their companies on the transformational journey from a technology enabler to an ecosystem orchestrator role that coordinates resources and fosters value cocreation on top of an IoT platform.

Industry analysts were predicting that the emerging IoT market would provide a big growth opportunity for telecoms operators. Telco Corp was eager to exploit this opportunity, as indicated by the Head of Business Customers:

> *"With enterprise IoT, we try to shift margins by diving deeper into our customers' businesses and learning more about their industries. So, we do not just equip them with mobile connectivity services, but also connect their assets. Hence, we decided to become a data-as-a-service company that, by leveraging innovation, can achieve greater lock-in effects."* Head of Business Customers, TelcoCorp

Before deciding to enter the IoT market, as a leading telecoms player, TelcoCorp had built up three significant competitive advantages that would help it in the future to become an IoT orchestrator. First, it operated the nation's largest mobile broadband network and thus enjoyed a reputation of trust and security. Leveraging its core value proposition as a connectivity service provider to build closer ties with business customers would help TelcoCorp to create and capture value in the enterprise IoT market. Second, the company had over 15 years' experience as an IT systems integrator, with a focus on SAP and Microsoft applications. In the words of TelcoCorp's Head of IoT, *"We have a unit of 400+ employees who do this professionally every day, not for IoT but very much for the ERP business domain in general."* Third, TelcoCorp provided many auxiliary services, such as 24/7 support, billing and maintenance, which facilitated its business network—and future IoT partners—to implement service-based business offerings on top of network-enabled devices.

Thus, before launching the IoT initiative, TelcoCorp had already been recognized as an IoT enabler with various connectivity-related solutions (e.g., 2G, 3G and 4G). However,

driven by a belief in the future business potential of IoT, TelcoCorp's management decided to more actively shape the market as an IoT ecosystem orchestrator.

B.4 TelcoCorp's Journey from IoT Enabler to Orchestrator

In line with its strategy of exploiting digital growth opportunities, TelcoCorp launched its IoT platform initiative in late 2014. The initiative was led by a new department that has steadily grown from less than five employees in 2015 to over 50 in 2020. From the beginning, TelcoCorp knew that realizing its IoT strategy would require key resources (a connectivity-based IoT platform) that enable customers and partners to innovate both IoT devices and applications (an IoT ecosystem) in joint activities (value cocreation). Thus, to implement the strategy, TelcoCorp needed to develop orchestration capabilities. We describe and organize the challenges TelcoCorp experienced and managed on its journey to establish its enterprise IoT platform ecosystem along the three dimensions of platform, ecosystem and value cocreation (Lusch & Nambisan, 2015).

B.4.1 Dimension 1: From Connectivity to IoT Platform

As of early 2015, TelcoCorp's role as an IoT enabler was to help the emerging IoT market to flourish. It faced several challenges as it set about building an enabling IoT technology, particularly in the areas of establishing a new IoT network and a platform-based modular architecture that would enable the integration of digital and physical resources. The latter involved TelcoCorp considering whether to make or buy the IoT platform.

IoT Network Challenges. The first challenge was to *build an ICT infrastructure that lowered the entry barriers for realizing IoT use cases.* Prior to 2015, the growth of the national IoT market had been constrained by the expensive SIM-card-based licenses customers had to buy to connect their devices, using TelcoCorp's 3G and 4G mobile networks. In April 2015, however, senior executives at TelcoCorp decided to deploy a new wireless IoT network—called the Low Power Network (LPN)—that facilitated long-distance communication at low data rates. By using a license-free radio frequency spectrum, the LPN significantly reduced the cost of IoT use cases with low energy consumption. For example, the LPN enabled the use of sensor devices with a battery life of over ten years. In addition, the LPN was powerful and secure, and provided extensive geographical coverage. Because the LPN operates via unique IDs, not SIM cards, TelcoCorp was able to significantly reduce hardware-integration and operational costs:

> *"We built the LPN network in […] so that certain use cases could be built on it. A few years ago, LPN was totally new and there was little hardware available. That is why we created device catalogs to ensure that hardware could get qualified for this network and would function smoothly in it."* Sales Manager, TelcoCorp

Another challenge arose from the need to *accelerate LPN expansion to drive IoT innovation.* To speed up the roll-out of the LPN, TelcoCorp drove the development of new communication standards by becoming a founding member of the LoRa Alliance—a non-profit association that fosters low-power network technology. Strategic partnerships with two major government organizations—the national railway and the postal company—helped to co-finance the cost of expanding the LPN, which particularly benefited rural areas. By the end of 2016, the LPN covered 95% of the country. Overall, its roll-out lowered connection costs and strongly stimulated IoT demand and thus laid the foundation for the market to create new IoT devices and digital services:

> *"The transition to higher layers of the IoT technology stack requires trusted, secure and scalable networks that enable specific IoT use cases, such as [using the] LPN for networking over long distances and for worldwide use."* IoT Project Manager, TelcoCorp

Later, in 2018, TelcoCorp complemented the LPN by deploying commercial communication technologies, such as Narrowband (NB) IoT or 5G, thus increasing its IoT momentum. By the end of 2018, TelcoCorp could not only provide a scalable IoT network, but also offer connectivity for IoT applications at different levels of scope—from battery-powered devices that sent little data (e.g., NB-IoT) to real-time applications that regularly transmitted large volumes of data (e.g., 5G). TelcoCorp was now perceived as an IoT connectivity "enabler"—but its ambitions were much wider than this.

Digital and Physical Resources Challenges. TelcoCorp recognized that *"connectivity will eventually make [up] about 5% of the overall IoT revenue"* (IoT Project Manager, TelcoCorp), so saw the urgency to extend its service portfolio to the upper layers of the IoT value chain. The firm needed capabilities to professionally manage its IoT network and connected IoT devices and thus faced the challenge of deciding whether to *make or buy an interoperable IT infrastructure to connect devices, manage data and operate applications.* However, because TelcoCorp lacked internal capabilities needed to develop digital platforms, and to avoid large upfront investments, it licensed an existing IoT platform from a German technology provider that specialized in device, connectivity, analytics and application management. This cloud-based IoT platform was installed

in TelcoCorp's data center, which ensured the security of the platform and compliance with national regulations, and thus emphasized the importance of data security and privacy. TelcoCorp was now in a position to oversee the efficient management of the connected devices. In addition to centralized connectivity management, the IoT platform provided device management capabilities for full control over device status and costs:

> *"Imagine you have to update the firmware of your IoT devices, for example, SSL certificates expire at some point. […] You cannot put 1,000 maintenance technicians in airplanes, who visit the devices all over the world to make manual cable-based updates. This way, a single device update would kill the whole business case. […] You need functions that address devices from your back end to upload and download data, to push a firmware update or certificate for example."* Head of IoT, TelcoCorp

Another integration challenge arose from the need to *gather, store, process and maintain IoT data pipelines at scale.* This issue was linked to device and data management, and required TelcoCorp to flexibly scale its cloud storage up or down. It adopted a hybrid approach, based on its own infrastructure and the cloud-based platform services provided by the German technology firm and Microsoft Azure. This approach enabled TelcoCorp to overcome big-data-related management challenges when handling the volume, velocity and variety of IoT-based data pipelines. As a consequence, TelcoCorp was able to offer its customers flexible data- or analytics-as-a-service models on a utility or subscription basis (Dremel et al., 2017).

In summary, licensing an IoT platform with ready-to-use functions helped TelcoCorp to shorten time-to-market and focus on interoperability between its network infrastructure and the cloud-based IT systems. This interoperability ensured data security and enabled TelcoCorp to develop additional analytics capabilities. Together, the network and platform created a strong IoT market offering that prioritized scale through growing the numbers of devices and platform licenses.

B.4.2 Dimension 2: From Supply Hierarchies to an IoT Ecosystem

After successfully establishing the LPN and the IoT platform in late 2016, TelcoCorp's IoT department decided to leverage its existing business partners to develop an IoT ecosystem. This required TelcoCorp to change its organization and business relationships, shifting from traditional buyer-supplier relationships to relationships with third-party providers. This change, however, raised challenges in the areas of customer centricity and partner management.

Customer Centricity Challenges. To leverage the platform-based ecosystem and deliver customer value, TelcoCorp had to *address the chicken-and-egg problem.* Should it first seek to build the demand or supply side? Though focusing first on the demand side would yield direct revenue opportunities, a lack of internal capabilities could lead to IoT projects ending prematurely. Despite this risk, in mid-2016, the IoT department decided to leverage its existing mobile telecoms customer base first. It focused on signing up those customers with a lot of industrial assets that could achieve IoT-based efficiency gains. This approach enabled TelcoCorp to deepen existing relationships and expand its business from mobile device connectivity to asset connectivity. It also meant that TelcoCorp could then incorporate data- and analytics-based services in its existing business model. As a consequence, some customers started building ecosystems around its IoT technology:

> *"Everything we do [including enterprise IoT] is customer-driven. Our rather single-sided ecosystem approach to learning about our customer domains and their pain points helped to grow interest in the platform ecosystem and created much market attention. Our partners then grew naturally in the ecosystem, as partners see us not just as a network and platform provider but also as a sales channel."*
> Head of Business Customers, TelcoCorp

Another challenge was to *reduce customers' anxiety of dependence.* Business customers face risks when joining IoT platforms, such as the high cost of retrofitting assets with sensors and connectivity, potential lock-in and loss of intellectual property. TelcoCorp, a highly regulated and trusted company, addressed this challenge by operating open technologies: the IoT network (providing license-free LoRa connectivity solutions) and the IoT platform (providing open data access via APIs). In addition, TelcoCorp supported standard methods for integrating Microsoft and SAP applications into cloud solutions and on-premises IT systems, which gave customers control over their devices, data and systems. By offering these high-quality solutions with long-term support at low costs, TelcoCorp could reduce its business customers' level of perceived risks. This openness was well received by partners and customers:

> *"TelcoCorp has a solid brand that stands for trust, quality and reliability, and we had a great experience with them as a telecoms provider. We thus saw great benefits in partnering [with TelcoCorp for IoT]. In addition, other telcos did not invest in the IoT market. Smaller connectivity providers only offer closed network systems, [but] TelcoCorp provides an open network system, open IoT platform and*

> *open ecosystem, with partners to support projects, which made our choice easy."* Head of Digital and IoT, Customer 2

Partner Management Challenges. TelcoCorp's success in attracting customers to the demand side of the platform ecosystem generated much interest among providers of IoT complements, with many of them deciding to join the platform ecosystem. However, the growth in the supply side meant that TelcoCorp faced the challenge of *extending its traditional buyer-supplier relationships with an IoT-focused partner model.* TelcoCorp's IoT department responded to this challenge by launching an official partner program in early 2017.

TelcoCorp distinguished its traditional supplier relationships (e.g., with Ericsson), which were defined by deterministic outcomes regarding volume, time and price, from its IoT partnerships, which were governed by flexible partner contracts. In the words of TelcoCorp's Partner Ecosystem Manager, these contracts were based on "*mutual agreement that joint business opportunities are not quantifiable and risks are not mitigatable [when cocreating IoT solutions]."* Thus, ecosystem partners, including IoT device providers, systems integrators, consulting firms and software vendors, agreed when they decided to collaborate in the ecosystem that business opportunities and risks could not be clearly quantified or prevented because of the uncertainty in IoT business outcomes. This contractual arrangement requires more trust than conventional supplier relationships, where contracts definitively cover all business aspects.

Nevertheless, TelcoCorp still had to govern the ecosystem by defining and enforcing new rules that prescribed partners' development and commercialization opportunities, to mitigate competitive tensions among partners providing similar service offerings:

> *"Trust and corresponding partner contracts in the ecosystem help to prevent competition, but often only until an order worth millions is received, at which point one party will try to capture the biggest slice of the cake and also accept any legal consequences."* Consulting Manager, Partner 3

As TelcoCorp recognized the market need for retrofitting customers' assets (i.e., connecting devices to the Internet and IoT platform), it formed strategic alliances with hardware firms. Each device that was certified for TelcoCorp's networks was guaranteed to be interoperable with the cloud, and its data model was guaranteed to be compatible with TelcoCorp's platform. Moreover, as each type of certified device was rolled out at scale, traffic on its network and IoT platform increased, creating a win-win-win situation. The ability to retrofit customers' machines, buildings or plants with average

lifecycles of more than 30 years with IoT technology provides a competitive advantage because it allows today's assets to function with tomorrow's IoT technologies.

By the end of 2018, TelcoCorp had established about 30 IoT partnerships. While these partners allowed TelcoCorp to scale its connectivity and platform business, differences in firm size and culture were impeding joint actions for value cocreation. To streamline the onboarding and business operations of third-party providers, TelcoCorp faced the challenge of *setting up clear governance with roles, responsibilities and shared activities* that prescribed the value cocreation opportunities of third parties. TelcoCorp addressed this challenge by introducing the "ecosystem manager" role to establish rules and mechanisms that defined these governance-based structural arrangements. For example, TelcoCorp's partner ecosystem could extend the cloud-based IoT platform by using open APIs to create new complements. Partners either charged customers directly for these complementary products and services or indirectly through TelcoCorp. Each new IoT complement helped to extend the platform, resulting in a wide variety of generalizable and reusable digital services.

In addition to organizing joint marketing events, ecosystem managers established new performance-based ecosystem goals, such as shared customer lifetime value. However, as mentioned by the CEO of a partner, some partners still missed "*a shared strategy […] to set up a concrete plan on how to create value together."* (Co-CEO, Partner 4)

In summary, TelcoCorp had to provide mechanisms to ensure ecosystem partners could cocreate value. As well as a deep focus on customers, these mechanisms involved establishing new roles, such as ecosystem managers, that defined community goals and encouraged partners to collaborate in a value-oriented manner while also holding them accountable.

B.4.3 Dimension 3: From Value Delivery to Value Cocreation

Between 2015 and 2020, TelcoCorp had enabled many IoT use cases through delivering connectivity. But to move forward from just providing value through connectivity, TelcoCorp had to overcome challenges as it reconfigured its role in the IoT ecosystem from enabler to orchestrator of ecosystem partners cocreating business value. We illustrate how TelcoCorp addressed these value cocreator and business challenges by referring to three IoT use cases of cocreating IoT value (see Table 12).

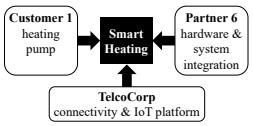
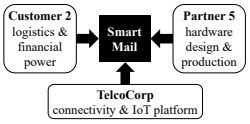
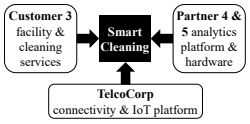
Illustration	Use case description
	Customer 1 (a leading building equipment supplier) uses an IoT-based smart heating application for predictive maintenance service of heat pumps. Its aim was to reduce field maintenance costs (about 700 field workers) by creating a service business with two new professions: remote diagnosticians and computer scientists. Together with Partner 6 (a hardware and systems integrator), it developed a successful regional pilot in 2016, which was rolled out nationwide in early 2017 with 3,000 connected heat pumps.
	Together with Partner 5 (a hardware designer and manufacturer, Customer 2 (a postal delivery service) created an IoT-based smart mail device that enables households to place simple delivery orders (such as stamps) by pressing a button on the device. Additional customer value was created by establishing an ecosystem of value-added services around the service button, such as food delivery. After a successful pilot in 2018, involving 1,000 households, Customer 2 has now deployed over 20,000 smart mail devices, which use TelcoCorp's LPN.
	Customer 3 (which provides facility and cleaning services) cocreated with Partners 4 and 5 an IoT-based smart cleaning device, initially as an internal service that allowed employees to place simple cleaning orders, e.g., cleaning coffee machines. Using this service-on-demand solution enabled Customer 3 to increase its operational efficiency by reducing the number of scheduled cleaning services. After a successful pilot in early 2019, the service button was extended with additional sensing functionality (e.g., temperature, CO2) in another cocreation project.

Table 12: IoT Use Cases of Value Cocreation

Value Cocreator Challenges. Before TelcoCorp and its ecosystem partners could start to cocreate IoT-based value, TelcoCorp faced the challenge of *understanding its customers' industries, use cases and technological needs.* This challenge was compounded because many use cases, even when appearing similar at first sight, required different solutions. For example, in the smart heating use case that required sensors monitoring the operating status of heat pumps, which are located underground in cellars, the connectivity solution and technology differed significantly from above-ground applications. Physical location, and other requirements, determine which technologies can be effectively used, with the result that superficially simple aspects can become a major challenge as use cases progress.

To address this challenge, TelcoCorp cultivated a "fail fast, learn fast" mindset. Its IoT department trained project managers to bridge customers' knowledge gaps related to technical aspects and the case's value-generating potential. To kick-start possible innovative IoT use cases, the IoT project managers ran co-innovation workshops with various partners, which followed agile principles and practices. More recently, TelcoCorp

has started to share technical knowledge through free online training using webinars and other channels, such as podcasts or innovation contests, to drive IoT-based innovation.

Another value cocreator challenge was how to *coordinate both customers and partners to co-develop IoT use cases.* When developing an IoT use case, it was vitally important that every partner focused on its role and the fundamental value proposition for the customer. The misalignment of roles had previously resulted in competition between TelcoCorp and partners as well as among partners.

Over time, TelcoCorp addressed the coordination challenge by evolving from a technology enabler to an ecosystem orchestrator. Successful IoT projects required it to orchestrate individual and standard IoT solutions, which meant it had to develop relationship-oriented capabilities that involve personal exchanges. For instance, the smart heating use case was orchestrated by TelcoCorp's IoT project managers, who subcontracted the creation of the gateway and antenna devices, and the associated software, needed to connect the cellar-based heat pumps with the IoT platform to hardware and systems integration partners:

> *"With TelcoCorp as a partner, we could already select large building blocks of their solution portfolio to realize our use case. As the business case was really tight, we decided that TelcoCorp should coordinate all aspects that were not heat-pump-specific. When decisions had to be made, for example, with regards to external competencies, they came up with different variants that all had a price tag, so we had the final say."* CIO, Customer 1

Business Value Challenges. To ensure it could capture maximum business value from IoT use cases, TelcoCorp needed to overcome the challenge of *scaling and scoping IoT use cases from prototype to full production.* Similar to customers who needed convincing use cases and evidence of concrete business value to justify their IoT investments, TelcoCorp, and its third-party partners, needed to capture value from IoT use cases through continuous revenue streams and growth of their customers' digital transformations:

> *"The challenge in IoT is actually rarely a technological one, but rather where exactly to generate value, how to develop the business case and how to transition your customers and partners into the pay-per-use model."* Consulting Manager, Partner 3

The scale of IoT use cases depends on the number of connected devices, the volume of data transmitted and the degree of standardized communication, whereas the scope is

determined by deploying hardware and software complements across different industries. To increase both the scale and scope of IoT use cases, TelcoCorp used an agile approach to orchestrate the ecosystem—starting with co-innovation workshops, then early proofs-of-concept and finally moving to prototype-testing. Moreover, the firm used its financing power to make IoT use cases with weak business cases profitable early on, for example, by ordering higher quantities of devices to reduce unit costs and to lower the overall service offering costs. Although co-financing use cases with partners was risky, there were several examples of this approach boosting ecosystem growth. Though new roles, such as IoT project and ecosystem managers, signaled a commitment to the ecosystem value capture approach, TelcoCorp's internal bonus-oriented incentive schemes still favored its traditional cash cow business, with those selling large connectivity packages receiving bigger bonuses.

TelcoCorp's final business value challenge was to *balance the development of standard vs. individual IoT solutions.* This key trade-off arose from the firm's go-to-market strategy. TelcoCorp's traditional business model was based on scale—a horizontal market approach—but the IoT department saw that there was much value capture potential in providing vertical industry-specific solutions. To address this challenge, TelcoCorp pursued a hybrid approach: co-developing vertical end-to-end solutions in the short term and scaling generic solutions across industries in the long term—as reported by one of TelcoCorp's partners:

> *"In [TelcoCorp's] IoT platform ecosystem, we try to achieve economies of scale with the projects we co-develop and thus place certain components as standard modules for other joint customers to reuse."* CTO, Partner 2

For example, the hardware design and software modules from the smart mail use case were reused in the smart cleaning use case to develop a multi-sensor device. Today, that device supports various smart building applications with services like ordering food and drinks, making it scalable across other industries, such as banking, retail and insurance.

To summarize, TelcoCorp took on the orchestrator role and co-developed end-to-end vertical solutions whenever it saw an opportunity to leverage its customers or scale generic downstream functionality across industries. Table 13 summarizes the key challenges in all three dimensions (platform, ecosystem and value cocreation) that TelcoCorp faced on its journey to establishing an IoT platform ecosystem and the actions taken to address them. Other telecoms operators seeking to extend their own IoT service offerings can use these actions as a source of guidance or inspiration.

Dim	Area	Challenges for TelcoCorp	Actions taken
Platform	IoT network	Building an ICT infrastructure to lower the entry barriers for complementors' and customers' IoT use cases	Deployed a network designed to facilitate various IoT use cases, even those with weak business cases, at different levels of scale and scope (e.g., local vs. regional vs. global)
		Accelerating ICT infrastructure expansion to drive IoT innovation	Co-financed the network rollout (e.g., LPN) with strategic partners (e.g., with the national postal company)
	Digital and physical resources	Making or buying an interoperable IT infrastructure to connect devices, manage data, and utilize applications	Licensed an existing IoT platform with device, connectivity, data and application management capabilities to shorten time-to-market and focus on integration with own systems
		Gathering, storing, processing, and maintaining IoT data pipelines at scale	Adopted a hybrid approach with own data center and cloud-based offering (e.g., Microsoft) to offer customers a flexible data-as-a-service model (e.g., utility or subscription-based)
Ecosystem	Customer centricity	Addressing the chicken-or-egg problem to grow the platform-based ecosystem	Focused first on existing customer base by deepening relationships (e.g., from mobile device connectivity to asset connectivity)
		Reducing customers' anxiety of dependence (e.g., lock-in effects)	Supported (partly) open and interoperable technologies and standards (e.g., APIs) and integration services (e.g., with third-party platforms or legacy systems), giving customers control over devices and data
	Partner management	Extending traditional buyer-supplier relationships to an IoT-focused partner model with new contracts	Balanced hierarchical and flat partner -management structures to cope with IoT-related uncertainty (e.g., less deterministic IoT partner contracts) and built alliances with hardware partners (e.g., for sensors)
		Setting up clear governance with partner roles, responsibilities, and shared activities with IoT focus	Established governance capabilities (e.g., ecosystem managers) that prescribe development and commercialization opportunities with return-based community goals (e.g., shared customer lifetime value)
Value cocreation	Cocreator role	Understanding customer industries, use cases, and technological needs	Trained staff to bridge IoT-related technical and business knowledge gaps (e.g., co-innovation workshops, online training)
		Coordinating both customers and partners to co-develop IoT use cases	Orchestrated IoT projects through architectural means (e.g., APIs) and relational mechanisms (e.g., IoT project managers)
	Business value	Scaling and scoping IoT use cases from prototype to productive usage	Made upfront bulk investments and co-financed the hardware design and development for feasible IoT use cases
		Balancing the development of standard vs. individual IoT solutions	Co-developed end-to-end IoT solutions when seeing an opportunity to grow with customers and scale generic functions across industries

Table 13: Summary of TelcoCorp's Challenges and Actions to Address Them

B.5 Recommendations for Orchestrating Enterprise IoT Platform Ecosystems

Other industry incumbents, such as Bosch, Siemens, Hitachi and Toyota, face similar challenges to those of TelcoCorp as they embark on their journeys from IoT enablers to IoT ecosystem orchestrators. Even though they operate in different industries, there are many similarities in their business mixes that make the insights from the TelcoCorp case relevant for industrial firms with traditional product and service businesses. These similarities include deep customer relationships, streamlined supply chains, traditional products or service businesses, and data access to assets and customers. Hence, our recommendations, which have been derived from our analysis of TelcoCorp's IoT journey, are applicable to all industry incumbents—including IoT customers and third-party providers—that seek to become orchestrators of their IoT platform ecosystems. For example, Siemens orchestrates its MindSphere ecosystem, has adopted Microsoft Azure technology and complements Amazon Web Services with its applications, demonstrating the dynamics of taking on different roles in IoT ecosystems. We believe that the following four recommendations will help IT and business leaders in industry incumbents to position their organizations for competitive roles in the enterprise IoT landscape.

B.5.1 Augment Key Resources with a White-Label IoT Platform to Shorten Time-to-Market

Once an industry incumbent has decided to embark on a digital journey, and thus extend its traditional pipeline business with a platform-based offering, it immediately faces a make-or-buy decision. There are many commercially available IoT platforms that come with preconfigured modules for connectivity, devices, data, analytics and application management. So, why reinvent the wheel if you can find an off-the-shelf solution? In fact, many leading IoT platform providers, such as Siemens MindSphere and GE Predix, started their journeys by licensing existing platforms, and then customized and branded them to their needs—i.e., they adopted a "white-label approach" (e.g., Hermes, Guhl, Schreieck, Weking, & Krcmar, 2021). Access to standard modules not only facilitates the development of IoT applications and collaboration, but also ensures "plug-and-play" integration with heterogeneous devices through communication protocols that are continuously being updated as new standards are agreed.

By choosing an off-the-shelf IoT platform, industry incumbents can continue to strengthen their core resources, integrate them with the licensed platform and focus on

cocreating customer value. Moreover, this approach enables incumbents to shorten time-to-market and test IoT business opportunities without the need for large upfront investments in infrastructure, such as data centers, or building new software development capabilities. Incumbents should also ensure that the licensed IoT platform complies with their governance or business rules and directly creates internal or external value, such as a "freemium" dashboard to monitor connected field devices.

Industry incumbents that have already committed to developing their own IoT platform should focus on tightly integrating it with the organization's overall digital strategy, and tailoring it to their customers' and markets' needs to differentiate their IoT offering from the competition. This will ensure they are not creating two corporate identities or cultures that later cannot be unified.

TelcoCorp licensed its IoT platform from a technology provider. This decision not only shortened time-to-market (because of the pre-installed device, connectivity and application enablement modules), but also allowed TelcoCorp to capture value directly by overseeing its own network devices, including gateways and antennas, which reduced routine maintenance costs significantly, especially in rural areas.

B.5.2 Leverage the Existing Customer Base for Ecosystem Growth through Bundling or Upselling

Any investment in establishing an IoT platform—whether developed in-house or licensed—will require a clear adoption strategy to create returns. Growing an IoT platform requires the platform owner to address the chicken-and-egg problem. Should the initial focus be on growing the supply side (third-party providers) or demand side (customers)? We recommend that industry incumbents intending to establish an enterprise IoT platform ecosystem should first focus on the customer side. To foster growth, they can encourage existing customers to migrate to the platform. For instance, they can offer their customers a preconfigured self-service analytics dashboard to monitor, control and maintain connected IoT devices.

More generally, there are two strategies that incumbents can use to encourage IoT adoption. The first, more aggressive, strategy is to bundle key resources (e.g., device, connectivity) with the IoT platform, for example, by ensuring plug-and-play connectivity for certified devices. The second less aggressive strategy is to upsell by persuading customers to move from basic services (e.g., data-as-a-service) to advanced ones (e.g., analytics-as-a-service) that require industry-specific domain knowledge to function.

At TelcoCorp, the IoT sales department adopted the upsell strategy by leveraging its relationships with existing mobile telephony business customers—moving from sales of mobile and broadband connectivity to commercial asset connectivity. It targeted customers that had immense potential for gaining value from IoT, such as those in the three use cases. Building on its existing customer relationships and reputation for trust, TelcoCorp was able to deepen its insights into customers' business models and operations and to help them along their digital transformation journeys by providing data-based services that extend their business models.

Once a substantial number of existing customers have committed to the IoT platform, potential supply-side partners have a greater motivation to join the ecosystem because of the opportunities to capture value. Incumbents must be prepared to manage and cultivate partners synergistically. Though trust and alignment are helpful for encouraging partners to collaborate, incumbents should put governance mechanisms in place through clearly defined roles (e.g., ecosystem managers) and responsibilities. The governance rules should specify the types of value-adding complements third-party partners are allowed to develop (e.g., open vs. closed APIs) and how they can monetize their offerings (e.g., licensing via the platform provider or directly to customers). The rules will differ depending on the type of third-party provider (e.g., hardware or software) and should be transparent within the ecosystem so that each partner is equally accountable. Governance is an essential component of the IoT platform ecosystem orchestration role.

B.5.3 Follow a Hybrid Growth Strategy of Cocreating Individual IoT Solutions but Striving for Scale

To achieve deeply integrated, context-specific and high-value IoT solutions for customers while also allowing for scalability, industry incumbents will need to balance the trade-off between horizontal and vertical market approaches. Horizontal IoT solutions scale across different industries—for example, reusing an asset-monitoring dashboard originally developed to track the status of tractors in farming for tracking garbage trucks in a city context. Vertical IoT solutions, on the other hand, are end-to-end solutions for a particular industry segment.

Even though vertical solutions run counter to what industry incumbents are ultimately trying to achieve with their platform businesses, we found that it is crucial to emphasize customer value over technology if the platform provider wants to be a long-term partner in a customer's digital transformation journey. From a value cocreation perspective, vertical solutions benefit the entire ecosystem by maximizing shared customer lifetime

value. Vertical solutions require collaboration beyond the platform's resources, involving, for example, arm's length relationships in the form of co-innovation workshops to understand the problem and cocreate a solution. Once an individual solution is in place, platform owners can abstract functionality from it to create standard platform modules, fostering a virtuous growth cycle. And as the platform owner creates more dedicated industry solutions, new areas for value cocreation are opened up (Marheine & Pauli, 2020).

However, increased specialization in vertical solutions will shrink the target group of potential platform customers, and thus reduce the incentive for third-party providers to contribute further applications and the potential to benefit from network effects. Achieving the right balance between horizontal and vertical solutions is not straight-forward and should be considered at a strategic decision-making level.

One of TelcoCorp's partners described the trade-off balance as follows: *"In [TelcoCorp's] IoT platform ecosystem, we try to achieve economies of scale with the projects we co-develop and thus place certain components as standard modules for other joint customers to reuse."* (CTO, Partner 2). For instance, TelcoCorp's customers could reuse hardware and software modules from the smart mail use case to create a multi-sensor device solution. Thus, TelcoCorp's ecosystem had created an industry-agnostic smart product that could be applied in many smart building contexts across different industries.

B.5.4 Consider the Options for New Revenue Streams from IoT Data

When adopting or providing IoT solutions, industry incumbents need to strategically plan how to capitalize on IoT data. We recommend they consider three options: (1) bundling traditional product or service revenues with IoT services; (2) selling IoT-based data; and (3) offering the IoT platform, analytics or software as a service (Russo & Wang, 2019).

First, incumbents could connect or retrofit their assets to securely access data, and monitor and control the devices' functions remotely. For example, Honeywell bundled its vast installed base of process control equipment with a digital service suite in 2015 to monitor and control process outcomes in industries such as oil and gas. TelcoCorp offered similar data-based services to its heat pump customer, which profited from moving its business model from physical, technician-based maintenance to predictive, software-based maintenance scheduling.

Second, incumbents could monetize IoT data either by anonymizing and selling it via a marketplace or by offering it to third-party providers for a fee to develop new analytics-based models. For instance, Schindler created a smart elevator platform that allows third parties to display content or advertisements to people using its elevators. TelcoCorp had not sold the IoT data acquired from its customers but allowed its partners to access the data via open APIs (with the consent of its customers) to develop business applications.

Third, incumbents can license their IoT platforms to customers or partners providing data or development resources. For example, Siemens MindSphere charges royalties for access to its Mendix platform, which provides pre-built visual drag-and-drop functions that allow engineering domain experts to develop IoT applications. At TelcoCorp, the licenses for the LPN and the IoT platform enabled, for example, the smart mail and cleaning use cases. However, its partners added different software-based functions that increased both the scale and scope of the use cases. Each new connected device amplified the traffic on the network or platform, and thus increased the usage-based licensing fees.

B.6 Concluding Comments

In this article, we have described how an incumbent telecoms operator (referred to as TelcoCorp) transitioned from an IoT enabler to become an orchestrator of an IoT platform ecosystem. We believe that incumbents in other industries, especially those with deep customer relationships, also have the opportunity of becoming orchestrators and thus gain financial benefits through cocreating value with ecosystem partners. They wouldn't even need to develop a bespoke IoT platform, but could license a platform such as Microsoft Azure. Such a strategy would enable them to collaborate early and compete later in an adjacent, or even in the same market, with a platform or software offering (Karhu & Ritala, 2020).

TelcoCorp's journey shows that industry incumbents should not be concerned about using platforms from major vendors such as Microsoft. Instead, they should exploit the opportunities to collaboratively establish and lead their industry IoT ecosystems as orchestrators. In fact, even though the IoT platform market share of firms such as Microsoft or Amazon is growing, the number of platform providers keeps increasing (Lueth, 2019). This indicates that the enterprise IoT market leaves much room for industry incumbents to compete through IoT platform ecosystems, given that they continuously realign their offerings with their customers' needs.

From our analysis of TelcoCorp's journey, we have provided insights into how industry incumbents can leverage their strengths to overcome the challenges of establishing an IoT platform and the associated ecosystem. IT and business leaders of industry incumbents can learn from and be encouraged by TelcoCorp's journey to become an IoT platform ecosystem orchestrator. They too have an opportunity to leverage an IoT platform ecosystem and orchestrate customer IoT use cases for joint value cocreation.

B.7 Appendix: Case Study Methodology

We conducted a single, in-depth case study of TelcoCorp to investigate its journey from IoT enabler IoT platform ecosystem orchestrator and how it overcame the challenges in three dimensions—platform, ecosystem and value cocreation (Yin, 2014). We believe this case study is "revelatory," because it provides early but unique insights into orchestration capabilities in the enterprise IoT context. TelcoCorp's journey began in 2015. The figure below summarizes the key events referred to in the case study for each of the three dimensions.

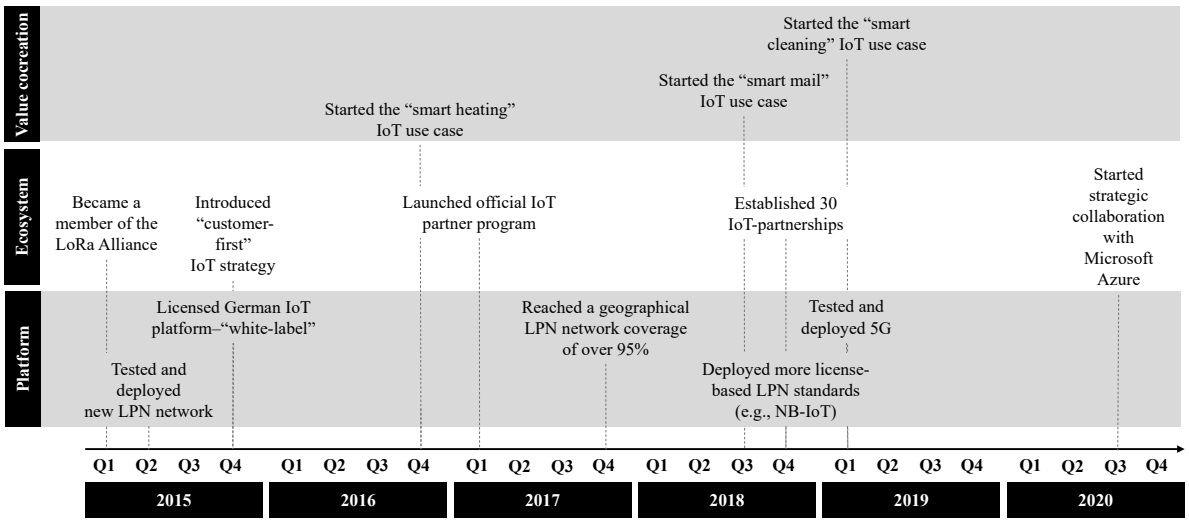


Figure 7: Case Timeline

Data collection. We used two main sources for data collection. First, we conducted semi-structured interviews with TelcoCorp (seven interviews), ten of its IoT partners and three IoT customers. Data collection began in April 2020, first by interviewing TelcoCorp's Head of IoT, who described the enterprise IoT strategy and some of the key challenges the firm had faced since beginning its journey in 2015. Subsequently, we conducted a further 19 interviews (see Table 14). The second source of data included TelcoCorp's annual reports (2015-2020), public information and internal documents.

Given our interest in the concept of value cocreation, which requires two or more firms to jointly realize an IoT use case, we triangulated the statements made by interviewees representing the three main ecosystem roles. To complement this triangulation, we selected three IoT use cases that highlight how TelcoCorp orchestrated value cocreation initiatives. We purposefully selected the cases to provide a mix of customer types, industry contexts and involved third parties, so we could assess the different ways in which value is created. However, common factors in the cases were that they were all B2B examples and TelcoCorp was involved as the orchestrator. These common factors meant that we could make comparisons between the use cases.

Nr.	Interviewee role	Firm acronyms	Firm size	Date	Duration (minutes)
1	Head of IoT	TelcoCorp	Large	Apr 20	118
2	Head of Analytics	TelcoCorp	Large	Apr 20	60
3	Sales Manager	TelcoCorp	Large	May 20	56
4	Partner Ecosystem Manager	TelcoCorp	Large	Jun 20	90
5	Head of Sales	TelcoCorp	Large	Jun 20	55
6	IoT Project Manager	TelcoCorp	Large	Dec 20	80
7	Head of Business Customers	TelcoCorp	Large	Jan 21	36
8	CEO	Partner 1	Small	Nov 20	37
9	CTO	Partner 2	Medium	Nov 20	57
10	Consulting Manager	Partner 3	Large	Nov 20	40
11	Co-CEO	Partner 4	Small	Nov 20	54
12	Head of IoT	Partner 5	Large	Nov 20	67
13	CEO	Partner 6	Large	Dec 20	28
14	CEO	Partner 7	Small	Nov 20	48
15	Head of IoT	Partner 8	Medium	Nov 20	68
16	CEO/Founder	Partner 9	Small	Nov 20	62
17	Technology Manager	Partner 10	Small	Dec 20	49
18	CIO	Customer 1	Large	Nov 20	114
19	Head of Digital and IoT	Customer 2	Large	Dec 20	36
20	Head of Digital	Customer 3	Large	Dec 20	32

Note: Partner roles ranged from hardware manufacturers to software developers. Firm size was coded based on the number of employees (small<50, medium<250, otherwise large).

Table 14: Overview of Interview Data

Data analysis. Before analyzing the empirical data, we read through all the interview transcripts and various other documents, and accessed TelcoCorp's website, so we could capture the most important information and build a common understanding. Then, we undertook a systematic coding process that included open, axial and selective coding. The open coding resulted in over 100 codes related to different aspects of TelcoCorp's challenges and actions taken to address them. During the axial coding stage, we

aggregated the open codes into second-order codes. Because of our focus on value cocreation, two authors then conducted the selective coding iteration against the backdrop of the three dimensions—platform, ecosystem and value cocreation (Lusch & Nambisan, 2015). After each coding iteration, the results were validated in research discussions among the first and second author.

Paper C – Motivational Factors to Join IoT Platforms

Attribute	Description
Title	From Suppliers to Complementors: Motivational Factors for Joining Industrial Internet of Things Platform Ecosystems
Short title	Motivational Factors to Join IoT Platforms
Authors	Christian Marheine, Tobias Pauli, Emanuel Marx, Andrea Back, Martin Matzner
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Ranking	C (Jourqual 3)
Publication status	Published

Table 15: Bibliographical Metadata on Paper C

Abstract. Spurred by the internet of things, industry firms are increasingly establishing platforms that animate an ecosystem of external actors to provide complementary offerings. But why do independent firms decide to join these ecosystems and to become complementors? The goal of this study is to disentangle their motivational factors in the context of the industrial internet of things. A theoretical framework is developed a priori based on the knowledge-based view of the firm and complementary logics. The framework is empirically explored using a case study design. Our results indicate that financial, technology, and knowledge gains positively influence the decision of complementors to join the ecosystem. Yet, our interviews reveal relative differences in motivations based on complementors' uncertainty. Our findings contribute to the research on joining nascent digital platform ecosystems from a complementor perspective and the growing stream of research on industrial internet of things platforms.

Keywords. Industrial internet of things, platform ecosystems, joining decision.

C.1 Introduction

Digital platform ecosystems have seen considerable growth during the past years (De Reuver et al., 2018), recently especially in the industrial internet of things (IIoT) domain (Hein, Weking, et al., 2019; Petrik & Herzwurm, 2019a; Sisinni et al., 2018). IIoT platforms, like technology or innovation platforms (Cusumano et al., 2019; Gawer & Cusumano, 2014), shift the locus of innovation from within the firm to an ecosystem of independent third-party firms—so-called complementors. They develop technical artifacts on top of a platform and become innovators for its owner. Prominent examples like Siemens's MindSphere or PTC's ThingWorx empower firms to (1) connect and manage various devices, (2) store and analyze data in a cloud, and (3) develop additional IIoT services, such as predictive maintenance, on top of the platform to serve different industry verticals (Marheine & Pauli, 2020). But why do firms decide to join these platform ecosystems and to become complementors? Which factors influence their decision? Are there variances in aspirations between different types of complementors or IIoT-specific ones? In this study, we refer to a firm's decision to join an IIoT platform ecosystem as becoming part of a group of firms (i.e., complementors) that focus parts of their business activities on developing and commercializing technical artifacts associated and compatible with the platform as the core technology (Altman, 2017; Ceccagnoli et al., 2012). Complementors leverage the platform by increasing technological variety that, in turn, serves the value propositions of others and raises technology adoption (De Reuver et al., 2018; Pauli et al., 2020; Tilson, Sørensen, & Lyytinen, 2013). So far, prior information systems (IS) literature has mainly examined the impact joining had on the firm performance of complementors with proxies like sales (Ceccagnoli et al., 2012; Koch & Kerschbaum, 2014; Sarker et al., 2012). If these effects studied equal the expectations complementors had before joining, they offer good indications on the motivational factors that caused their decision to join a priori. Accordingly, most studies have reported that gaining access to the platform's customer base is the strongest incentive to join (Ceccagnoli et al., 2012; Chellappa & Saraf, 2010; Huang et al., 2009). However, we see three gaps that make it worthwhile to conduct this research. First, scholars have not provided many insights from the complementors' perspective (Hein et al., 2020). Second, most studies focus on complementors that are essentially software developers (Ceccagnoli et al., 2012; Tiwana, 2015b). Although this type of complementor is often found in consumer platforms, it does not draw the full picture in complex domains such as the IIoT. In the latter, typical complementor roles involve manufacturing, connectivity, data analytics, and software providers (Petrik & Herzwurm, 2020). We thus consider

the IIoT domain as an interesting domain to learn more about the characteristics of complementors and platforms hoping that these insights may contribute to our innovation platform knowledge in general (Gawer & Cusumano, 2014). Third, while prior work has explored complementors' choice of specific platform ecosystems (Pauli et al., 2020), we take a step back in this paper to uncover firms' motivational factors for becoming complementors in the first place. Additionally, given the nascent character of the domain (Hein, Weking, et al., 2019; Sisinni et al., 2018), we are interested in the effect of uncertainty when firms extend or switch their business model from supplier to complementor. Thus, as an in-depth extension of a previous study (Pauli et al., 2020), this article addresses the following research question: *Why do firms join IIoT platform ecosystems and how does uncertainty in the IIoT domain affect their decision?*

To address this research question, we analyze the IIoT platform ecosystem of a multinational German automation technology firm. We conducted 18 interviews with both platform managers and complementors who recently decided to join the platform ecosystem. We found evidence for all three proposed incentives that explained the complementors' motives to join an IIoT platform ecosystem: (1) financial, (2) technology, and (3) knowledge gain. In addition, we examine relative differences in complementors' uncertainty to join functioning as a moderator of our proposed incentives. Our findings contribute to the literature on platform ecosystems in the IIoT domain by highlighting that while all complementors are attracted by the proposed incentives, they are weighted differently depending on complementor-specific factors. We thus recommend platform managers to address these differences in their governance practice. The remainder of this paper is structured as follows: In section C.2, we introduce our research model, present the theory, and develop our propositions. The method is described in section C.3. Section C.4 presents our findings. We then discuss our findings in section C.5 and conclude with the study's limitations and avenues for future research in section C.6.

C.2 Theoretical Background

The theoretical framework of this study is built on prior findings on the commercial interest in platform ecosystems (financial gain) (Ceccagnoli et al., 2012; Koch & Kerschbaum, 2014), the boundary resources theory (technology gain) (Ghazawneh & Henfridsson, 2013; Hein, Weking, et al., 2019), and the knowledge-based view of the firm (knowledge gain) (Foerderer et al., 2019; Grant, 1996). In addition, the theoretical model includes complementors' uncertainty in their joining decision as the IIoT domain

is considered an uncertain environment (Hodapp, Hawlitschek, et al., 2019). In Figure 8, our model is illustrated.

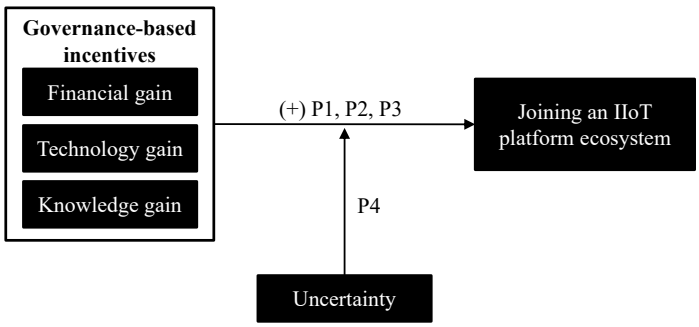


Figure 8: Theoretical Model

C.2.1 Joining IIoT Platform Ecosystems

We conceptualize an *IIoT platform ecosystem*, a close relative of a digital platform (Constantinides et al., 2018; De Reuver et al., 2018) and business ecosystem (Moore, 1993), as a corporate network that is centered around an industrial firm's digital platform (Adner, 2017; Jacobides et al., 2018; Lusch & Nambisan, 2015). Participating firms can develop and exchange technical artifacts via the platform and thus add functionality in the form of peripheral modules (Pauli & Lin, 2019; Selander et al., 2013; Tiwana et al., 2010). These modules include generic functional specifications and can be customized to meet the needs of various industrial end-customers, e.g., to enrich IIoT data with data of different information systems (Hein, Weking, et al., 2019; Petrik & Herzwurm, 2019a, 2020). To theorize why complementors decide to join IIoT platform ecosystems and what factors might influence an objective decision, we began our reasoning by looking at prior literature—literature that examined not just platforms in the IIoT domain (Pauli et al., 2020), but in all domains related to digital platforms, such as mobile devices (e.g., Eaton et al., 2015) or enterprise software (e.g., Ceccagnoli et al., 2012). Here, we studied both papers focusing on the complementor as well as the platform owner perspective. The latter was helping us to grasp the governance decisions made by platform owners, which in turn, establish the incentives for complementors to join (Altman, 2017; Ceccagnoli et al., 2012; Petrik & Herzwurm, 2020). We define *platform governance* as the rules and regulations designed by the platform owner that stipulate complementors' development and commercialization opportunities (Ghazawneh & Henfridsson, 2013; Tiwana, 2015a). These incentives influence the "yes or no decision" of complementors. In general, governance mechanisms can be classified into architectural and relational ones (Van Alstyne et al., 2016). While architectural mechanisms target the platform's

properties and functionalities, such as application programming interfaces (APIs) or software development kits (SDKs) (Tiwana et al., 2010), relational mechanisms focus on the alignment and intensity of ties between vendors and partners (Marheine & Pauli, 2020; Sarker et al., 2012). For example, Apple's success in attracting millions of third-party developers is enabled through its architectural and relational governance decisions it has made. Apple built a large user community for its well-designed products like the iPhone (financial gain), created a platform architecture that allows third-party developers to develop complementary iOS apps (technology gain), and managed the relations and learning journeys of its third-party developers with mechanisms like its Worldwide Developer Conference (knowledge gain).

C.2.2 Commercial Interest

In general, we assume that technology does not exist independent from commercial interests. Accordingly, our theoretical model acknowledges that all complementors that are thinking about joining an IIoT platform ecosystem seek to profit from their (future) technological artifacts and to access a network of firms that have adopted the platform (Koch & Kerschbaum, 2014). As networks, platform ecosystems are characterized by firms of complementary strengths, trust, and interdependence (Adner, 2017; Powell, 1990). In (growing) networks, the joining decision is often motivated by the financial gain that comes with it, as has been shown in prior studies. For example, in studies of the enterprise software domain, Huber et al. (2017) have explored how partner managers leveraged their complementors' business opportunities while balancing against inflating coordination costs. Moreover, scholars found that joining SAP's platform ecosystem increased complementors' sales and the likelihood of an initial public offering (Ceccagnoli et al., 2012; Huang et al., 2009). In addition, researchers found that the decision to join is mainly advantageous to demonstrate compatibility with the platform in large user networks. This way, complementors can exploit a large installed base, again increasing sales (Chellappa & Saraf, 2010). While the IIoT experiences limited scalability in terms of numbers of users yet (Sisinni et al., 2018), firms can profit from heterogeneous industry verticals with little competition. Heterogeneity also enables complementors to project an IIoT solution to other fields or to leverage value capturing based on the number of connected devices (or transactions) rather than users (Pauli et al., 2020). Thus, the first proposition is put forth.

> **P1:** *Financial gain is a significant incentive that fosters a complementor's decision to join an IIoT platform ecosystem.*

C.2.3 Boundary Resources

As mentioned before, platform research has coined the concept of *boundary resources* as the technical and social software-based tools a platform provides to its users (Ghazawneh & Henfridsson, 2013). They characterize the arms-length relationship between the platform and its ecosystem through the use of SDKs or APIs. Boundary resources seek to support the development endeavors of complementors. During the process of development and based on other users, that interact with them, they can evolve through the process of distributed tuning (Eaton et al., 2015). "The boundary resources can enhance the scope and diversity of a platform" (Hein, Weking, et al., 2019, p. 506) through the process of resourcing like in the case when Siemens introduced Mendix, a low-code tool, to lower the entry barriers for app-developing complementors (Petrik & Herzwurm, 2019a). The process of securing helps the platform owner to reinforce control over the services (Ghazawneh & Henfridsson, 2013). Thus, boundary resources influence the potential scope and scale of innovation by third parties. Accordingly, the likelihood of firms to contribute to a platform rises with its utility, i.e., how popular and expandable is the platform, how easy is it to work with, and how many users have adopted it? Taken together, complementors require a stable core technology (platform), resources to utilize them (boundary resources), and various actors who bring in individual domain-knowledge and innovation capabilities (ecosystem) that foster the speed of device integration, data analytics or software development (value cocreation) (Marheine & Pauli, 2020; Tiwana et al., 2010). This technology-related observation leads to the second proposition.

> **P2:** *Technology gain is a significant incentive that fosters a complementor's decision to join an IIoT platform ecosystem.*

Recent research analyzed knowledge boundaries in enterprise software platforms (Foerderer et al., 2019). While this study addresses the question of how a platform owner can design knowledge boundaries, it remains unclear how a platform ecosystem's extent of knowledge influences the decision of complementors to join.

C.2.4 Knowledge-Based View of the Firm

The knowledge-based view (KBV) of the firm is a theory that originated from its predecessor—the resource-based view (RBV) (Grant, 1996). While the RBV considers resources as the critical input in production and as the primary source of value and competitive advantage (Barney, 1991), the KBV assigns this role to knowledge (Dibbern, Winkler, & Heinzl, 2008; Grant, 1996). The KBV proposes that each firm is defined by

its unique set of human resources and their respective knowledge (Dibbern et al., 2008). Differences between firms stem from knowledge asymmetries and their "relative efficiency of knowledge utilization" (Grant, 1996, p. 119). This includes the knowledge transferring and integration capabilities of a firm (Dibbern et al., 2008). In domains like the IIoT, where much customer-specific knowledge is needed to perform innovation or service creation tasks, complementors decide for those platform ecosystems that offer the best opportunities to learn and absorb knowledge that will eventually result in complementary offerings to the platform and commercial success. Since IIoT complementors have different levels of experience (e.g., data analytics start-up versus long-term supplier), their ability to absorb customer or industry-specific knowledge likely varies—a factor we account for in our theoretical model. Accordingly, the following effect is proposed.

> **P3:** *Knowledge gain is a significant incentive that fosters a complementor's decision to join an IIoT platform ecosystem.*

C.2.5 Impact of Uncertainty in the IIoT Domain

A complementor's decision to join an IIoT platform ecosystem, as compared to consumer platforms, brings about unique challenges related to uncertainty (Hodapp, Hawlitschek, et al., 2019). Although previous studies have argued that the uncertainty construct is elusive (Scott, 2001), scholars still resort to it to emphasize the idiosyncratic nature of decision making in an uncertain environment (Krishnan & Bhattacharya, 2002; Lusch & Nambisan, 2015). The IIoT represents a nascent and uncertain domain, that is, scholars have found that IIoT platforms and "the ecosystem is uncertain and difficult to predict" (Hodapp, Hawlitschek, et al., 2019, p. 11), e.g., what types of complementing partners are already part of the ecosystem, what and whom do they know, how strongly are they tied to the platform owner, and how will the platform evolve. We structure our reasoning for the impact of uncertainty on a complementor's decision to join using the tripartite framework of Lusch and Nambisan (2015), i.e., ecosystem, platform, and value cocreation. First, as the firms in IIoT ecosystems have different value propositions (e.g., manufacturing, consulting, analytics) and operate in diverse verticals (e.g., agriculture, chemical engineering, automotive), profiting from knowledge sharing and cocreation projects is uncertain (**ecosystem**) (Marheine & Pauli, 2020). Second, complementors may be uncertain whether an IIoT platform is generic enough to be compatible with a broad range of hardware (e.g., sensors, machines) and software (e.g., communication protocols, enterprise systems) and specific enough to bear a value for its customers'

verticals (Marheine & Pauli, 2020). Platform uncertainty may also depend on the degree of complementarity (e.g., unique or supermodular) (Jacobides et al., 2018) or trust in its longevity (**platform**). Third, value cocreation and capture are uncertain in the IIoT because of the diversity of industries and heterogeneity of customers and devices, which requires complementors to have the appropriate domain know-how and the capabilities to implement end-to-end (E2E) solutions with different integration, security, and reliability requirements (**value cocreation**) (Hein, Weking, et al., 2019; Marheine & Pauli, 2020; Sisinni et al., 2018). Accordingly, the following moderating impact is proposed.

> **P4:** *The positive impact of financial, technology, and knowledge gain on a complementor's decision to join an IIoT platform ecosystem is moderated by the degree of uncertainty—high degrees decrease and low degrees increase the decision to join.*

C.3 Method

To test the research framework on joining an IIoT platform ecosystem, we conducted a case study (Dibbern et al., 2008; Miles, Michael Huberman, & Saldaña, 2020; Yin, 2017). This approach appeared well-suited to address our research question on how and why firms decide to join these ecosystems and to become complementors (Dibbern et al., 2008; Dubé & Paré, 2003; Yin, 2017). "The utilization of the case research methodology follows a widely recognized positivist research approach" (Dibbern et al., 2008, p. 343; Dubé & Paré, 2003; Lee, 1989). Positivist case studies seek to test propositions (Dubé & Paré, 2003). Instead of testing our propositions based on a survey, we consider each complementor's incentives to join as a separate test (or small case) of the theoretical model (Dibbern et al., 2008; Yin, 2017). Comparing the propositions against the empirical results will increase generalizability through a replication logic (Dibbern et al., 2008; Yin, 2017). Since the constructs, such as technology and knowledge gain as well as uncertainty, would have been difficult to access quantitatively, the empirical case study approach seemed appropriate for testing our theoretical model (Dibbern et al., 2008). Moreover, the qualitative approach allowed us to explore how the positive impact of incentives provided by the platform owner (i.e., financial, technology, and knowledge gain) on the complementors' decision to join will be moderated by the level of complementors' uncertainty. Adding this exploratory view to our positivist case study helped us in staying flexible and challenge or add constructs as the field of IIoT platform ecosystems is still emerging (Dibbern et al., 2008).

C.3.1 Sampling and Data Collection

We pursued a purposeful case selection and (complementor) sampling strategy to stay in line with our research objective (Dibbern et al., 2008; Dubé & Paré, 2003; Lee, 1989). The research employs a case study design in which the unit of analysis is a single IIoT platform ecosystem. Our case is an internationally operating industrial automation firm with three years of experience as an IIoT platform and ecosystem provider. For reasons of anonymity, we name the case firm AutoCorp and its IIoT platform JOIN. AutoCorp tapped into the IIoT platform business in 2017 with its platform JOIN. Its major business, among other things, is to provide products and services for factory automation. AutoCorp intends to connect all industrial things (e.g., machines, controllers, sensors) to JOIN to exploit and leverage the vast amounts of data for the optimization of manufacturing processes as well as other industry verticals. Today, JOIN does not only serve as central cloud storage for machinery data but as an industrial operating system (or innovation platform) that serves complementors as the basis to develop and commercialize their additional services and products. By interviewing complementors that have already decided to join JOIN, we control for potential bias due to the single research site.

In addition to three partner managers of AutoCorp (see Marheine, 2020), we collected 15 semi-structured interviews with complementors between the end of 2018 and 2019 (see Pauli et al., 2020) (see Table 16). While the partner manager interviews exposed the key incentives established by the platform owner, the complementor interviews queried the fit between platform engagement and their current business model as well as anticipated business model innovations. As a result, we could examine if the platform owners' incentives mapped to the complementors' motives to join their platform ecosystem. Both median and average of our interviews were at approximately 37 minutes. Length ranged from around 20 to 60 minutes. The interviews were based on an interview guideline including questions about general business information as well as questions regarding the constructs of our theoretical framework (see Pauli et al., 2020). We interviewed partner managers (including "head of" or "vice president"), sales managers, project managers, or executive managers (e.g., CEO) of firms with various business backgrounds. A typical complementor role is *consulting,* which in most cases is connected with a software development role. Based on the interviews, we learned that consulting is an enabler for both customer-specific software projects and for developing generic applications. We refer to a *data analytics* role when firms integrate technologies like artificial intelligence (AI), blockchain, or security into the platform. *Device providers*

have a focus on (producing and) distributing hardware components to clients. *Connectivity* partners provide both hardware and software to connect industrial customers' assets to the platform. Lastly, *industry service* providers are industry experts, i.e., they focus their value proposition on automation technology in a specific industry, such as automotive.

ID	Firm size	Year joined	Partner main role	Interviewee	Minutes
PO A	Large	2017	N.A.	Partner Manager	41
PO B	Large	2017	N.A.	Partner Manager	60
PO C	Large	2017	N.A.	Partner Manager	47
CO A	Large	2018	Connectivity	Sales Manager	29
CO B	Large	2018	Consulting	Project Manager	26
CO C	Large	2019	Consulting	Executive Manager	37
CO D	Large	2017	Consulting	Sales Manager	49
CO E	Large	2017	Consulting	Executive Manager	21
CO F	Large	2018	Device provider	Sales Manager	42
CO G	Medium	2018	Industry service	Analytics Manager	35
CO H	Medium	2018	Industry service	Managing Director	38
CO I	Medium	2018	Data analytics	Partner Manager	37
CO J	Small	2019	Connectivity	Partner Manager	43
CO K	Small	2018	Consulting	Managing Director	21
CO L	Small	2018	Data analytics	Partner Manager	30
CO M	Small	2018	Data analytics	CEO and Co-Founder	29
CO N	Small	2019	Data analytics	Manager and Founder	45
CO O	Small	2018	Data analytics	Manager and Founder	43

Note: The table describes the empirical sample of our interview study (see Pauli et al., 2020). PO stands for platform owner. CO stands for complementor. Firm size is coded based on the number of employees (small<50, medium<250, otherwise large).

Table 16: Overview of Interview Data

C.3.2 Data Analysis

All 18 interviews were recorded and transcribed. The transcripts were structured and coded using the software Atlas.ti. The coding procedure was done as follows: First, the second and third author read and coded the interview transcripts by identifying text passages that included information about the constructs of the theoretical model. In addition, uncertainty-related constructs, such as "platform survival" and "customer-centricity" emerged in the process of data collection and analysis. They represent additional IIoT-specific characteristics that we explored in the data. Following the coding by the second and third author, the first author likewise coded the transcripts. After that, the codes were examined to agree on a final code-matrix that was used for the data analysis. To increase internal validity, we not only performed a pattern matching between our theoretical constructs and the interviewees' statements but also by examining statements

that by themselves included causal linkages (Miles et al., 2020). Table 17 summarizes the constructs we examined based on our research model.

Construct	Description and conceptual source
Financial gain	The extent to which a firm can benefit from selling its products and/or services in an IIoT platform ecosystem (Ceccagnoli et al., 2012).
Technology gain	The extent to which a firm can benefit from utilizing the platform and its boundary resources in an IIoT platform ecosystem (Ghazawneh & Henfridsson, 2013).
Knowledge gain	The extent to which a firm can benefit from absorbing the information and competencies of other actors in an IIoT platform ecosystem (Foerderer et al., 2019).
Uncertainty	The extent to which a firm is uncertain about the sustained benefits of an IIoT platform ecosystem on the ecosystem, platform, and value cocreation level (Lusch & Nambisan, 2015).

Table 17: Incentives for Complementors to Join

C.4 Results

A first look in the case data revealed that all three incentives proposed have positively influenced the interviewed complementors' decisions to join AutoCorp's platform. Next, we examine Propositions 1 to 3.

C.4.1 Explaining the Decision to Join an IIoT Platform Ecosystem

Financial gain. Our data clearly indicates that all complementors decided to join AutoCorp's JOIN platform to access new customers and to benefit financially (Proposition 1). In the case of AutoCorp, its brand image, market position, industrial anchorage, and continuous leadership in automation technology have mainly attracted complementors of all kinds. Many firms mentioned AutoCorp's superb global brand image and large customer base, which has its automation devices in use, as the most dominant factor to join.

> *"We chose JOIN because of AutoCorp's footprint worldwide. We got access to customers which we would not have gotten because of our small size, but JOIN was the enabler."—CO L*

In addition, many firms saw a chance to develop a new service-based business model—ranging from hardware-as-a-service, consulting, and selling generic apps via JOIN's app store to developing, deploying, and managing end-to-end IIoT solutions.

> *"JOIN changes our business model in terms of projects, because before we were selling apps directly to the customer. Now, with the JOIN partnership, we are part of a huge ecosystem selling apps via the platform. We are also working with our partner manager for new go-to-market strategies."—CO I*

Furthermore, all interviews indicated that the IIoT is very customer-driven. If customers decided for JOIN, complementors naturally saw a financial gain in following their lead and scaling their business too.

> *"We chose JOIN as we can scale much easier. If we develop a product for a customer and this customer uses JOIN already and the customers of our customer also rely on JOIN, it is really easy to get the data available. When JOIN becomes the standard in the industry, it makes scaling really easy for us."—CO M*

Our data also indicates that a few larger firms have extended their partner role from being a supplier only to becoming a complementor. While this transformation is already reflected in their desire to profit from new business models and innovation, the finding emphasizes the importance of prior business relationships as stated by some larger firms. Thus, business relationships denote a strong motivator for firms to join.

Technology gain. We also found evidence for the technology gain incentive (Proposition 2). To accelerate the value capture process from joining a platform, complementors must be able to develop and commercialize their value offerings against the costs of affiliating with it. This value capture potential depends on a platform's technological maturity. As a leader in automation technology, AutoCorp develops, sells, and services many of its controller devices. In addition to its industrial expertise, AutoCorp has built a solid software portfolio on top of its industrial product portfolio. On that basis, complementors can focus on developing further offerings without having to set up their own infrastructure.

> *"Basically, the main value in this cooperation is for us the connectivity, availability, and security of the data which AutoCorp brings to our partnership. It is a strong enabler to jumpstart training algorithms."—CO I*

Yet, few complementors also mentioned technological drawbacks that were connected with the flow of data, only going to the cloud and not back to the devices. This way, automated predictive maintenance services, which trigger the regulation of a machine when certain values are exceeded, cannot be developed.

> *"Currently, we cannot make our energy control solution available on JOIN because the edge agent between the control and JOIN does only allow the consumption of data, but not the way back. So, playing back data to the controller and optimizing the machine is not possible."—CO N*

In addition, two platform managers revealed other technological incentives working in the background of JOIN, but differentiate many current offerings in terms of quality and

utility for new business models like selling IIoT apps via an app store. For example, JOIN offers a low-code tool that enables beginners to program and a billing service that allows partners and customers to focus only on value creation projects.

> *"When a developer builds an app on our platform, it's actually a lot of stress to rent things, do the licensing management, write invoices, etc. and that's just something we offer as a service."—PO A*

Knowledge gain. Besides the perception of one industry service provider, there was clear evidence that complementors joined AutoCorp's ecosystem to access valuable information and to learn (Proposition 3). In the data, the interviewees often mentioned the words "competency", "capability", or "expertise" which we associated with their ambition to absorb knowledge in the ecosystem. While broadcasted information about the platform's roadmap is needed to align strategies with the platform owner, the complementors hoped to get more tailored information that would accelerate their business growth. Yet, complementors did not only decide for JOIN to access AutoCorp's knowledge repository but that of other partners too. In particular, many firms—smaller ones especially—were seeking partners' skills and more tailored information for learning faster and to cocreate solutions with them.

> *"A JOIN partner is an expert in data analytics and AI-based algorithms. With our collaboration, we can extend our solution with competencies we don't own. In turn, our partner doesn't have the domain know-how for automation industry applications and benefits from our expertise in this field. Together, we can target customer-specific IIoT solutions."—CO O*

However, we identified missing staff as a recurring theme in the data that sometimes led to early endings of promising projects, as reported by a managing director.

"We wanted to work together with other JOIN partners in terms of shared resources and skills. For example, we worked with a JOIN partner with similar competencies because, as a small company, we didn't have the manpower to do it alone."—CO K

C.4.2 Exploring the Impact of Complementor-Specific Uncertainty

During the interviews, however, it became clear that the decision to join an IIoT platform ecosystem because of financial, technology, and knowledge gain was also dependent on complementors' uncertainty. As perceptions of uncertainty are enacted by the perceiver, we explored each complementor's uncertainty-related factors which either increased (low degree of uncertainty) or decreased (high degree of uncertainty) their

willingness to join. We structured the factors along with the tripartite framework of Lusch and Nambisan (2015): (1) ecosystem, (2) platform, and (3) value cocreation.

Ecosystem. Although most firms decided for JOIN to be granted access to its ever-growing partner ecosystem and knowledge-base, some reported that AutoCorp keeps the partner ecosystem non-transparent in terms of who is part of it and what capabilities they possess, etc. Without these insights, complementors' uncertainty may increase and the likelihood to join might decrease.

> *"We don't have a transparent overview of the roles and competencies of other participants."—CO B*

A few firms, however, did not care about the benefits a large partner ecosystem was offering, as their primary motivation was the financial gain. One executive manager of a large consulting firm said:

> *"In the end of the day, we want to earn money, so the customer-centric approach without the involvement of other companies is the best one."—CO E*

Moreover, while most partners did not mention that competition was affecting their decision to join, the founder of a small data analytics firm stated concerns in this regard, emphasizing the danger of losing customer attention among many partners in the ecosystem.

> *"Potential customers have due to the broad partner ecosystem a large offering which could have the effect that we get lost in the shuffle. We could lose potential customers to partners only because of more attractive marketing."—CO O*

Platform. Many complementors stated concerns in regards to platform survival and the decision authority of their industrial customers. The complementors we interviewed did often not decide for JOIN to extend their business, but to sustain it by following their customers' decision of adopting JOIN. Our data indicate a highly customer-centric decision making in favor of or against a particular platform as long as it does not take away the flexibility to switch platforms or to multihome.

> *"We also use two other IoT platforms. [The first] has a strong footprint in the US market, so most of our US customers prefer it over JOIN. As mentioned before, the customer decides which IoT platform is used in the end, also depending on the region he is from."—CO E*

Accordingly, a customer's platform decision bears greater risks in affiliating its machines and devices with it in comparison with a complementor. Complementors seek flexibility to serve their customers independent of their platform choice.

> *"It finally depends on the infrastructure the customer has and wants. If the client already has a specific IoT infrastructure, we need to use the infrastructure he wants. We need to be flexible there."—CO K*

Also, platform survival and market consolidation became a recurring theme that increased uncertainty of a few firms but strengthened others' willingness to join.

> *"Besides, we really believe in JOIN's longevity and survival as a dominant IoT platform […] We also think that the market will consolidate. There will only be a few IoT platforms survive in the market and JOIN is going to be one of them. That is why we adopted JOIN as our main platform for our manufacturing clients."—CO D*

Value cocreation. Uncertainty was also prevalent in the value cocreation opportunities of complementors. While some complementors were seeking to create joint solutions, tight resources proved to be a bottleneck.

> *"We also considered working with a [competitor platform], but as we are a small company, the collaboration plans were put on-hold because it wasn't manageable in parallel. We thus concentrated on JOIN, because our resources are quite tight."—CO J*

In addition, value cocreation in the IIoT is highly dependent on customer projects. Customers require E2E solutions and are not interested in generic apps as they—standalone—do not generate any value in use. Hence, joining an IIoT platform without any project inquiry can increase uncertainty. Besides, developing a generic app requires an upfront investment with no secure return.

> *"The financial investment with application development can be a six-digit amount, the lead time for a project is approximately 12 months. This leads to high risks, and thus we develop an application only if there is a real customer project"—CO C*

Finally, we found that a firm's degree of experience in an industry can create an advantage, whereas little experience may lead to uncertainty. Experienced firms are rather independent in developing their E2E solutions. Having little or no experience in the IIoT

domain may, in turn, increase uncertainty as both clients and partners would have high costs for knowledge transfer before the project could start.

> *"A main reason we do not have a joint solution is the speed of deployment, because our goal is to go quite fast with applications. From our experience, if we add some more actors into the projects, it takes much longer to develop the solution."—CO I*

C.5 Discussion

This study was motivated by the need to improve our understanding of why complementors join IIoT platform ecosystems and to better understand what factors lead to variances in their motivations to join. While previous literature has mainly focused on the effects of joining and did not differentiate between different types of complementors (Ceccagnoli et al., 2012; Huang et al., 2009; Wareham et al., 2014), our study concentrates on the key incentives (and moderators) that caused their decision to join. Our insights provide evidence for all three proposed incentives: (1) financial, (2) technology, and (3) knowledge gain (Propositions 1 to 3). Table 18 also indicates that all the incentives were, on average, mentioned more often by digital firms (i.e., data analytics and consulting firms). Moreover, physical product-oriented and automation technology firms—as opposed to digital firms—had a strong focus on financial gain. This seems logical as a large part of their business is to build, sell, and install machines and devices. However, due to the smaller number of product firms in our sample, we want to state this observation carefully. In addition, our study showed that these incentives are moderated by complementors' idiosyncrasies and their decision-making uncertainty. We explored the different uncertainty-related factors of complementors along with the tripartite framework of Lusch and Nambisan (2015).

Construct	**Impact on complementor types**				
	Industry service (n=2)	Device provider (n=1)	Connectivity (n=2)	Consulting (n=5)	Data analytics (n=5)
Financial gain	4	5	8	21	19
Technology gain	3	1	3	11	13
Knowledge gain	3	2	5	13	16
Total	10	8	16	45	48
Average	5.0	8.0	8.0	9.0	9.6
Note: The average indicates the total number of quotes divided by the number of interviewed complementors of that type (n).					

Table 18: Number of Quotes

C.5.1 Building Incentives to Join an IIoT Platform Ecosystem

Our study contributes to the literature on partner management (Huber et al., 2017) in nascent platform ecosystems (Hodapp, Hawlitschek, et al., 2019), particularly in the context of IIoT platform ecosystems. Prior work has documented the importance of partner management as an instrument of platform governance from various perspectives including an architectural view on boundary resources and modularity (Baldwin & Clark, 1997; Eaton et al., 2015; Ghazawneh & Henfridsson, 2013; Yoo et al., 2010) and a relational view on value cocreation and strategy (Boudreau, 2012; Ceccagnoli et al., 2012; Huber et al., 2017; Lusch & Nambisan, 2015). Yet, a comprehensive picture of the complementors' incentives to join did not exist. Our theoretical model sheds light on the causes and uncertainty-related differences between complementors to join IIoT platform ecosystems and thus extends prior findings (e.g., Pauli et al., 2020). In this context, differences and dependencies appeared rather related to organizational relationships than architectural decisions—especially as value cocreation is mainly dependent on the customer's willingness to execute cost-intense IIoT projects. With our findings, we underline the reason why generic apps in the IIoT are for one thing difficult to develop and for another thing difficult to scale (Marheine & Pauli, 2020).

In addition, while prior studies, which looked at the complementor perspective, have only focused on independent software vendors, our sample also includes those focusing on industry services, device manufacturing, and connectivity. While for the latter, the financial gain was of utmost importance, firms that rather had digital offerings were motivated by all three incentives, smaller ones especially by knowledge gain (see Table 18). With these results, we confirm existing studies in that previously established incentives are primarily attracting software developers on the one hand and show that IIoT platform managers should establish new incentives for (smart-) product firms on the other hand. Creating transparent ecosystems could support (small) firms in finding their niche, connecting with partners, and starting projects. By implementing these measures, complementors and customers could better engage in value cocreation projects in the IIoT domain.

C.5.2 Looking Beyond the Complementor

Our interviews show that two-thirds of the complementors have joined multiple IIoT platforms and thus engaged in multihoming. While previous studies have shown that multihoming—if not associated with considerable costs—is common among both consumers and complementors, it is an undesired behavior from the perspective of the

platform owner (Boudreau, 2012; Cennamo et al., 2018). Hence, platform owners try to decrease multihoming tendencies of consumers and complementors through locking-in users by increasing switching costs, e.g., through the use of exclusive contracts (Hagiu & Wright, 2015). Therefore, both lock-in effects and multihoming seem to be less vibrant for complementors as compared to customers. As complementors follow the lead of their customers, building solutions for the platforms they chose, owners need to extend their focus to customers as they seem to represent the strongest incentive to join. As opposed to demand-side economies of scale, where the value of the product or service is contingent on the number of users (Hagiu & Wright, 2015), in the IIoT, it is contingent on the industry customer, the number of connected devices, and the data volume transferred.

C.6 Limitations and Future Research

Our study is subject to limitations. First, although our results follow a replication logic, generalizing them based on a single case study is challenging. We have studied what incentives positively influenced the joining decision of different types of complementors of a single IIoT platform ecosystem. In other domains, such as healthcare, relationships between complementors and platform owners could have different characteristics. Second, our sample includes firms that have already decided to join an IIoT platform, not those that refused to join—possibly due to uncertainty-related factors. Third, the study covers a relatively short period. A longitudinal design could yield more details in the idiosyncratic decision-making process of complementors.

Finally, we suggest two avenues for future research. First, applying our research model in other domains or to IIoT customers for analyzing their incentives to join could strengthen the validity of the three key incentives we proposed. The results could help platform owners to attract more customers and complementors to join. Second, we suggest examining how platforms should be designed to gratify the needs of different types of complementors (see an analysis of IIoT stakeholders, Petrik & Herzwurm (2020) and the project-oriented nature of current IIoT apps (Marheine & Pauli, 2020). Overall, our study answers a call for research on the incentives of joining digital platform ecosystems (Hein et al., 2020).

Paper D – Early Growth of IoT Platforms

Attribute	Description
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Table 19: Bibliographical Metadata on Paper D

Abstract. While the generativity of digital platform ecosystems has been studied extensively in many business-to-consumer domains, research on the novel phenomenon of IIoT platforms is sparse. The peculiarities of IIoT platform ecosystems are a double-edged sword: On the one hand, the heterogeneity of actors and devices leads to high generative potential. On the other hand, the resulting complexity can impede its realization. Even though generativity is often seen as a platform's inherent characteristic, our study suggests that it must be driven deliberately in complex domains like the IIoT. As initial results of a theory elaboration case study, we propose two modes that drive generativity in the form of a virtuous cycle by moving from abstraction of individual solutions to concretization of generic modules and vice versa. Our final results will contribute to extant literature on generativity in complex digital platform ecosystems and provide valuable insights for practitioners in the IIoT domain.

Keywords. Generativity, industrial IoT, digital platform ecosystems, platform governance.

D.1 Introduction

The Internet of Things (IoT) has affected how industry firms create and capture value moving slowly but surely from product-oriented supply chains to service-oriented ecosystems. These ecosystems are often formed around a digital platform (Hein, Weking, et al., 2019; Hodapp, Hawlitschek, et al., 2019). For example, Siemens, a large European industrial company, has launched its industrial IoT (IIoT) platform MindSphere in 2017. As an industrial operating system, MindSphere enables external firms to (1) connect and manage their devices, (2) communicate, store, and analyze data in its cloud, and (3) develop IIoT applications, such as predictive maintenance services, for different industry verticals (Petrik & Herzwurm, 2019a). Hence, IIoT platforms like MindSphere represent a generative system (Pauli & Lin, 2019). In this paper, we refer to generativity as a digital platform's capacity "to produce unprompted change driven by large, varied, and uncoordinated audiences" (Zittrain, 2006, p. 1980). Digital platform ecosystems are shifting the locus of value creation from inside the firm to an ecosystem of complementors (Constantinides et al., 2018; Parker et al., 2017). These third-party firms leverage the core modules of the platform to develop peripheral modules or applications to increase technological variety that serves many value propositions and increases platform adoption (De Reuver et al., 2018; Tilson et al., 2013). For example, Apple provides developers with software tools like Xcode, Swift, or the ARKit to enable individual development endeavors. Developers can, in turn, use these boundary resources provided by Apple's platform ecosystem to develop novel iOS applications for the iPhone or other devices. The platform's generativity leverages both internal (platform owner) and external (complementor) innovation output. Initial insights indicate that generativity is difficult to achieve in IIoT platform ecosystems due to their high technological and organizational complexity (Hein, Weking, et al., 2019; Pauli & Lin, 2019). Although information systems (IS) research has studied generativity in digital platform ecosystems as well as governance mechanisms that foster it (Eck & Uebernickel, 2016), most studies focus on business-to-consumer (B2C) markets with prominent examples, such as Apple's App Store (Eaton et al., 2015), Mozilla's Firefox browser ecosystem (Tiwana, 2015a), or Sony's PlayStation (Cennamo & Santaló, 2019). In contrast, research on business-to-business (B2B) platform ecosystems is sparse with some exceptions stemming from the enterprise software domain (Huber et al., 2017; Sarker et al., 2012; Wareham et al., 2014) and initial studies emerging in the IIoT (Hein, Weking, et al., 2019; Hodapp, Hawlitschek, et al., 2019; Pauli & Lin, 2019). As a result, there are few, if any, theoretical accounts of what strategies actors can pursue to drive generativity in complex

environments like the IIoT. We thus seek to bridge this void by addressing the following research question: *How can generativity be stimulated in IIoT platform ecosystems?*

To answer this research question, we conduct a theory elaboration case study (Ketokivi & Choi, 2014) at a large telecommunication provider which recently tapped into the IIoT platform market. The paper at hand presents preliminary results of the first conceptual phase of our study. To this end, we conducted a literature review on generativity in digital platform ecosystems and—guided by our first semi-structured interviews—mapped our findings to the IIoT domain. Drawing on the service-dominant logic and the concept of boundary resources as an analysis lens, we present our initial model, illustrating how actors can drive generativity. In particular, we propose two modes—*Mode 1: diversity of end-to-end solutions* and *Mode 2: diversity of modules*—that reinforce each other moving from abstraction to concretization and vice versa. We argue that the application of both modes may finally result in a virtuous cycle of generativity. We offer the modes together with their underlying governance mechanisms to contribute to prospective theorizations on the strategies that drive generativity in complex digital platform ecosystems, especially in the IIoT (Hein, Weking, et al., 2019; Pauli & Lin, 2019). With that, we see great potential in the research project to shift the ongoing debate on balancing control and generativity (Wareham et al., 2014) to the actions needed to deliberately stimulate generativity (or external innovation) in the IIoT. In addition, our results provide practitioners in the IIoT business with initial guidance on how to drive generativity.

D.2 Theoretical Background

D.2.1 Digital Platform Ecosystems and Generativity

We conceptualize *digital platform ecosystems*, which are based on digital platforms (Constantinides et al., 2018; De Reuver et al., 2018) and business ecosystems (Moore, 1993), as collaborative arrangements among economic actors who are centered around a focal firm's digital platform (Adner, 2017; Jacobides et al., 2018; Lusch & Nambisan, 2015). These actors develop and exchange technical artifacts via a platform and thus add functionality in the form of peripheral modules (De Reuver et al., 2018; Selander et al., 2013; Tiwana et al., 2010; Yoo et al., 2012). Modules include generic functional specifications to meet the needs of various end-users (Tiwana et al., 2010) ranging from browser plug-ins (e.g., Mendeley's Web Importer) to mobile games (e.g., Niantic's Pokémon GO) to industrial services (e.g., Siemens's Asset Performance Monitoring).

Following this socio-technical view (Bostrom & Heinen, 1977), digital platform ecosystems generate a variety of applications on an unanticipated scale (Tilson et al., 2010; Yoo et al., 2010).

Generativity represents the scale of complementary output, i.e., the digital platform ecosystem's ability to fuel the generation of complementary applications by autonomous actors (Cennamo & Santaló, 2019; Tilson et al., 2010; Yoo et al., 2010). The concept was originally defined as "a technology's overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences" (Zittrain, 2006, p. 1980). Accordingly, generativity necessitates core modules (digital platform), resources to utilize them (boundary resources), and a variety of actors who bring in individual domain-knowledge and innovation capabilities (value cocreation) (Tiwana et al., 2010). For example, Apple's platform comprises the mobile operating system iOS (to develop apps), the App Store (to access apps), and the iPhone (to use apps). Apple provides boundary resources, such as application programming interfaces (APIs) and software development kits (SDKs), to reduce individuals' development efforts. With every new iOS application, Apple addresses more consumer needs and drives the generativity of the overall platform ecosystem (Eaton et al., 2015). However, developers must follow the rules that Apple imposes in terms of development and commercialization. The question of how to drive generativity in digital platform ecosystems dates back to the early 2000s—with works on "complementary innovation" and "modular substitution" (Gawer & Cusumano, 2002; West, 2003)—and has recently received much attention in the IS community (Cennamo & Santaló, 2019; Eaton et al., 2015; Hein, Setzke, Hermes, & Weking, 2019; Tilson et al., 2010). Eck and Uebernickel (2016), who conducted an in-depth review of 20 IS-papers on generativity, identified two distinct perspectives: *generative properties* and *generative patterns*. While the latter view emphasizes the evolutionary character of generativity that leads to changes even beyond the system designer's original intentions (Henfridsson & Bygstad, 2013; Tilson et al., 2010), the former view defines generativity as a consequence of system design, making a system's degree of generativity comparable to others as a function of its inherent qualities (Eaton et al., 2015; Wareham et al., 2014). This means that the degree of modularity (Yoo et al., 2010), the diversity of boundary resources (Ghazawneh & Henfridsson, 2010), or the pricing decisions (Schreieck et al., 2016) made by the platform owner affect generativity. In this sense, the generativity of a digital platform ecosystem can be influenced by the governance strategies employed by the platform owner (Marheine, 2020).

Platform governance refers to the rules and processes, designed by the platform owner, that prescribe the development and commercialization opportunities of complementors (Ghazawneh & Henfridsson, 2013; Tiwana, 2015a). Platform governance has an architectural and a relational dimension (Foerderer et al., 2014; Van Alstyne et al., 2016). Architectural governance targets the platform's properties and functionalities and is thus shaped by mechanisms like APIs (ways to interact with the platform), SDKs (ease to develop), and the frequency of changed modules (Tiwana et al., 2010). As such, a platform's architectural design has an effect on relational governance as it can lower or increase coordination efforts in value cocreation activities. Relational sources to leverage generativity have pointed, for example, to the alignment and intensity of ties between vendors and partners (Sarker et al., 2012). For instance, Apple's generativity depends on its platform architecture and the organizational relationships it spans. If Apple did not provide development kits for new pieces of software or forgo its international developer conferences, not nurturing close ties to developers, it could affect individuals' development progress and business models. Hence, the design of both architectural and relational governance can foster or impede generativity (Eaton et al., 2015; Tilson et al., 2010).

D.2.2 Mapping Related Work on Generativity to the IIoT Domain

Most related work on generativity relies on extreme cases with a consumer focus (Cennamo & Santaló, 2019; Eaton et al., 2015; Tiwana, 2015a) that follow a winner-takes-all logic and emphasize network size and the quantity and quality of complements (Boudreau, 2012). In smart factories—the paragon of the IIoT— platforms are used to connect the industrial assets to a firm's information systems and business processes with the goal to analyze more data sources improving industrial operations (Sisinni et al., 2018). With that, IIoT platforms can help factories to become "smart", facilitating the emergence of new business models and opening up for complementary innovation by third parties. Digital platform ecosystems with such business focus have smaller networks and display higher levels of complexity (Tilson et al., 2013) emphasizing the need for novel strategies to drive generativity. Research in the nascent field of IIoT platform ecosystems has therefore tried to study different governance mechanisms to stimulate innovation by third parties.

In particular, Hein et al. (2019) studied value cocreation activities among actors in IIoT ecosystems and found three practices to drive them: supply-side integration, demand-side platform readiness, and servitization through application enablement. Marheine

(2020) identified five governance strategies in IIoT platforms based on a multiple case study and emphasized that the degree of platform openness was not comparable to the scale of B2C domains and would depend on the owner's traditional business. Petrik and Herzwurm (2019) studied three types of boundary resources of Siemens MindSphere, namely technical, development, and social boundary resources. Even though these studies highlight different governance mechanisms to leverage generativity, they view it as an implicit characteristic of IIoT platform ecosystems. As a result, they do not provide insights on how to drive generativity in such complex environments in the first place. However, as actors in nascent IIoT platform ecosystems are facing significant challenges with regard to value cocreation (Hodapp, Hawlitschek, et al., 2019), such insights are needed to overcome these complexity-related challenges and drive generativity. This is underlined by recent studies that found IIoT platform ecosystems not to be as "generative" as many of their B2C counterparts because of many impeding factors such as the high cost and complexity of complement development and adoption insecurity (Pauli & Lin, 2019; Pauli et al., 2020).

We thus try to synthesize the studies' key arguments for increased complexity in the IIoT and structure our line of thought using the tripartite framework of Lusch and Nambisan (2015), i.e., ecosystem, platform, value cocreation. First, ecosystems and their constituting actors are legal organizations and, as such, diverse and oftentimes interdependent (e.g., device manufacturers, system integrators, consultancies). Second, the core modules of an IIoT platform must be generic enough to be compatible with a broad range of hardware (e.g., sensors, machines) and software (i.e., communication protocols, enterprise systems) and specific enough to bear value across different industry verticals (e.g., agriculture, manufacturers, logistics). Third, value cocreation in the IIoT is more complex because of the diversity of industries and heterogeneity of customers and devices which requires complementors to have the appropriate domain know-how and the capabilities to implement end-to-end (E2E) solutions with different integration, security, and reliability requirements (Hein, Weking, et al., 2019; Sisinni et al., 2018). Therefore, generativity as defined by Zittrain's (Zittrain, 2006) will not be applicable unconditionally to IIoT platforms (Pauli & Lin, 2019).

In conclusion, these peculiarities of IIoT platform ecosystems are a double-edged sword: On the one hand, heterogeneity of actors and devices increases a system's generative potential (Yoo et al., 2010). On the other hand, the diversity and individuality of customer settings and the challenging requirements regarding integration and reliability impede the manifestation of the generative potential, especially in the form of a variety of

generic solutions (i.e., modules) available to the whole ecosystem (Pauli et al., 2020). To resolve this contradictory dualism, governance strategies are needed that enable the actors in IIoT platform ecosystems to drive generativity in the sense of a complementary duality (Wareham et al., 2014).

D.3 Research Method

Our research follows a theory elaboration approach as proposed by Ketokivi and Choi (2014). Case studies with the objective of theory elaboration place equal importance to theory and empirical evidence (Ketokivi & Choi, 2014). To this end, the researcher takes general theory and analyzes it in light of the specific empirical context. The resulting "preexisting conceptual ideas or a preliminary model" (Fisher & Aguinis, 2017, p. 441) form the basis for the subsequent iterative examination of the empirical material. Thus, our research project consists of two phases and a total of three steps: (1) literature review, (2) transfer to domain, and (3) empirical evidence (Ketokivi & Choi, 2014) (see Table 20). In the paper at hand, we present the **conceptual definition phase** of our research-in-progress in form of our preliminary model (see Figure 9). We drew our theoretical preunderstanding from a literature review and mapped concepts of the general theory on generativity to the domain of IIoT platform ecosystems. The **(1) literature review** traversed three steps. First, we scanned related work on digital platform ecosystems (De Reuver et al., 2018) and generativity—a topic sparked by two calls for research (Tilson et al., 2010; Yoo et al., 2010). Due to the 10-year gap between both calls and today, we followed a journal-based search with a focus on the AIS Senior Scholars' Basket, checking the titles, abstracts, and keywords of each hit for "generativity" in the context of platforms. Second, we complemented the journal papers with conference papers (e.g., ICIS, ECIS) to include some of the latest findings. We were able to double-check these results with the review of Eck and Uebernickel (2016). Third, we performed a forward and backward search which led to a final list of 34 papers that we analyzed in depth. As some of these papers related to both our concept and domain of interest (e.g., Hein, Weking, et al., 2019) they supported us in the **(2) transfer to domain**. The theoretical preunderstanding presented in this paper will guide our **empirical elaboration phase** as the next step in our study. The objective of this phase is to go back and forth between empirical evidence and the preliminary model and extend existing theory by analyzing it in light of the empirical observations (Fisher & Aguinis, 2017). In contrast to a theory-testing approach, however, the researcher does not intend to purely test preconceived hypotheses but strives to maintain "a logic of discovery rather than only a

logic of validation" (Van Maanen, Sørensen, & Mitchell, 2007, p. 1146). Our case analysis will rest on **(3) empirical evidence** from a large European telecommunication provider called TelcoCorp (for reasons of anonymity), which has recently tapped into the IIoT market with its IIoT platform ecosystem. TelcoCorp's platform enables firms to build a variety of IIoT solutions, e.g., optimized production in the medical technology industry, improved customer experience in the brewery industry, or cleaning robots for facility management. In sum, TelcoCorp combines its connectivity business (horizontal approach) with its system integration business (vertical approach)—a balancing act that can provide new insights into generative properties or patterns. So far, we have conducted four initial interviews with the head of IoT (I1), an IoT project manager (I2), the head of analytics (I3), and the head of sales IoT (I4)—each lasting over an hour.

Phase	Step and outcome	Scope
Conceptual definition (Theory focus)	**(1) Literature review** • A set of relevant papers on generativity in digital platform ecosystems (N=34) **(2) Transfer to domain** • A model (Figure 9) to drive generativity in IIoT platform ecosystems	**Paper at hand**
Empirical elaboration (Empirical evidence focus)	**(3) Empirical evidence** • A series of interviews with TelcoCorp, partners, and customers • A refined/extended model and set of governance mechanisms for both modes	In progress

Table 20: Research Design

D.4 Driving Generativity in IIoT Platform Ecosystems

Guided by our conceptual definition phase, we present two modes that drive generativity in IIoT platform ecosystems. In particular, we follow Hein et al. (2019) and combine the service-dominant (S-D) logic (Lusch & Nambisan, 2015) and the theory of boundary resources (Ghazawneh & Henfridsson, 2010, 2013) as an analysis-lens to uncover how the two modes differ from and interact with each other. The S-D logic theorizes how actors cocreate services in digital platform ecosystems and is thus appropriate to analyze how generativity can be stimulated. We use the ecosystem, platform, and value cocreation dimensions of the S-D logic to organize our findings (Lusch & Nambisan, 2015). The concept of boundary resources emphasizes the diversity of a platform's technical and social software-based tools that seek to support complementors' development endeavors (Ghazawneh & Henfridsson, 2010, 2013). We draw on this concept to emphasize the relative importance of boundary resources in both modes.

Figure 9 presents our model and lists each mode's explanatory governance mechanisms which will guide our empirical elaboration phase. Following the lines of the Head of

IoT at TelcoCorp—*"When we talk about IIoT solutions, for the moment, they will always be a mixture of horizontally scalable and vertical individual solutions" (TelcoCorp_I1)*—generativity in IIoT platform ecosystems needs to be viewed along two dimensions: the diversity of E2E solutions and the diversity of generic modules. While customers are primarily interested in specific vertical solutions (Schermuly et al., 2019), the platform owner, as well as the complementors, have great interest in horizontally scalable ones. Coming back to the double-edged sword metaphor discussed above, our model resolves the dualism of heterogeneity-driven generative potential, on the one hand, and complexity-related barriers, on the other hand. Our model proposes to exploit the heterogeneity by driving E2E IIoT solutions and overcome the complexity by driving horizontally scalable modules.

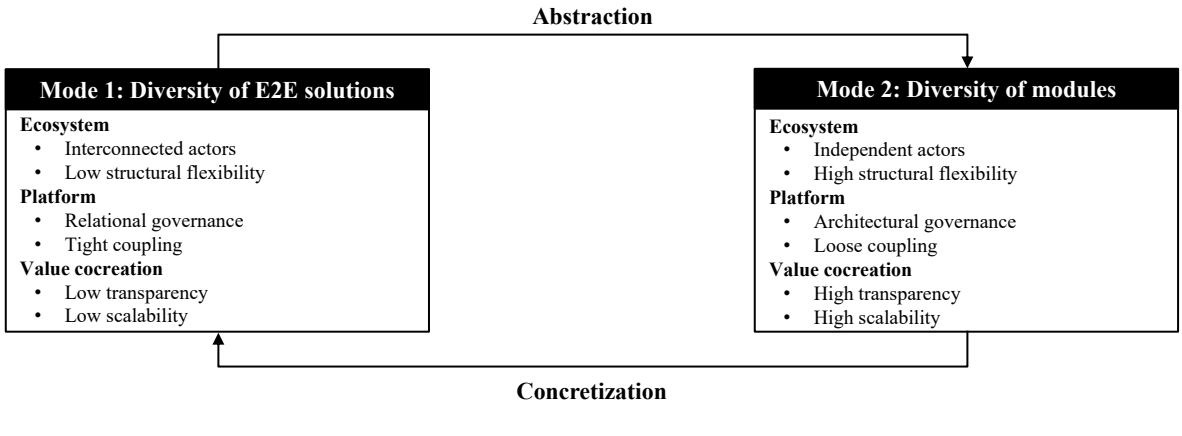


Figure 9: A Virtuous Cycle of Generativity

Mode 1: Diversity of E2E solutions drives generativity indirectly as the platform owner coordinates a set of economic actors beyond the platform's boundaries to cocreate E2E customer solutions, while parts of the solution can afterward extend the platform through abstraction. Here, the cocreating actors are *interconnected* (or mutually dependent) in terms of resources and capabilities. As most IIoT vendors cannot provide a one-stop E2E solution, they cooperate with sensor manufacturers, connectivity providers, cloud partners, and software developers to cover all technical layers, i.e., device, connectivity, middleware, and applications (Guth et al., 2018; Petrik & Herzwurm, 2019a). While customers contribute their domain knowledge, defining and communicating requirements, platform owners and their trusted partners drive the development of E2E solutions, which allow for *low structural flexibility* (**ecosystem**). The cocreation of E2E solutions follows a project logic, which goes beyond the provision of boundary resources, emphasizing *relational governance* over architectural governance. Our preliminary case results demonstrate that most customers ask TelcoCorp for E2E solutions as

their standard services do not fit all settings. E2E solutions require larger integration effort at the customer site which is often supported by the platform owner or integration partners. Thus, E2E solutions are *tightly coupled* (**platform**). Also, E2E solutions lead to *low transparency* in systems, processes, and actors involved. TelcoCorp, for example, faces large coordination efforts and constant tensions of *"who does what"* (I2) in the partner ecosystem. TelcoCorp aims at resolving such tensions through dedicated governance mechanisms, such as cocreation workshops (I3). Even though customers benefit from well-integrated E2E solutions, they run counter to standardized processes and value exchanges over the platform (Hein, Weking, et al., 2019). Partners, who are repeatedly preferred over others for E2E projects, might cause tensions in the ecosystem affecting the individual's value capture opportunities and the collective's worldview (Huber et al., 2017; Wareham et al., 2014). Lastly, while E2E solutions have *low scalability*, they help the IIoT platform ecosystem to build a strong reputation and capitalize on follow-up projects (**value cocreation**). Even though Mode 1 functions stand-alone, platform owners and partners have a great interest in feeding back parts of E2E solutions into the platform to increase its resource richness (Ghazawneh & Henfridsson, 2013; Lusch & Nambisan, 2015). We refer to this process as **abstraction**.

Mode 2: Diversity of modules drives generativity directly, as the platform owner enables economic actors within the platform's boundaries to develop and to commercialize peripheral modules, while these can afterward be tailored to the customer through concretization. In this mode, the cocreating actors are mostly *independent* of each other. Yet, they must still follow the rules, dictated by the platform owner, to integrate their modules (Ghazawneh & Henfridsson, 2010, 2013; Hein, Weking, et al., 2019). Accordingly, Mode 2 provides *high structural flexibility* to all actors (**ecosystem**). To support this process, platform owners focus on *architectural governance* and provide boundary resources. While technical resources like APIs and SDKs regulate the access of functionality and reduce development efforts, social boundary resources, such as developer communities and hackathons, foster development success and community building (Marheine, 2020; Petrik & Herzwurm, 2019a). Therefore, Mode 2 emphasizes *loosely coupled* modules. For example, customers of Siemens MindSphere can decide to use the predictive maintenance application of Siemens or that of a third-party developer (**platform**). Also, all of the standardized services offered on top of the platform are characterized by *high transparency* and *high scalability*. Yet, offering apps in the IIoT is often not enough to meet the requirements of industry customers who face connectivity (e.g., long vs. short range, high vs. low frequency), integration (e.g., legacy systems), and

deployment (e.g., local vs. global) challenges (**value cocreation**). Hence, standard modules must be recombined, integrated, or customized to the customer's needs, leading back to Mode 1. We refer to this process as **concretization**. Since Mode 1 flows into Mode 2 through the process of abstraction and vice versa in the form of concretization, we propose a virtuous cycle that indirectly (Mode 1) and directly (Mode 2) reinforces generativity. Table 21 synthesizes our preliminary results in form of a visualization, conceptual description, and first empirical evidence based on interviews with TelcoCorp.

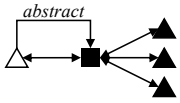
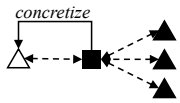
Mode	Conceptual description	Preliminary empirical material
Mode 1 	Mode 1 drives generativity indirectly, as the platform owner coordinates a set of economic actors beyond the platform's boundaries to cocreate E2E customer solutions, while parts of the solution can afterward extend the platform through abstraction.	*"When we talk about IIoT solutions, for the moment, they will always be a mixture of horizontally scalable and vertical individual solutions." (TelcoCorp_I1)* *"[…], I get a customer call for a project and then gather the partners who can do the job." (TelcoCorp_I1)* *"We currently look for bits that we can standardize and reuse. Standardization benefits everyone." (TelcoCorp_I2)*
Mode 2 	Mode 2 drives generativity directly, as the platform owner enables economic actors within the platform's boundaries to develop and to commercialize peripheral modules, while these can afterward be tailored to the customer through concretization.	*"We offer some standard applications on top of our IoT platform, especially analytics dashboards" (TelcoCorp_I3)* *"Such customization projects are ways to deepen our customer relationships and extend our business. Why should I let someone else do the job?" (TelcoCorp_I3)* *"We especially need partners for the sensor devices and domain know-how […] Compatibility is key" (TelcoCorp_I4)*
Demanding actor (customer) · *Supplying actor (complementor)* · *Tight coupling* *Platform owner (with platform)* · *Mode transitioning (abstract or concretize)* · *Loose coupling*		

Table 21: Preliminary Results

D.5 Discussion and Next Steps

Synthesis of preliminary results. This short paper presents two modes to drive generativity in nascent, complex digital platform ecosystems: Mode 1 and the process of abstraction and Mode 2 and the process of concretization. Guided by the conceptual definition phase, our preliminary results illustrate why scholars should distinguish precisely between different types of digital platform ecosystems and the mechanisms that may or may not apply. IIoT platform ecosystems, as more complex types, emphasize Mode 1 and the process of abstraction to drive generativity in addition to the well-known Mode 2 highlighting the provision of boundary resources. We thus propose to shift the view to

the economic actors who require new types of relational resources and patterns to effectively cocreate value in complex environments like the IIoT.

Initial contributions. In line with the chosen theory elaboration approach, our initial model is anchored in existing theory. As a consequence, the preliminary results presented in this paper contribute to ongoing discourses by "modifying the logic of general theory in order to reconcile it with contextual idiosyncrasies" (Ketokivi & Choi, 2014, p. 236) of the IIoT platform domain. The absorption of peripheral innovation into the platform, for example, has been discussed extensively in the literature (e.g., Parker et al., 2017; Sarker et al., 2012; Schreieck, Wiesche, et al., 2017). These studies approached generativity from a value capture perspective, seeing it as an outcome of the platform ecosystem (Hein, Setzke, et al., 2019). Even though we follow this line of thought, we emphasize that in complex digital platforms, facilitation and abstraction of E2E solutions is an antecedent rather than merely an outcome of generativity. Furthermore, our model suggests that abstracted solutions need to be fed back to the platform in the form of standardized modules for the overall platform ecosystem to flourish. Thus, we contribute to the discourse on resolving the tension between individual and collective value appropriation (Wareham et al., 2014).

Next steps. As illustrated in Table 20, the insights described in this paper are the results of the conceptual definition phase of our research project. The first interviews conducted at TelcoCorp (N=4) and the initial insights from the literature informed the transfer of the general theory to the domain of IIoT platform ecosystems. The result was our initial model, intended to serve as prescriptive knowledge regarding how to stimulate generativity in IIoT platform ecosystems. However, our initial interviews were primarily of exploratory nature, generating descriptive knowledge as to how our theoretical deliberations relate to a real-world IIoT platform ecosystem. Currently, we are conducting further semi-structured interviews with managers of TelcoCorp in different positions. In our elaboration phase, we will then iterate between theory and empirical evidence, thereby using the tactics of contrasting, specification, and structuring proposed by Fisher and Aguinis (2017) for theory advancement. This will allow us to see if the model is indeed suited to drive generativity, serving as prescriptive knowledge, or needs further refinement. However, data collection will not be restricted to the platform owner, but also include peripheral actors such as complementors and customers that have largely been neglected in research so far (Schreieck et al., 2016). We hope that this approach will provide valuable insights into further unknown governance mechanisms (e.g., structures to reduce coordination efforts in E2E IIoT projects) and may help to expand the

scholarly discussion from a static consideration of well-known trade-offs in platform research (e.g., control vs. generativity) to a more dynamic one (Wareham et al., 2014).

Paper E – Industry Incumbent Organizational Routines

Attribute	Description
Title	Microfoundations of Dynamic Capabilities for Platform Ecosystem Establishment: Evidence from Enterprise IoT
Short title	Industry Incumbent Organizational Routines
Authors	Christian Marheine, Dimitri Petrik
Year	2021
Publication outlet	Proceedings of the 42nd International Conference on Information Systems
Publication type	Conference paper
Ranking	A (Jourqual 3)
Publication status	Accepted

Table 22: Bibliographical Metadata on Paper E

Abstract. The internet of things (IoT) and digital platforms have offered industrial companies new opportunities to compete against digital platform-native companies. To succeed in this competition, industry incumbents must learn to extend their traditional product and service business through platforms. However, extant research has focused primarily on the ability of platform owners to govern mature platforms for innovation but has largely ignored how industry incumbents can build these capabilities internally during the establishment of their platform ecosystems as part of larger transformational journeys. To address this gap, we conduct a multiple case study of three incumbent organizations, drawing on a dynamic capability lens. We identify 11 practical microfoundations of sensing, seizing, and reconfiguring dynamic capabilities that aided three incumbents in establishing their IoT platform ecosystems. Besides the transformational activities, our findings contribute to the literature on platform establishment through three IoT-related shifts that deviate from known digital platform paradigms.

Keywords. Platform establishment, internet of things, digital platform, ecosystem, value cocreation, dynamic capabilities, microfoundations.

E.1 Introduction

Since 2015 digital platforms have gained increasing relevance in the context of the internet of things (IoT) (Pauli et al., 2021; Wortmann & Flüchter, 2015). Companies, such as Microsoft (Azure IoT), Bosch (IoT Suite), and AT&T (Control Center) enable enterprises in interconnecting and digitizing their physical assets for operational efficiency gains and equip them with a base technology for extending their business through complementary applications for revenue gains, e.g., predictive maintenance services (Cusumano et al., 2019; Pauli et al., 2021). If designed openly, IoT platforms inspire the formation of business ecosystems that offer digital solutions to complex business problems across domains, such as smart manufacturing, buildings, or logistics (Porter & Heppelmann, 2014; Sandebrg et al., 2020). Market researchers have reported that the IoT platform market is highly fragmented, with more than 600 offerings (Lueth, 2019). As none of the extant platforms launched have yet reached a maturity stage, the current picture does not align with the winner-takes-all paradigm indicating additional difficulties to establish enterprise IoT platforms (Pauli et al., 2021).

Our research departed from the notion of a platform lifecycle, describing different evolutionary stages, such as birth, expansion, leadership, and self-renewal (Teece, 2017; Tiwana et al., 2010). While prior information systems (IS) research has studied the governance decisions of multiple mature platforms, insights into their establishment are scarce (De Reuver et al., 2018; Saarikko et al., 2019). However, extant studies show that the establishment phase is the most difficult, with 85% of born platform ecosystems failing to survive (Cusumano et al., 2019; Pidun et al., 2020). Despite the various challenges associated with the establishment of platform ecosystems, such as solving the chicken-or-egg problem (Caillaud & Jullien, 2003), findings often stem from consumer contexts, such as Apple's and Google's mobile operating systems (Tilson, Sørensen, & Lyytinen, 2012). The enterprise IoT offers a novel and challenging context that allows scrutinizing "how" industrial firms with traditional product and service business (referred to as industry incumbents), such as GE, Bosch, or Toyota, are transforming their internal capabilities and resources to run both pipelines and platforms (Hanelt et al., 2020; Van Alstyne et al., 2016; Vial, 2019). So far, related work lacks concrete insights into the organizational processes that have helped them to thrive in their establishment, leaving room to contribute to the research stream on these challenging digital platform transformations (Pauli et al., 2021; Vial, 2019).

Since IoT platform ecosystems represent uncertain and dynamic environments (Hanelt et al., 2020; Hodapp, Hawlitschek, et al., 2019), we draw on dynamic capabilities (DCs) theory that helps us to explain how industry incumbents can establish IoT platform ecosystems successfully (Teece, 2017; Teece et al., 1997). In particular, industry incumbents need DCs to "attract and maintain a healthy ecosystem of complementors" (Teece, 2017, p. 223). However, as DCs refer to the macro-level capabilities of organizations to achieve a sustainable competitive advantage, scholars have called for more research on the micro-level practices that enable the manifestation of DCs (Schilke, Hu, & Helfat, 2018; Vial, 2019). Hence, in this article, we focus on the microfoundations of DCs, which refer to the organizational processes and routines that allow explaining how DCs reveal in practice (Felin et al., 2012; Mahringer & Renzl, 2018; Vial, 2019). This construct provides the right granularity level allowing us to infer DCs inductively from empirically collected data. Hence, we seek to identify the microfoundations of DCs that support the establishment of IoT platforms, enabling owners to cope with ecosystem dynamics (Teece, 2017). We, therefore, ask: *How can industry incumbents develop dynamic capabilities through microfoundations to establish enterprise IoT platform ecosystems effectively?*

To understand the establishment of enterprise IoT platform ecosystems from a DC lens, we used a multiple case study design (Yin, 2017). We gained insights into how a software, telecommunication, and hardware provider—typical incumbent IoT platform providers (Lueth, 2019)—developed their platforms, established their ecosystems, and fostered value cocreation among partners. To the best of our knowledge, this paper is the first to scrutinize microfoundations of DCs needed to establish platform ecosystems in the enterprise IoT context. Besides the identification of 11 microfoundations of DCs, we contribute prescriptive knowledge to theory and practice by shifting the viewpoint from platform providers' external activities (e.g., ecosystem governance) towards their internal transformations of effectively managing the establishment of enterprise IoT platforms. Our findings may help decision-makers of incumbent companies to implement DCs that foster IoT platform establishment journeys and to reach the maturity phase. Responding to various calls, we contribute to research on platform establishment in general and enterprise IoT platforms in particular (De Reuver et al., 2018; Jacobides et al., 2018; Pauli et al., 2021).

This paper is structured as follows: First, we present the conceptual background of IoT platform ecosystems, reassess findings of related work on platform establishment, and present the concept of DCs as a research lens. Second, we describe our qualitative,

exploratory research approach using a multiple case study design based on interview data (Yin, 2017). We interviewed managers who have accompanied and influenced the development of the incumbents' platforms. Third, we describe the 11 microfoundations of DCs that had an impact on platform establishment. Fourth, we discuss the implications for the super-phenomenon of digital platforms (De Reuver et al., 2018), synthesizing IoT-related shifts in the form of three propositions. Lastly, we draw a short conclusion on the paper's limitations and future research opportunities.

E.2 Background

This section introduces the concept of enterprise IoT platforms (**object of interest**), presents related work on digital platform establishment (**phenomenon of interest**), and offers a research framework based on DCs (**theory of interest**) as a theoretical lens for investigation.

E.2.1 Enterprise IoT Platform Ecosystems and Establishment

The rise of the IoT affects how businesses create, deliver, and capture value (Porter & Heppelmann, 2014). The concept of *IoT* refers to pervasive links between physical and digital assets via the internet (Wortmann & Flüchter, 2015). IoT makes a physical product "smart" as functionalities are decoupled from its corpus through code (Yoo et al., 2010). Hence, IoT solutions typically involve technical architectures that comprise four layers: hardware, connectivity, platform, and application (Porter & Heppelmann, 2014; Wortmann & Flüchter, 2015). They enable organizations to reduce costs by unlocking insights into internal operations and to add value propositions through data-based services (Porter & Heppelmann, 2014; Yoo et al., 2010). Besides various business-to-consumer (B2C) application contexts (e.g., wearables, smart home), growth in IoT is mainly expected in business-to-business (B2B) (or enterprise) sectors, such as smart manufacturing, grids, or logistics. Advances in product design (e.g., multi-sensors) and communication technologies (e.g., LoRa, 5G) foster the IoT market growth. To overcome technical hurdles of implementing IoT services, IoT platforms offer an interoperable and scalable digital architecture to process automatically generated data from the field and to control the assets' actuators (Wortmann & Flüchter, 2015).

In addition to representing a digital infrastructure for physical asset and data management, enterprise IoT platforms leverage the creation of digital services and are thus consistent with the concept of innovation platforms (Cusumano et al., 2019; Pauli et al., 2021; Yoo et al., 2010). Accordingly, we follow the joint notion of Tiwana et al. (2010)

and Tilson et al. (2012) and coin *enterprise IoT platforms* as socio-technical systems with central, extendable software stacks and social or economic actors that adopt, extend, or appropriate IoT-based innovation (De Reuver et al., 2018). Hence, enterprise IoT platforms represent an instantiation of innovation platforms (Cusumano et al., 2019). In contrast to transaction platforms (e.g., Amazon, Uber, Google Search), innovation platforms enable complementors to innovate additional modules (e.g., Siemens MindSphere's Asset Operations Analytics). These IoT modules range from dashboards to communication protocols, sensors, applications, and full-stack end-to-end solutions (Pauli et al., 2021). Hence, the business model of enterprise IoT platforms relies typically on software-based subscription models that can create indirect network effects, that is, supply-side IoT innovation increases platform adoption of customers and vice versa, i.e., attracts partners to join the IoT ecosystem (Cusumano et al., 2019; Jacobides et al., 2018).

Departing from the notion of a platform life cycle that describes different evolutionary phases from launch to renewal (Teece, 2017; Tiwana, 2014), prior research indicates that the earlier phases, which we refer to as the establishment, are essential to set the course for a dominant market offering (Cusumano et al., 2019). While research has studied multiple mature, native platform providers (De Reuver et al., 2018; Saarikko et al., 2019), insights on establishment, especially from the perspective of incumbents in enterprise IoT, are scarce (Pauli et al., 2021). These firms must change their organizational routines to add a platform business (Mody, Wirtz, Fung So, Chun, & Liu, 2020; Van Alstyne et al., 2016). The technological complexity of IoT solutions and market fragmentation stretch this challenge. IoT platform customers expect stable, reliable, and secure solutions—especially when production operations or critical business data are involved (Pauli et al., 2021). According to information systems (IS) and management scholars, companies that seek to establish digital innovation platforms, such as enterprise IoT platforms, must focus on mastering three dimensions: (1) developing a platform with a standalone value proposition, (2) establishing an ecosystem with co-specialized partners, and (3) fostering value cocreation as joint activities among partners (Ceccagnoli et al., 2012; Hein, Weking, et al., 2019; Sarker et al., 2012). Figure 10 presents our understanding of the establishment phase of digital platform ecosystems.

Platform. First, related work suggests that firms seeking to launch a platform should develop one with a standalone value proposition (Edelman, 2015). The platform should provide digital resources, empowering customers and partners to solve problems that were unsolved before (Cusumano et al., 2019; Gawer & Cusumano, 2008; Saarikko et

al., 2019). Successful platform launches were often studied from the viewpoint of the platform owner's governance decisions, such as openness (e.g., Gawer, 2014), leadership (e.g., Gawer & Cusumano, 2014), or boundary resources (e.g., Eaton et al., 2015), or market strategies, such as market entry decisions (e.g., Karhu & Ritala, 2020), pricing (e.g., Tiwana, 2014), and co-opetition (e.g., Hein, Weking, et al., 2019). In enterprise IoT, platforms often comprise large solution portfolios of modular applications to solve heterogeneous customer problems, combining both software and hardware (Pauli et al., 2021; Wortmann & Flüchter, 2015). Since diverse industries expect to source a variety of IoT use cases and end-to-end solutions from single IoT platforms (Menon, Kärkkäinen, & Wuest, 2020; Pauli et al., 2021), their providers seek to profit from products/services of complementors (i.e., software developers, system integrators, sensor designers).

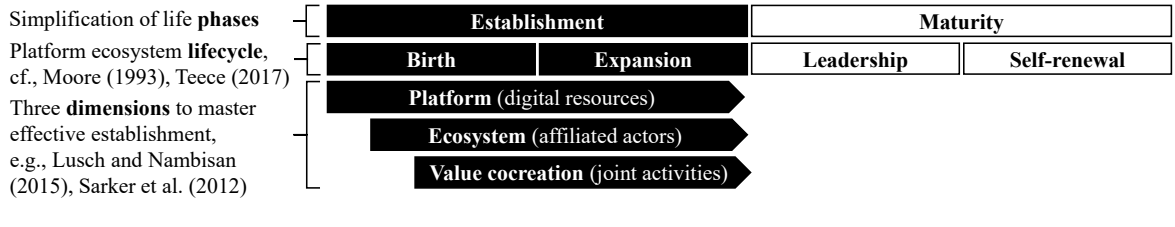


Figure 10: Conceptualization of Platform Ecosystem Establishment

Ecosystem. Second, to cope with the technological and business complexity in enterprise IoT, platform owners need to establish a platform-based ecosystem, convincing value-adding partners of joint goals (Jacobides et al., 2018; Pauli et al., 2021). Conceptually, ecosystems are related to platforms and describe non-hierarchal business networks that are defined through collaboration of business actors (Jacobides et al., 2018). Platform providers try to scale through complementary platform-based products or services, so that all ecosystem actors profit from innovation, leading to positive indirect network effects (Ceccagnoli et al., 2012; Nischak & Hanelt, 2019). To do so, owners must solve the chicken-or-egg problem (Stummer et al., 2018). Strategies to overcome this challenge typically rely on the commitment of marquee users (i.e., influential customers) that induce others to join the ecosystem (Edelman, 2015; Jacobides et al., 2018). In IoT, the number of partners (and dependence) grows due to technological complexity and the need for domain experts. As incumbents are used to managing supply chains with contractually defined quantity, time, and price of goods or services, they must learn to thrive in dynamic cocreation environments (Hein, Weking, et al., 2019; Marheine & Pauli, 2020).

Value Cocreation. Third, platform providers should enable and incentivize joint activities between actors to generate customer value. Originating from marketing research, value cocreation has become a dominant concept in IS research (Lusch & Nambisan, 2015) and platform research (Ceccagnoli et al., 2012; Hein, Weking, et al., 2019; Sarker et al., 2012). Platform ecosystems build a suitable organizational form for value cocreation (Jacobides et al., 2018). They serve as a source of unprompted (and uncoordinated) innovation (Wareham et al., 2014). As they ease the interaction between ecosystem participants, each component of an IoT end-to-end solution can be provided by the "best-in-class" complementors to cope with the heterogeneity of IoT (Wortmann & Flüchter, 2015). Another aspect of value cocreation is the increase in compatibility between complements, agreeing to use the same interfaces that are defined by the IoT platform owner (Ceccagnoli et al., 2012; Hevner & Malgonde, 2019). In addition, value cocreation in IoT requires customer agreement, as they own the digitalized assets, generated data, and intellectual property (IP) of the solution. Table 23 shows the findings of selected studies on establishing digital (and IoT) platform ecosystems.

Article	Dimension	Main contribution
Edelman (2015)	Platform	Convincing marquee users to adopt the platform before scaling.
Khanagha et al. (2020)	Platform	Process model through collaboration with and exploitation of platform natives.
Mody et al. (2020)	Value cocreation	Emerging convergences between the platform and the product offerings.
Ofe & Sandberg (2019)	Value cocreation	Tension-derived shift towards value-driven lock-ins of ecosystem actors.
Saarikko et al. (2019)	Value cocreation	Entrepreneurial ability to leverage explorative and exploitative skills.
Stummer et al. (2018)	Ecosystem	Six platform launch strategies addressing the chicken-or-egg dilemma.
Teece (2017)	Ecosystem	Emphasizing the need for dynamic capabilities to manage platform lifecycle.
Weiss et al. (2020)	Value cocreation	Onboarding of app developers with a focus on knowledge transfer.

Table 23: Selected Literature on Platform Ecosystem Establishment

As Table 23 indicates, contemporary research on platform establishment lacks concrete insights about the internal managerial routines that companies need to develop to thrive in the platform establishment phase. Current studies rather focus on ecosystem governance mechanisms and strategies platform owners should incorporate when launching a platform (Ofe & Sandberg, 2019; Stummer et al., 2018). While we observe much research on mature, native platform providers such as Google, Microsoft, and Apple (Cusumano et al., 2019; Eaton et al., 2015), we still know relatively little about how non-native platform providers must transform to effectively establish platform business

models (Van Alstyne et al., 2016). In this regard, the antecedents of governance decisions and platform strategies, which form their fundament, are still scarce (Saarikko et al., 2019). Moreover, only a few of the sighted papers shed light on the establishment decisions from the viewpoint of incumbents that are new to a platform business model (e.g., Khanagha et al., 2020; Weiss et al., 2020). As industry incumbents typically operate one or more business models both upstream and downstream, we need to explore the organizational routines and managerial processes required to foster platform-based value cocreation activities without abruptly breaking any "path dependency".

E.2.2 Research Framework based on the Dynamic Capabilities View

Figure 11 depicts our research framework and summarizes our understanding of an incumbent's task when establishing an IoT platform from the DC view (Teece, 2017). Unlike a research model, a research framework does not claim the rigorous description of constructs and relationships (Teece, 2007).

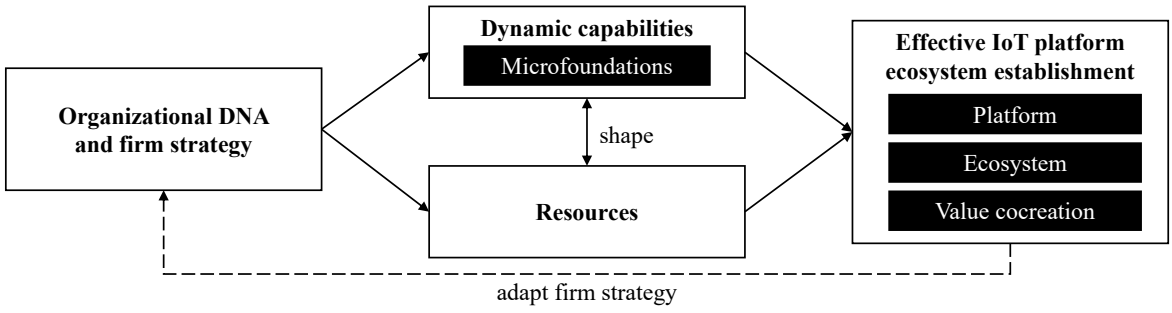


Figure 11: Research Framework

Dynamic Capabilities. The dynamic capabilities view (DCV) can be related to but extricates from other organizational theories of the firm, such as the resource-based view (RBV) (Barney, 2001; Helfat & Peteraf, 2003). While resources rather represent a firm's static tangible (e.g., machines) and intangible assets (e.g., patents), *dynamic capabilities* (DCs) refer to a "firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments" (Teece et al., 1997, p. 516). DCs help firms to regularly adapt their resources and capabilities to the dynamics of changing technologies, markets, and competitive environments and thus have a transformative effect on the DNA of organizations in terms of their traditional business models and current strategies (Teece, 2007). Hence, effective DCs represent the change management ability of a firm—i.e., the ability to proactively transform business routines with an inward (operational efficiency) and outward focus (commercial opportunities). According to Teece (2007, 2017), DCs can be disaggregated into a firm's ability to

effectively **sense** new business opportunities, **seize** them, and **reconfigure** the business for strategic change. In contrast to operational or ordinary capabilities that are directed toward maintaining a firm's current production (e.g., product development), DCs are forward-looking to explore and capture new business opportunities (e.g., regular reconfiguration of product development by external partners) (Teece, 2014; Winter, 2003). Overall, DCs represent a recognized theory to study why and how organizations evolve and master strategic renewal (Helfat & Raubitschek, 2018; Schilke et al., 2018; Vial, 2019), which is otherwise difficult to explain. As depicted in Figure 11, we seek to analyze how DCs can be developed through specific microfoundations that help industry incumbents to establish their enterprise IoT platforms, that is, to develop their platforms, establish their ecosystems, and foster value cocreation (Teece, 2007, 2017).

Microfoundations. To recognize and capture opportunities and threats in such dynamic environments, decision-makers in platform companies require implementation guidance for achieving or developing DCs (Helfat & Raubitschek, 2018). As DCs refer to abstract, macro-level capabilities of organizations, scholars called for a micro-level construct to explain how organizations can build DCs in practice (Felin et al., 2012). The construct to achieve this analysis level is that of microfoundations (Teece, 2007). *Microfoundations* represent the managerial processes and routines on an individual- and organizational group-level (Felin et al., 2012; Mahringer & Renzl, 2018; Winter, 2013). Microfoundations enable the researcher to understand how DCs can be created and benefit practice, as they rather instantiate DCs (Felin et al., 2012; Mahringer & Renzl, 2018; Salvato & Rerup, 2011; Winter, 2013). Table 24 defines the primary constructs.

Construct	Description	Key references
Dynamic Capabilities	A "firm's ability to [sense, seize, and reconfigure] internal and external competencies to address rapidly changing environments" (Teece et al., 1997, p. 516).	Teece (2007), Teece et al. (1997) Winter (2003)
Micro-foundations	A firm's managerial processes and organizational routines on an individual- and group-level explaining the dynamic capabilities on a mid-analytical level between abstract capabilities and concrete case-based manifestations.	Felin et al. (2012), Mahringer & Renzl (2018), Winter (2013)
Platform Ecosystem Establishment	A firm's ability to launch a platform with a standalone value proposition, establish an ecosystem with affiliated collaborating actors, and foster value cocreation activities among actors for value-adding complements.	Lusch & Nambisan (2015), Saarikko et al. (2019)

Table 24: Description of Constructs

E.3 Research Design

As we recognized the lack of empirical studies on microfoundations of DCs in platform contexts, we decided to collect primary data by conducting an exploratory qualitative interview study with three industry incumbents in the software, telecommunication, and hardware sector. We choose a multiple case study as the appropriate design for this research as the objective was to identify what microfoundations of DCs and how they had been applied by the cases to establish enterprise IoT platform ecosystems (Yin, 2017).

E.3.1 Case Selection and Description

In the enterprise IoT context, platforms are offered by a variety of organizations. Among these firms are not only platform natives (e.g., Microsoft, Google, Helium) but industry incumbents, such as IBM, AT&T, or General Electric. This paper focuses on the latter, industry incumbents, that are characterized by a pipeline business that must be operated efficiently and reliably on a daily basis.

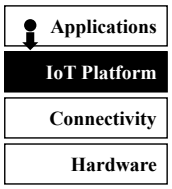
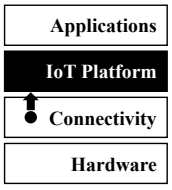
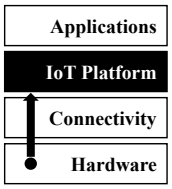
Case	Description of cases
SoftCorp 	Softcorp is a well-established software company that serves its international business customers with a wide range of proprietary cloud-based and on-premises solutions (**who**). As SoftCorp already developed software-based innovation platforms for its business customers, seeing great business opportunities in IoT, Softcorp decided to gain market share, one of the strategic initiatives being the launch of its IoT platform ecosystem (**why**). Its IoT platform complements its software licensing business and existing enterprise software suites for API management, process mining, multipurpose databases and relies on the already developed and sold building blocks of the previously sold platforms (**what**).
TelcoCorp 	TelcoCorp is a large European telecommunication provider that serves consumer and business markets with mobile and broadband connectivity, media entertainment, and cloud services (**who**). Since TelcoCorp had been facing significant operational challenges over the past years, such as stagnating sales and fierce competition against over-the-top (OTT) service providers, it decided to tap into the emerging IoT market and capture some of the data-based value (**why**). Its IoT platform complements and logically extends its connectivity solutions, such as LoRa and 5G. The IoT platform, which is well-perceived by customers in the market, can be extended through external data and innovation by its IoT business ecosystem (**what**).
HardCorp 	HardCorp is a multinational European conglomerate that serves consumer and business markets with a broad product and service portfolio yet being known for its industrial technology business (**who**). To protect its current hardware technology sales business from commoditization and digitization and as a tactical response to competition in the area of digital IoT-based services (e.g., predictive maintenance), HardCorp decided to build up software capabilities to harness more value in the digital era (**why**). As a result, the developed IoT platform initially enabled internal software development for enterprise IoT applications and was later opened to complementors along with active partner ecosystem building (**what**).

Table 25: Description of Cases

Despite their strengths vis-à-vis platform natives, such as established product or service businesses, customer relationships, domain know-how, and access to an installed base, little has been reported on incumbents' experiences in setting up digital platform businesses. Although the global IoT platform market undergoes a concentration with firms like Microsoft at the forefront, it is not yet consolidating, indicated by growing numbers of IoT platform providers (Lueth, 2019). Among the incumbent providers are software (e.g., IBM), telecommunication (e.g., AT&T), and industrial hardware providers (e.g., General Electric) (Briglauer, Ohnemus, & Viete, 2018; Lueth, 2019). To choose a representative case for each of the groups, we selected three multinational European companies, we refer to through the pseudonyms *SoftCorp*, *TelcoCorp*, and *HardCorp*. Doing so allows us to derive more general knowledge about IoT platform establishment for the whole group of industry incumbents (cross-case analysis) as well as to capture possible differences in DCs of the individual cases (within-case analysis). Table 25 briefly describes the three cases (who) and elucidates their strategic direction—expressed through the four-layer IoT technology stack—when decided to develop their IoT platform ecosystems (why, what).

E.3.2 Data Collection

We conducted an interview study from April 2020 to April 2021. Since our interest was to identify microfoundations of DCs, we purposefully conducted 19 semi-structured interviews with managers to get multiple perspectives on the IoT platform decisions. All managers we interviewed had accompanied the establishment of the IoT platform ecosystems from the beginning—with a retrospective of four to six years—or had been brought into play with a leadership role early after launch. Typically, we started interviewing the representatives of the middle (e.g., head of sales, ecosystem manager) and the senior management (i.e., vice presidents). In some cases—based on the interest in our study—they forwarded us to the C-level management (e.g., chief executive officer (CEO), chief product officer (CPO))—a sampling strategy known as snowballing (Corbin & Strauss, 2014). The top management interviews aided in gaining an in-depth understanding of organizations' business history and current strategy, including their decision to tap into the IoT platform market, as top executives typically have much corporate or industry experience. Most interviews were conducted by both researchers using Microsoft Teams. While one researcher was guiding the interview, the other asked follow-up questions based on interviewees' responses (Corbin & Strauss, 2014). We adhered to theoretical saturation (Eisenhardt, 1989; Glaser & Strauss, 1967) and ended the data collection when major themes were repeated regularly. For example, as

managers of HardCorp started mentioning the same details connected to the processes of a recent company acquisition in the platform context, we felt the saturation point. Table 26 shows an overview of the interviews conducted, including the individuals' management affiliations, number, and average duration. As we conducted semi-structured interviews, we followed a pre-defined guideline derived from the literature on DCs and platform establishment. While the guideline focused on questions related to the DCs, it was flexible enough to adapt to the interviewee's profile or background regarding the platform context. After the interviews were conducted, we transcribed the audio-recorded interviews (i.e., raw data) for analysis. In addition to this interview study, which served as the main source of information for this research, we used other data sources, as advised by Yin (2017), to triangulate the interviewees' statements and thus test their robustness. Besides these interviews, publicly available information such as company websites, informal conversations with other company representatives, and internal documents of the case firms also served as data sources

Management affiliation of interviewees	SoftCorp	TelcoCorp	HardCorp	Total
C-level management (e.g., CEO)	1	-	1	2
Senior management (e.g., vice president)	1	4	3	8
Middle management (e.g., head of sales)	3	3	3	9
Total (average duration in minutes)	**5** (~61)	**7** (~71)	**7** (~67)	**19**

Table 26: Overview of Interviews

E.3.3 Data Analysis

Before analyzing the empirical data, we read through all transcripts and the incumbents' websites to capture relevant information about the platform contexts, building a common understanding. Then, we started our three-step coding process. First, we **openly coded** relevant themes related to our pre-defined constructs (see Table 24), focusing on microfoundations of DC (i.e., processes, routines). This first identification step was conducted independently by the two researchers to prohibit potential biases (Corbin & Strauss, 2014). Second, we applied **axial coding** by comparing our codes for each interview, case, and across cases. During this step, differences in open coding were discussed among the two researchers to arrive at a common understanding, increasing intercoder reliability. The process resulted in themes that we iteratively and continuously compared to prior literature on platform establishment, including rigorously investigated concepts, such as governance, openness, and leadership (Tiwana, 2014). Doing so ensured that we would rather adopt established concepts and themes than renaming them. To do so, the researchers conferred in weekly online meetings lasting several hours to share their

analyses and interpretations on the relevant themes. Third, recognizing the number of relevant themes, we followed **selective coding** to effectively yield answers to the research question. Therefore, we decided to exclude codes that were not (1) IoT-specific, (2) proactively related to change management, and (3) actionable to arrive at codes that would map into our understanding of microfoundations of DCs. Lastly, we classified the final, recurring codes in Figure 12. The framework assigns all microfoundations to the three types of DCs (sensing, seizing, and reconfiguring) and the establishment dimensions (platform, ecosystem, and value cocreation). We validated the results (i.e., the classification of microfoundations in the framework) and the two dimensions of the framework regarding their appropriability to answer our research question through numerous iterations between both authors, feedback discussions with more than five of the associated IS professors of the authors' research institutes, and a brief practitioner workshop—all of which provided verbal feedback that was incorporated in the final artifact (see Figure 12) (Corbin & Strauss, 2014).

E.4 Microfoundations for Establishing IoT Platform Ecosystems

Figure 12 presents the main findings of our study, showing the microfoundations (i.e., processes, routines) of DCs the three firms developed to effectively establish their IoT platform ecosystems (i.e., platform, ecosystem, value cocreation).

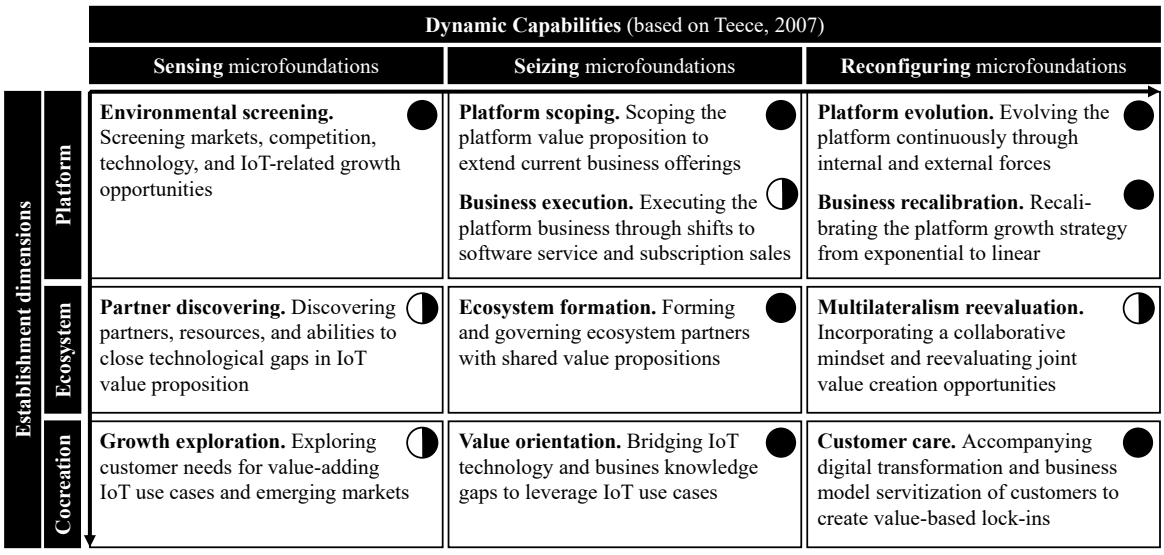


Figure 12: Summary of Findings

We use Harvey balls to show whether microfoundations, described in the next sections, stemmed from statements of one (empty), two (half-full), or all three cases (full).

Despite differences in the concrete activities of the case firms, we were able to identify 11 microfoundations of DCs that were backed by at least two firms from our sample.

E.4.1 Sensing Microfoundations

We identified three sensing microfoundations along the three establishment dimensions: (1) environmental screening, (2) partner discovering, and (3) growth exploration.

Environmental screening. In the early days around 2015, SoftCorp, TelcoCorp, and HardCorp sensed the platformization across markets (e.g., banking, healthcare) and the use of emerging technologies, such as IoT. These environmental analyses were carried out internally or conducted by consulting and research firms. HardCorp, for example, noticed how its main competitor pioneered the platform- and IoT-based service business in the manufacturing space. In addition to responding to its direct competition at the time, HardCorp and other incumbents had to protect against the vertical business expansion of platform natives, such as Microsoft and Amazon Web Services (AWS). Microsoft, for instance, competed against SoftCorp in the software-as-a-service (SaaS) market, pushed against TelcoCorp in the network digitization space, and penetrated the digital manufacturing business, making HardCorp fear the commoditization of its product business. Their sensing ability helped the incumbents to identify the competition and prepare response tactics. Besides reacting to the external environment, incumbents realized a lot of potential in IoT, shifting their product business to a service business. In fact, multiple companies across industries have sensed the major trends of digitalization, servitization, and automation, for example, in the context of manufacturing systems. HardCorp, in particular, recognized the potential to improve its operational efficiency (e.g., cutting onsite maintenance) and commercialize digital services (e.g., asset management, predictive maintenance). Doing so independently from large software firms required HardCorp to rethink its IoT-based business opportunities and the need for a digital platform. Hence, the company proactively evaluated the platform business potential with internal and external stakeholders. Lastly, some senior managers, who sensed the growth potential of an IoT platform early on, had a high weight on the final decision to tap into the IoT-platform business in 2015, predicting that it would become the fundamental building block of a virtuous business ecosystem.

> *"Our catchphrase in 2015 was "beat [main competitor]", which led us to look at the topic much more broadly. In addition, we could not let ourselves be disconnected from our hardware and compete against commodity providers. That was the major rationale for launching the platform […]. We have also recognized the*

> *trend of servitization, which was accelerated by digitalization and IoT. Traditionally, we have been a physical product and onsite service business. From this case, we developed a strategy with concrete use cases, for example, how we could help customers in improving production operations without having technicians onsite—what we call predictive maintenance today. To offer such industrial services, we needed an IoT platform. Ideas regarding network effects came later."*—Middle manager, HardCorp

Partner discovering. Like HardCorp, SoftCorp's and TelcoCorp's managers discovered the emergence of technology-centered business ecosystems. An ecosystem represented an appropriate approach to close potential value gaps based on joint goals. Hence, incumbents scouted potential partners, resources, and abilities that could complement their core value proposition. TelcoCorp, for instance, offered connectivity solutions and profited from collaboration with sensor and device manufacturers. Likewise, SoftCorp sensed collaboration potential in the same complementor group, derived from customers' needs to retrofit assets, i.e., to equip physical assets with connectivity ex-post. In fact, few companies manufacture products with out-of-the-box connectivity, although industries such as manufacturing look at 30+ years of asset lifecycles. The incumbents' partner discovery ability came to light through various information exchange processes. For example, one of SoftCorp's board members sensed the potential for creating a joint venture (to market IoT solutions for the manufacturing industry) together with multiple incumbents of the manufacturing industry through its supervisory function in one of the other companies. Yet, only HardCorp and SoftCorp developed dedicated partner management functions that would sustainably establish the partner discovery ability.

> *"Partner discovery happens both formally and informally or by accident. For example, [a joint venture] was born through the dual function of one of our board members: he was in our management board and the supervisory board of one of the founding members (of the joint venture). […] Think about the 38,000 manufacturing companies in Germany alone, a large portion of which, unlike the big automakers, come without connectivity. We realized early on that we required a retrofitting capability in our ecosystem portfolio to seize our IoT platform business."*—Senior manager, SoftCorp

Growth exploration. Throughout all interviews, managers equated value with customer value and described it as the most critical goal for success as it would eventually determine platform and ecosystem growth. Yet, before the incumbents could add value for their customers, they needed to understand their customers' current problems and listen

carefully. TelcoCorp, for example, instructed its business developers to regularly, but unobtrusively, check in with customers about digitization projects so they would learn about IoT business cases early on. In that, they sensed the complexity within the IoT context and inferred to develop advanced consulting skills to bridge technological and business gaps for promising IoT projects. Customer workshops represented a popular method that was excessively used by SoftCorp and TelcoCorp (with little domain expertise) to identify valuable customer business cases. Hence, they profited from their employees' ability to co-explore IoT opportunities with customers.

> *"Everything we do is customer-driven, also in enterprise IoT. Our rather single-sided ecosystem approach to learning about our customer domains and their pain points helped to grow interest in the platform ecosystem and created much market attention. Our partners then grew naturally in the ecosystem, as partners see us not just as a network and platform provider but also as a sales channel."*—Senior manager, TelcoCorp

E.4.2 Seizing Microfoundations

We identified four microfoundations of seizing along the three establishment dimensions: (1) platform scoping, (2) business execution, (3) ecosystem formation, and (4) value orientation.

Platform scoping. As incumbents sensed the opportunity for an IoT-based platform-as-a-service (PaaS) business, they allocated resources in the form of budget, staff, and autonomy (e.g., cross-functional teams) to develop the platform. The incumbents directed their internal innovation and R&D departments to ideate functions and features the platform had to comprise or conducted acquisitions to accelerate development of features and market entries. Crucially, all incumbents designed platforms primarily to extend their current business offerings. For example, SoftCorp expanded its software integration business through its IoT middleware, supplying it to third-party IoT platform providers. TelcoCorp, specialized in connectivity and device management (e.g., firmware updates) to get more load on the networks. Lastly, HardCorp focused on leveraging its installed base of hardware devices through asset management and digital twins. However, effective platform scoping required incumbents to balance internal and external content creation. To foster ecosystem innovation, they defined complementary markets that would be left untapped.

> *"One success pattern, we had to learn, was to develop the platform offering, focusing on both internal and external value. Regarding our market offering, we*

started with a focus on specific niches and then grew increasingly broadly. We kept this focus phase very short, which led to difficulties."—Senior manager, HardCorp

Business execution. To seize the IoT platform opportunity, incumbents had to master software product development and sales management. First, HardCorp, in particular, reported some transitions that had to be learned in the area of software platform development, such as availability, incident, change management, and service desk processes. The focus was on becoming a software company and allowing for an appropriate and state-of-the-art customer experience in the case of errors. Second, the platform launch was promoted by dedicated sales teams. As the incumbents sensed potential internal conflicts between traditional product line sales teams and platform sales teams, they launched new sales units trained to sell the PaaS offerings. However, platform and software sales, which were closed on 3-year consumption-based subscriptions on average, were less attractive than large, perpetual software license sales regarding the sales bonuses. To solve this tension, SoftCorp's management, for instance, calculated theoretical bonuses looking three years into the future. To allow for shifting from license sales to subscription revenues, incumbents had to create much legal, financial, and operational groundwork to pay and receive subscriptions.

"Even if it sounds trivial, it is very difficult to handle a subscription model commercially. Although SAP only offers options for the traditional product and service business, we have to be able to sell subscriptions. We have developed 1000 pages of financial reporting guidelines for this. Without this groundwork, we would always have hit the wall because no one would have been able to book a subscription."—Middle manager, HardCorp

Ecosystem formation. To effectively outmanage tasks and innovation, two incumbents started building dedicated partner ecosystems. Instead of following the notion of large partner ecosystems, all firms briefly realized a different saying to be true, namely "few but valuable partners help a lot". Hence, they focused intensely on developing transparent onboarding processes. Managers of SoftCorp and HardCorp reported a shared value proposition to be of major relevance, as the business potential and the partners' raison d'être had to be proven through training, joint prototypes, a co-selling strategy, and leads. In parallel to platform development, incumbents defined ecosystem rules and determined the complementary markets that would be left untapped. In fact, the goal was to leave specific, complementary markets untapped for companies to innovate and create platform traffic. However, for some incumbents, the same internal tensions in sales

became apparent when competing for profit within the ecosystem, impeding ecosystem development. As a result, several companies that became partners of the incumbents failed to meet their sales targets, leading to the termination of the partnership. Others flourished in collaboration with joint marketing, service, and co-selling strategies. SoftCorp, for example, allowed new partners six months to complete foundational training, develop an initial IoT prototype, and acquire a paying customer. Missing out on this goal, partners would drop out of the partner program. A similar process, but not as a standalone function, could be seen at TelcoCorp, which changed its strategy to offer more services on its own, reducing the number of partners. These performance-oriented participation architectures helped incumbents to decrease ecosystem noise, helping customers and partners to find each other and to increase their level of engagement.

> *"We actively collaborate with a company that develops augmented reality solutions. These solutions nicely complement our platform business and one of our larger application areas—process mining. Once partners show they are worth the time and effort that they and we put into the evaluation, onboarding, co-developing, and co-selling process, we typically generate great business outcomes and give more value to our customers and partners than take."*—Middle manager, SoftCorp

Value orientation. To seize value from the platform and ecosystem, SoftCorp, TelcoCorp, and HardCorp fixated on customer value orientation, painting the picture backward from customers to products/services. Doing so, required them to focus on bridging IoT technology and business knowledge gaps. SoftCorp and HardCorp, for example, stated that collaboration with customers and learning about their industries and cases was required to define valuable IoT business cases. To achieve such value orientation, incumbents had to develop a consulting ability involving actions, such as asking the right questions, hinting at useful solutions and technologies, and connecting customers to internal experts or trusted ecosystem partners in cases of knowledge gaps. As a result of a valid IoT business case, incumbents prototyped and tested it in an agile fashion to evaluate its technical feasibility and potential to scale. On a strategic level, this value orientation ability—especially making sense of or solving customer business cases—allowed incumbents to enter new markets outside their traditional business domains, such as manufacturing, energy, or buildings.

> *"You have to roughly understand the customer's industry and use case and be able to empathize with the customer and his culture […]. But understanding the customer's business case is not enough. You have to translate this business case into*

> *IoT or IT know-how. So, you have to make sure that digital assets, whether that's a database, a data model, or a networking solution, can be developed, operated, maintained, and supported […]. There is a large difference in going from a proof-of-concept with few connected devices to mass production, to roll-out, and to managed operations—especially with regard to the hardware and when considering that many assets must be retrofitted to be IoT-capable."*—Middle Manager, TelcoCorp

E.4.3 Reconfiguring Microfoundations

We identified four microfoundations of reconfiguring: (1) platform evolution, (2) business recalibration, (3) multilateralism reevaluation, and (4) customer care.

Platform evolution. To realize a platform offering demanded in enterprise IoT, SoftCorp, TelcoCorp, and HardCorp had to improve their IoT platforms continuously. In fact, we could identify platform evolution to be driven by internal and external forces. Internally, incumbents shifted software development procedures towards methods and tools that would be aligned with the way the PaaS and SaaS offerings were consumed by customers. For example, incumbents adopted the DevOps paradigm, evolving from larger release cycles to producing and deploying small software increments at shorter intervals. Yet, to avoid code-breaking or dependencies as a result of frequent updates, they automated the testing of code and platform updates before deployment. In addition, they developed basic IoT services that worked across different domains to support all applications, for example, in fault diagnosis. For instance, the diagnosis of a sensor-based error message could be caused by a plant, sensor, or software error. Building software-based monitoring abilities with machine learning models was essential to detect and eliminate negative effects from model predictions, such as data biases in error diagnoses. HardCorp, in particular, described how recalibrating its software development, deployment, testing, and monitoring capabilities required expert developers and data scientists. Externally, incumbents acquired firms with a software or platform development background and integrated (or cored) the platform technologies over time. For example, SoftCorp purchased a platform that would enable device management, TelcoCorp profited from buying a connectivity management platform to manage its IoT devices across national borders, and HardCorp absorbed a low-code platform to empower its subject matter experts in their development endeavors. Doing so, allowed the incumbents to absorb the knowledge, best practices, and mindset of acquired or partner companies to boost platform evolution.

> *"There was a tectonic shift from developing the [platform] compared to classic software development. The [platform], along with a few platforms at [HardCorp], was the first to follow the DevOps approach (you make it, you run it) and this awareness that you always have to be online, meet SLAs, and cannot afford downtime anymore every Thursday. [...] With a versioned development in terms of quality management, we have transformed a lot"*—Senior manager, HardCorp

Business recalibration. Building an IoT platform required the incumbents to recalibrate several aspects of their business strategy, organizational structure, and internal culture. First, regarding platform strategy and its scaling approach, incumbents realized they needed to expand their (business investment) planning cycles from 1-3 years known from their traditional business to 5-10 years. This learning process was due to the wrong role models, such as Apple and Airbnb, used for planning goals, KPIs, and governance. Once the incumbents experienced that early IoT platform adoption would not scale exponentially but rather linearly, they implemented success measures, emphasizing value-based traffic over short-term monetization (e.g., from expensive PaaS subscriptions to focus on exceptional free trial experiences). As the platforms did not perform standalone from a financial viewpoint, one incumbent reorganized the platform business as a cost center, not a profit center, which had a synergistic effect on multiple business units when working with or for the platform. Second, all incumbents created expert sales functions shortly after their platform launches. They were deliberately guided and trained to market the subscriptions (with 1-3-year contracts). SoftCorp, for example, incentivized the sales of PaaS and SaaS subscriptions via theoretical bookings over standard 3-year contracts. Building this ability helped incumbents combat the lack of incentives of subscription sales compared to perpetual software licenses. As a consequence, they had to create new incentives to sell PaaS subscriptions. Accordingly, expert sales gained authority to design the fiscal, legal, and internal processes for platform-related subscription sales. Third, an even bigger platform-related shift involved the change of culture and leadership. For example, HardCorp trained its management with platform experts like Van Alstyne. This top-down enforcement for managers to educate on platform strategies prompted awareness and company-wide interest in platform thinking and architectural design issues. Moreover, the training, workshops, and cross-functional discussions supported the discovery of new IoT use cases.

> *"We tried to make a lot of money too fast with our platform and charged partners 30% after the first year. Then they asked why. For what? For customer access? At the end of the day, every platform lives from traffic. If we were to realign our*

platform business, our products would have to pay for the platform to get traffic. It's not just money, it's a competitive disadvantage to monetize early. You have to place the question of traffic in the whole corporation and think in a 10-year horizon. You have to convince customers who trust you and the added value and also need manpower to launch, scale, and operate the business and drive sub-transformations [...] You can't achieve exponential growth in B2B. It's more complex than Clubhouse or Tik-Tok."—Senior manager, HardCorp

Multilateralism reevaluation. The establishment of ecosystems aimed at enabling complementors to add technology, knowledge, data, and pecuniary value contributions to the incumbents' platform offerings. Hence, a major microfoundation was the ability to reevaluate multilateral partner management with KPIs associated with it. The multilateralism included partnerships that were not traditionally established by the incumbents prior to their entries into the IoT platform business. While SoftCorp, for instance, had often collaborated with software providers and system integrators, it additionally built close ties with IoT device manufacturers. All incumbents reflected the ecosystem spirit through a high degree of openness, diversity, and tolerance for competition, manifested in contracts that asked to obey clear rules. The tenor behind the positive interpretation of "co-opetition" was that partners were better off doing business (in collaboration) than not doing business (because of competition in other business fields). To manage this multilateralism, incumbents developed new KPIs to evaluate onboarded partners (e.g., co-sales) and measure the ecosystem value (e.g., ecosystem sales, churn). For example, SoftCorp dictated clear co-selling targets with its partners, the first of which had to be achieved within 6 months (in the form of subscription sales).

"The key challenge lies in understanding how to leverage your ecosystem partners to scale the IoT platform business, similar to SAP's business that got multiplied through its integration partner ecosystem. While we have always had certified software integration partners, we now have hardware, system integration, consulting and other partners, so not just a larger variety of partners but a shift in tasks and responsibilities to deliver constant and recurring customer value."—CPO, SoftCorp

Customer care. After companies like SoftCorp and HardCorp incentivized the sales teams in selling PaaS subscriptions and increase IoT platform adoption, it became evident that they had no after-sales customer care process, i.e., a routine to stay with and talk to customers and observe their platform adoption journey. Business developers were typically compensated by larger transactions and once they signed up for a 3-year

subscription, things quickly went quiet. Accordingly, customer success management represented a function that was introduced by all incumbents. The creation of this function and customer success manager role was, for example, initiated bottom-up at SoftCorp after having made a major acquisition. Customer success managers accompany customers in their own transformational journeys when adopting, integrating, and extending platform services to their needs. This way, customer success managers can help customers while receiving incentives for supporting the customers' expansion of platform use, e.g., measured based on PaaS consumption that is fostered through cross-selling and up-selling of SaaS services. This new role had to be filled with hires. TelcoCorp also mentioned that their customers wanted close guidance on the IoT journeys, which would require dedicated consulting skills and ecosystem partners to scale. This microfoundation was based on incumbents' ability to understand their customers' transformational readiness as a dominant force for linear, consumption-based platform growth and to generate high value-based lock-ins in the future.

> *"You need someone else to focus on customer value, and that's the customer success manager. It's a role that we didn't have in the past. These people come in after the sales and take the customer from land to expand. […] As soon as customers gain value from a connected asset, process, or plant, they want more, it's a continuum. This is how scaling works without pushing, because customers recognize the value and apply it to other use cases or industries."*—Middle manager, SoftCorp

E.5 Discussion

In this paper, we offer insights into how industry incumbents with established business models, associated product portfolios, and existing processes developed DCs to create and operate IoT platform ecosystems. We identified 11 microfoundations (i.e., processes, routines) and analyzed how the case firms implemented them to establish their IoT platforms effectively. In that, we attempted to address a research gap on dynamic capabilities for IoT platform establishment (Pauli et al., 2021; Teece, 2017). Therefore, our findings have two major contributions: first, they contribute to platform research in general and the challenge for incumbents to launch and scale IoT platforms in particular (De Reuver et al., 2018; Moore, 1993; Teece, 2017). Second, we add to the DCV as a valuable, strategic management lens to scrutinize platform ecosystems helping to understand internal transformations required to integrate a platform business model. In the nexus between platform and management research, we add to a promising research

dialogue about DCs needed to develop and manage digital platform ecosystems and vice versa (L. Li et al., 2018; Linde et al., 2021; Teece, 2017) and respond to calls for research on the microfoundations for successful digital transformations (Schilke et al., 2018; Teece, 2007; Vial, 2019).

E.5.1 Contribution to Research

Platform. The microfoundations of DCs, found in the primary data, provide an intra-organizational view of the transformation processes needed to establish an IoT platform. In contrast, platform launch strategies describe the general themes platform owners must master or goals they must achieve, yet, often without contextualization and externally observable (Edelman, 2015; Stummer et al., 2018). These strategies lack insight into how incumbents that are tied to their traditional business models can achieve such goals. Two particular results, extending our knowledge on IoT platforms (Pauli et al., 2021), came to the fore. First, we contribute to platform scoping (Gawer & Cusumano, 2008). Although scholars have extensively discussed platform scoping from a supply-side perspective with results on horizontal vs. vertical approaches (Hein, Weking, et al., 2019) or standalone value propositions (Edelman, 2015), we recall earlier understandings of a platform's value contribution—not only to an external but to an internal user group (Gawer, 2014). In particular, our cases show that incumbent business units are using IoT platforms internally for software development. Aligning an incumbent's traditional product portfolio with the platform and partner offerings becomes a strategic objective for platform scoping and is thus associated with the phenomenon of platform-pipeline convergence (Mody et al., 2020). Second, we extend findings on pricing strategies for digital platforms (Caillaud & Jullien, 2003; Stummer et al., 2018), shifting the discussion from subsidization problems to business model implications. In particular, the cases show that platform offerings were marketed as subscriptions which caused challenges for business operations in areas such as paying operating costs, budgeting, or even stock market valuation. In that, it became clear that the managerial pressure to capture value from the PaaS offering alone—without value-added SaaS offerings—led to false growth assumptions fueled by perceptions of a winner-takes-all paradigm that was grounded on misleading B2C platform examples. In contrast to prior findings, our results indicate a slower, linear (non-exponential) path pattern to platform growth when establishing IoT platforms—so, in the early phase. Hence, we propose:

> **P1:** *Effective IoT platform development requires a shift from exponential to linear growth thinking in the establishment phase.*

Ecosystem. In addition, our study moves forward the ecosystem research stream, creating a link between a platform provider's existing product portfolio and complements in the ecosystem (Jacobides et al., 2018). In IoT, platform providers not just seek complementors specialized in designing, developing, integrating, and maintaining software products but also need expertise in hardware devices (e.g., sensors, gateways, assets) and specific industry domains (e.g., process manufacturing, automotive) (Petrik & Herzwurm, 2020). In addition, IoT spans traditional industry boundaries as physical assets become pivotal points of two or more value propositions and market sides (Porter & Heppelmann, 2014), e.g., Schindler's smart elevator infotainment services. In particular, we contribute to the famous chicken-or-egg problem with a strong endorsement that incumbents value customers over partners' joining decisions. However, we also found that the incumbents do not clearly separate between the two stakeholders, as both sides are priced (Caillaud & Jullien, 2003). Regarding the partner-side, focused on within the ecosystem analysis, we found that all incumbents valued the quality of partners over quantity, mentioning early mistakes they made when trying to scale through partners. While the idea of scaling through large partner ecosystems is correct, the effort generated for platform providers with each new partner acquired is often underestimated. In B2B domains, such as enterprise IoT, partner management cannot be fully automated. Platform providers need to better understand heterogeneous IoT partners in order to leverage them on the platform, which is challenging because these partners have the domain expertise that platform providers often do not have. In addition, costs for partner management (i.e., evaluating, onboarding, training, co-selling) are not yet offset by revenues, especially if joint revenue is not generated regularly (Huber et al., 2017). Our microfoundations not just describe but prescribe how "platform wannabes" can do the "right things" to effectively grow their ecosystems in IoT and, more broadly, in B2B contexts. We thus propose:

> **P2:** *Effective IoT ecosystem establishment requires a shift from quantity to quality of partners in the establishment phase.*

Value cocreation. Furthermore, we contribute to platform research on value cocreation (Ceccagnoli et al., 2012; Lusch & Nambisan, 2015; Sarker et al., 2012). Acknowledging a paper that focused on knowledge transfers to complementors in IoT platform establishment (Weiss et al., 2020), our primary data show that customers represent the more important stakeholder group within the establishment phase. This is in line with various papers (Hein, Weking, et al., 2019; Pauli et al., 2021). Customer workshops, training, and cocreation have still remained relatively unexplored in prior research on platform

establishment. Above all, customers must be trained and persuaded to adopt IoT platforms as the internal transformations of the incumbent platform owners are closely linked to the digital transformations of their customers as paying platform users. We thus extend the understanding of value-driven lock-ins (Ofe & Sandberg, 2019), which was previously largely determined by the design of boundary resources, by showing that value-driven lock-ins are achieved through solution-oriented ecosystems and a value orientation towards cocreation activities. In addition, we found that incumbents have expanded their sales function for continuous and value-oriented support of customer solutions through customer success management. This function has become more important due to the shift to subscription-based revenue streams, demonstrating how difficult it is to scale or standardize coordination activities with IoT platform customers, unlike in the B2C space. Thus, we propose:

> **P3:** *Effective IoT value cocreation requires a shift from product-centered to value-based lock-ins in the establishment phase.*

Dynamic capabilities. As an attempt to stop the paucity of platform ecosystem analyses through a DCV, our results add to Teece's (2017, 2018) findings on DCs in digital platform ecosystems by exploring a more detailed, microfoundational level of analysis in the complex enterprise IoT context (Helfat & Raubitschek, 2018; Linde et al., 2021). Resting on Linde et al. (2021), who studied DCs for ecosystem orchestration, DCs present an appropriate research lens to analyze the dynamic nature of platforms and how firms transform to thrive and survive in dynamic contexts such as IoT platform ecosystems (Teece, 2017). We thus provide a transformational view of the processes required for platform establishment. Accordingly, we realized the research gap between knowledge on platform natives vs. non-natives like industry incumbents. Therefore, we call for more research looking at DCs and transformational processes required for successful platform and ecosystem launches. DCs and their microfoundations help to understand the transformation, establish an adequate platform design, set the right goals, and accomplish effective governance. In this direction, we see the potential for research in the nexus between platform research, strategy and management research, and digital transformation (e.g., Khanagha et al., 2020; L. Li et al., 2018).

E.5.2 Contribution to Practice

To this point, both platform research and research on DCs lack practice-oriented applicability (Helfat & Raubitschek, 2018; Mahringer & Renzl, 2018; Teece, 2017). Therefore, our findings may help managers of industry incumbents to instantiate DCs to

foster their success in establishing IoT platform ecosystems. We thus offer 11 microfoundations of DCs to managers that had been operationalized in practice. Moreover, we present the empirical details on how the three case firms built the microfoundations, involving methods (e.g., DevOps), functions (e.g., customer success management), and organizational structures (e.g., cost center) that could be (partly) applied by other incumbents to implement microfoundations. In this regard, we want to recall that DCs (and microfoundations) must be developed internally and cannot be simply bought in or copied. They require, similar to the platform establishment, years until established fruitfully (Teece, 2007, 2018; Winter, 2013). We recommend managers also to focus on the three principles for early platform establishment: (1) linear growth thinking (platform), (2) quality of partners (ecosystem), and (3) value-based customer lock-ins (value cocreation). Since the identified microfoundations of DCs turned out to be largely IoT-unspecific, they can also be used as a guideline for larger digital transformation journeys in the B2B context, in particular, when establishing platform ecosystems.

E.6 Limitations and Outlook

In conclusion, our findings are generalizable and applicable by incumbents seeking to extend their existing business through a platform business model (Van Alstyne et al., 2016). However, this paper has limitations that must be considered. First, despite a careful case selection, we realized that the "effective" or "successful" establishment of IoT platform ecosystems is difficult to assess, and thus to claim. While this understanding supported us in our qualitative, explorative research design, we cannot argue to have studied successfully established IoT platforms as the case companies have not yet completed the establishment process. Due to the immature and fragmented state of the IoT market, it is also not possible to find mature companies among the incumbents. However, the microfoundations and learnings identified provide more guidance to current research and practice than postponed insights would. Second, as a consequence, our findings do not claim to be exhaustive or applicable to native platform companies. While we have selected three cases to exhaustively represent each of the three IoT platform provider groups (i.e., software, telecommunication, and hardware providers), our findings were not verified by other companies in these groups. In terms of applicability, the microfoundations might turn out to have different relevance for more established platform native companies, as they are used to different processes and routines since their founding, such as Google, e.g., pursues management via the objectives and key results (OKR) approach. Besides, our data sample mainly relies on the coding of the interview

data. Despite the consensus among the authors on the coded microfoundations of DCs, the results must be viewed cautiously. In the future, we intend to improve the robustness of the findings by conducting expert workshops or additional interviews

Setting out to the future, we see great potential in furthering our understanding of platform establishment through a DC lens (Teece, 2017) and believe the enterprise IoT context is suitable for further investigation of this phenomenon due to its complexity and novelty. First, empirical research into the routinization of microfoundations can be continued in the context of enterprise IoT platforms. In particular, one could determine the weight of and relationships between the microfoundations quantitatively to measure differences in their impact on IoT platform establishment or potential moderating effects. Because several microfoundations identified (in the value cocreation layer) are about customer value, explorative follow-up research is required to bridge the value-based strategy (Brandenburger & Stuart, 1996; Helfat & Raubitschek, 2018), scrutinizing specific cocreation activities during establishment. Second, in a broader context, it seems important to contrast successful cases with more unsuccessful innovation ecosystems, launched by incumbents (Jacobides et al., 2018). Such work would help bolster the evidence on whether the absence of DCs would hinder enterprise IoT platform ecosystem development and innovation. Doing so would require a cross-sectional longitudinal research design. One had to follow up on current cases on the one hand and extend the sample through less innovative firms on the other hand. As the control of the variables is difficult to reach, we could also imagine the use of a longitudinal qualitative research design.

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Appendix

Appendix A: Glossary of Key Concepts

Concept	Description and key references
Customer	An organization that uses the platform and its modules (Boudreau & Lakhani, 2009).
Digital platform	The "digital resources—including services and content—that enable value-creating interactions between external producers and consumers" (Constantinides et al., 2018, p. 381).
Ecosystem	A group of organizations, including the platform owner, third parties, and customers, that cocreate value on a platform (Jacobides et al., 2018; Wareham et al., 2014).
Enterprise IoT	The B2B domains in IoT (Jayashree & Selvakumar, 2020; Marheine et al., 2019).
Industry incumbent	A large organization with an established pipeline business that has demonstrated industry success through existing value propositions, customer relationships, resources, and knowledge (Macmillan & Selden, 2008; Van Alstyne et al., 2016).
Innovation platform	The "extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it, and the interfaces through which they interoperate" (Tiwana et al., 2010, p. 675).
IoT	The linking of physical and digital things with the internet (Guth et al., 2018; Wortmann & Flüchter, 2015).
IoT platform	The socio-technical systems that comprise a central, extendable software base that can be complemented by an ecosystem of third-party organizations (Marheine & Pauli, 2020; Pauli et al., 2021; Tiwana et al., 2010).
IoT solution	The physical products and digital services that interface with the IoT platform and leverage its value for users (Marheine et al., 2019; Marheine & Pauli, 2020)
Platform adoption	An organization's "decision to join an IIoT platform ecosystem as becoming part of a group of firms (i.e., [third parties]) that focus parts of their business activities on developing and commercializing technical artifacts associated and compatible with the platform as the core technology" (Marheine et al., 2021, p. 5955).
Platform capabilities	An organization's internal capabilities to extend a pipeline business with a platform business (Svahn et al., 2017; Teece, 2017; Van Alstyne et al., 2016).
Platform establishment	The actions of an organization to launch a platform, establish an ecosystem, and foster value cocreation (Lusch & Nambisan, 2015; Saarikko et al., 2019).
Platform governance	The rules and mechanisms employed by the platform owner that prescribe the value cocreation opportunities of third parties (Tiwana, 2015a; Tiwana et al., 2010).
Platform owner	An organization that establishes and controls a platform (Tiwana, 2015a).
Third-party	An organization that utilizes the platform to develop and sell products and services compatible with the platform (Gawer, 2014; Huang et al., 2013).
Third-party innovation	The physical products and digital services that are developed and marketed by third parties via the platform (Cusumano et al., 2019; Gawer & Cusumano, 2002).
Value cocreation	The process and activities of integrating resources into the IoT platform by the organizations affiliated with it (Ceccagnoli et al., 2012; Lusch & Nambisan, 2015).

Table 27: Glossary of Key Concepts

Appendix B: Overview of Interviews

These interviews represent the primary data of this thesis and constitute the data basis for Papers A–E. All interviews were transcribed for subsequent use for coding. While I conducted most of the interviews as a lead interviewer, in the interviews marked with *, co-authors or supervised students conducted the interviews.

Nr.	Interviewee role	Date	Firm size	Industry
1	IoT Consulting Manager	13.11.2018	Large	Enterprise software
2	IoT Product Manager	22.11.2018	Large	Enterprise software
3	Vice President IoT	28.11.2018	Large	Enterprise software
4	Head of System & Analytics	08.11.2018	Large	Industry technology
5	Head of Trend Evangelist	12.11.2018	Large	Industry technology
6	IoT Platform Manager	16.11.2018	Large	Industry technology
7	Manager Field Application	06.11.2018	Large	Mobility technology
8	Director IoT Portfolio	14.11.2018	Large	Mobility technology
9	IoT Partner Manager	28.11.2018	Large	Mobility technology
10	Senior IoT Sales Manager	09.11.2018	Large	Manufacturing
11	Partner Manager	16.11.2018	Large	Manufacturing
12	Head of Application Portfolio	27.11.2018	Large	Manufacturing
13	IoT Platform Market Expert	30.11.2018	Medium	Market research
14*	Sales Manager	22.07.2019	Large	Telecommunication
15*	Project Manager	22.07.2019	Large	Consulting
16*	Executive Manager	23.07.2019	Large	Software
17*	Sales Manager	24.07.2019	Large	Software
18*	Executive Manager	25.07.2019	Large	Technology
19*	Sales Manager	28.08.2019	Large	E-commerce
20*	Analytics Manager	01.08.2019	Large	Mobility technology
21*	Managing Director	05.08.2019	Large	Software
22*	Partner Manager	18.07.2019	Large	Software
23*	Partner Manager	30.07.2019	Medium	Telecommunication
24*	Managing Director	26.07.2019	Medium	Software
25*	Partner Manager	26.07.2019	Medium	Software
26*	CEO and Co-Founder	26.07.2019	Small	Software
27*	Manager and Founder	01.08.2019	Small	Software
28*	Manager and Founder	29.08.2019	Small	Automation technology
29	Head of IoT	07.04.2019	Large	Telecommunication
30	Head of Analytics	22.04.2020	Large	Telecommunication
31	Sales Manager	28.05.2020	Large	Telecommunication
32	Partner Ecosystem Manager	09.06.2020	Large	Telecommunication
33	Head of Sales	30.06.2020	Large	Telecommunication
34	IoT Project Manager	07.12.2020	Large	Telecommunication
35	Head of Business Customers	25.01.2020	Large	Telecommunication

Nr.	Interviewee role	Date	Firm size	Industry
36*	CEO	05.11.2020	Small	Engineering
37*	CTO	06.11.2020	Medium	Software
38*	Consulting Manager	09.11.2020	Large	Consulting
39*	Co-CEO	12.11.2020	Small	Software
40*	Head of IoT	03.11.2020	Large	E-commerce
41*	Co-CEO	09.12.2020	Large	Industry technology
42*	CEO	02.11.2020	Small	Industry technology
43*	Head of IoT	01.11.2020	Medium	Industry technology
44*	CEO/Founder	02.11.2020	Small	Software
45*	Technology Manager	17.12.2020	Small	Software
46*	CIO	24.11.2020	Large	Building technology
47*	Head of Digital and IoT	02.12.2020	Large	Logistics
48*	Head of Digital	09.12.2020	Large	Facility management
49	Ecosystem Manager	19.04.2021	Large	Enterprise software
50	Ecosystem Manager	20.04.2021	Large	Enterprise software
51	CPO	26.04.2021	Large	Enterprise software
52	Senior Principle	23.04.2021	Large	Enterprise software
53	Product Manager	22.04.2021	Large	Enterprise software
54	Platform & Product Manager	07.04.2021	Large	Industry technology
55	Platform Dev Ops Manager	07.04.2021	Large	Industry technology
56	Ecosystem Manager	08.04.2021	Large	Industry technology
57	Ecosystem Manager	09.04.2021	Large	Industry technology
58	CTO	02.04.2021	Large	Industry technology
59	Vice President	26.04.2021	Large	Industry technology
60	Vice President	28.04.2021	Large	Industry technology

Note. *Lead interviewer was co-author or supervised student.

Table 28: Overview of Interviews

Curriculum Vitae

Personal information

Name	Christian Marheine
Date of birth	04.11.1993
Place of birth	Weinheim, Germany
Nationality	German

Education

2019 – 2022	**University of St.Gallen, Switzerland** Doctor of Philosophy (Ph.D.) in Management (PMA)
2016 – 2019	**University of Mannheim, Germany** Master of Science (M.Sc.) in Information Systems
2018 – 2018	**Lund University, Sweden** Semester abroad at Lund School of Economics and Management
2013 – 2016	**Baden-Württemberg Cooperative State University, Germany** Bachelor of Science (B.Sc.) in International Management for Business and Information Technology
2004 – 2013	**Johann-Heinrich Voss Gymnasium, Germany** General A-levels (i.e., Allgemeine Hochschulreife)

Professional experience

2019 – 2022	**University of St.Gallen, Switzerland** Research assistant
2016 – 2019	**DLCON AG, Germany** Intern and working student
2017 – 2017	**KPMG AG, Germany** Intern
2013 – 2016	**ECENTA AG, Germany** Dual student