Patterns of business model innovation for advancing IoT platforms

Received 7 December 2020
Revised 8 June 2021
26 July 2021
10 October 2021
14 October 2021
Accepted 16 October 2021

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Abstract

Purpose – The emergence of Internet of Things (IoT) platforms in product companies opens up new data-driven business opportunities. This paper looks at the emergence of these IoT platforms from a business-model perspective.
Design/methodology/approach – The study applies a mixed method with two research studies: Study I–a cluster analysis based on a quantitative survey, and Study II–case studies based on qualitative interviews.
Findings – The findings reveal that there is no gradual shift in a company's business model, but in fact three distinct and sequential patterns of business model innovations: (1) platform skimming, (2) platform revenue generation and (3) platform orchestration.
Research limitations/implications – The results are subject to the typical limitations of both quantitative and qualitative studies.
Practical implications – The results provide guidance to managers on how to modify the components of the business model (value proposition, value creation and/or delivery and profit equation) in order to enable platforms to advance.
Social implications – As IoT platforms continue to advance, product companies achieve better performance in terms of productivity and profitability, and more easily secure competitive advantages and jobs.
Originality/value – The paper makes three original contributions: (1) it is the first quantitative study on IoT platforms in product companies, (2) identifies three patterns of business model innovations and (3) offers a first process perspective for understanding the sequence of these patterns as IoT platforms advance.

Keywords IoT platform, Digital servitization, Business ecosystem, Business model innovation
Paper type Research paper

Journal of Service Management
Vol. 33 No. 1, 2022
pp. 70-96

1757-5818
DOI 10.1108/JOSM-11-2020-0429

This paper forms part of a special section "The Future of Servitization in a Digital Era (Part 2)", guest edited by Christian Kowalkowski, Tim Baines and Ali Ziaee Bigdeli.

1. Motivation

Product companies are embarking on a so-called digital servitization journey, combining the advantages of servitization with digital transformation (e.g. Frank *et al.*, 2019; Kohtamäki *et al.*, 2020). By blurring the boundaries between physical products and digital services, the Internet of Things (IoT), allows companies for example to unlock vast innovation and business opportunities by making products and services smarter (e.g. Porter and Heppelmann, 2014). Product companies link the physical and digital worlds by connecting their products to an IoT (digital) platform, collecting data from and on these products, aggregating and analyzing these data for greater value creation and capture (Gebauer *et al.*, 2020a; Jovanovic *et al.*, 2021). IoT platforms enable connecting various IoT-enabled products (e.g. devices, machines, equipment, industrial assets), to collect data on product operation and customer usage and to conduct data analytics (e.g. machine learning) so as to provide more advanced digital services (e.g. digital twins, continuous optimization, asset management) (Bilgeri *et al.*, 2019; Cenamor *et al.*, 2017; Frank *et al.*, 2019; Wei *et al.*, 2019). This enables companies to continuously make new and better digital (smart) products and services that, in turn, enables them to perform better in terms of competitiveness and profitability (Jovanovic *et al.*, 2021; Brynjolfsson and McAfee, 2012).

However, the theoretical understanding of advanced use of IoT platforms is still in its early stages (e.g. McIntyre and Srinivasan, 2017) and the commercial success of IoT platforms has been mixed to date. For example, while Hitachi's IoT platform, Lumada™, already contributes about 12% to Hitachi's total revenue in 2020 (Hitachi, 2019), General Electric's IoT platform, Predix™, struggled to meet the initial revenue expectations (Gebauer *et al.*, 2020b).

While previous research has shown that IoT platforms go hand-in-hand with the emergent discussion on digital servitization, there are still four important research gaps. First, previous literature looks either at specific digital technologies or their implications for the actual business models (Burström *et al.*, 2021; Zambetti *et al.*, 2021; Opresnik and Taisch, 2015) or at many digital technologies and their general implications for business models. In this study, the focus is on IoT platforms as well as a technology stack covering technologies for facilitating product connectivity, data collection, data analysis and data utilization for new and existing (digital) services.

Second, a major concern regarding the current research is that scholars focus largely on a few selected case studies. For example, recent insights of Jovanovic *et al.* (2021) into the three platform archetypes, (1) product platform, (2) supply chain platform and (3) platform ecosystem, were revealed from qualitative data obtained from four companies. Similarly, the typology of Tian *et al.* (2021) for explaining platform-based servitization relies on four longitudinal case studies. The study of Kapoor *et al.* (2021) is taking a platform ecosystem view on servitization in manufacturing drawing its conclusions from 14 interviews. Moreover, the study of Zambetti *et al.* (2021) is suggesting a data driven product-service-system framework, relying on seven case studies. While all these insights are valuable and encouraging, the current dominance of qualitative research might prevent further theoretical development and validation. As a nascent theme in literature, IoT platforms (and digital servitization) require interviews, case studies and direct observation of the phenomena. In order to become a more mature theory, it is necessary to establish quantitative measures of established constructs and to test them statistically.

Third, scholars argue that IoT platforms challenge the traditional assumption of company value proposition, value creation and profit equation. IoT platforms are increasingly considered as innovation platforms embracing a new business logic. This logic is likely to supplement, and partly replace, the previous business logic of product companies (Gebauer *et al.*, 2020a; Sjödin *et al.*, 2020; Skylar *et al.*, 2019; Tronvoll *et al.*, 2020). Accordingly, IoT platforms need to be investigated from a business-model perspective. These investigations consider platforms in general as new and innovative business models (Parker *et al.*, 2016; Cusumano *et al.*, 2019; Van Alstyne *et al.*, 2016). Thus, there is general consensus that IoT platforms will require changes in business-model components (McIntyre and Srinivasan, 2017). Despite the emerging research on business model innovation through IoT technologies (e.g. Paiola and Gebauer, 2020), studies on the emergence of IoT platforms from a business model perspective in the context of digital servitization are still sparse, with few exceptions (e.g. Allmendinger and Lombreglia, 2005; Hasselblatt *et al.*, 2018; Tian *et al.*, 2021).

Fourth, and most importantly, the current IoT platform literature lacks a process perspective in terms of how the business logic and business-model components change over time (e.g. Parker *et al.*, 2016; Cusumano *et al.*, 2019; Van Alstyne *et al.*, 2016). Until now, the literature has highlighted three gradual shifts, namely IoT platforms: (1) make more data available, (2) embrace an ecosystem approach, (3) drive outcome-based business models. *IoT platforms induce advances in the availability of data* and in the data analysis (e.g. machine learning, artificial intelligence) adding novel features to a company's value proposition (e.g. Ardolino *et al.*, 2018; Paschou *et al.*, 2020; Paiola and Gebauer, 2020; Rymaszewska *et al.*, 2017). *IoT platforms enable ecosystems consisting of multiple companies to emerge* as a new organizational form for creating value (Jacobides *et al.*, 2018; Jovanovic *et al.*, 2021; Ozalp *et al.*, 2018). This in turn means that IoT platforms are always considered in connection with an ecosystem approach. This approach assumes that value co-creation within ecosystems is economically more viable than value creation within the own corporate boundaries. Companies should orchestrate, manage, or participate in ecosystems (e.g. Sklyar *et al.*, 2019). *IoT platforms are associated with outcome-based models*. Thus, they are a prerequisite when it comes to getting paid for product usage, performance, or output (Gebauer *et al.*, 2020b; Sjödin *et al.*, 2020). Altogether, this challenges the traditional business logic of how companies propose value to customers, how they create value together with customers and how they capture value. Nevertheless, it remains unclear whether these challenges lead to a gradual evolution of the business logic and business model components or to distinct patterns of business-model innovations as IoT platforms become more advanced.

Considering the aforementioned gaps in the literature, this paper develops, through a mixed method approach, new theoretical insights into the patterns of business-model innovations when IoT platforms become more advanced. More specifically, this paper aims to answer the following question: *what patterns of business-model innovation support product companies in advancing their IoT platforms?*

This paper combines two studies (Study I: cluster analysis using survey data of 81 companies; Study II: three case studies using rich interview data). All participating companies have invested in IoT platforms in such a way that they support more advanced digital services. The findings of the first study delineate three distinct patterns of business model innovations: (1) *platform skimming*, (2) *platform revenue generation* and (3) *platform orchestration*. Each pattern consists of specific configurations among the key components in the business model. The results of the second study suggest that these patterns form specific, sequential phases during the platform evolution, starting with the emergence of platforms (platform skimmer), continuing with further platform development (platform revenue generator), finally accomplishing an advanced level of platforms (platform orchestrator). Altogether, this paper extends the perspectives in the literature on digital servitization, business models and platforms.

2. Theoretical background

To answer the research question, this study combines the recent literature on digital servitization and platform business models (see Table 1).

2.1 Digital servitization

The term digital servitization emphasizes the convergence of the two research areas of servitization and digitalization (Vendrell-Herrero *et al.*, 2017; Coreynen *et al.*, 2017;

Authors	Research approach	Contribution
Key contributions on digital servitization		
Vendrell-Herrero *et al.* (2017)	Empirical (focus on publishing industry)	- Explores how digital technologies affect firm interdependencies by examining upstream and downstream pricing strategies in the publishing industry - Demonstrates that during digital servitization upstream firms should deploy unique resources to ensure their strategic position in the supply chain is not diminished
Coreynen *et al.* (2017)	Empirical (case studies in the SME context)	- Illustrates that digital technologies can enable manufacturers to deliver new service offerings, providing better integration with customer processes - Emphasizes that the most advanced services cannot be provided without significant technical support
Kohtamäki *et al.* (2019)	Conceptual (theory of the firm)	- Uses four theories of the firm (industrial organization, the resource-based view, organizational identity and the transaction cost approach) to understand digital servitization business models in the context of ecosystems - Identifies five business models (product provider, industrializer, integrated solutions provider, outcome provider, platform provider) and their configurations
Raddats *et al.* (2019)	Conceptual (literature review)	- Reviews four major research streams between 2005 and 2017 and identifies five main themes (service offerings; strategy and structure; motivations and performance; resources and capabilities; service development, sales and delivery) - Points out that technological developments are increasingly relevant to manufacturers' service activities - Calls to replace the focal-manufacturer perspective with a multi-actor perspective in further research
Sklyar *et al.* (2019)	Empirical (case studies)	- Analyzes underlying processes of organizational change in the ecosystem in the context of digital servitization and suggests that within-firm centralization and integration play a key role in the capacity to organize for digital servitization - Highlights the need to foster service-centricity to take full advantage of digitalization
Tronvoll *et al.* (2020)	Empirical (theories-in-use approach, interviews)	- Examines three strategic organizational shifts that underpin digital servitization and are required to achieve digital service-led growth: from planning to discovery, from scarcity to abundance, from hierarchy to partnership - Emphasizes the role of organizational identity, dematerialization and collaboration in the transformation
Paschou *et al.* (2020)	Conceptual (systematic literature review)	- Characterizes the phenomenon "digital servitization" and points out benefits of digital servitization for customers, providers, and environment and society - Calls for an extended scope of investigation (regarding technologies covered and their combinatory effect, potential benefits and application domains) and for models and frameworks that support decision-making

(*continued*)

Table 1.
Literature overview

Authors	Research approach	Contribution
Sjödin *et al.* (2020)	Empirical (case studies)	- Explores how manufacturing firms and their customers co-create digital service innovations - Suggests that value co-creation in digital servitization is best managed through an agile micro-service innovation approach - Proposes an agile co-creation model providing insights into phases, activities and organizational principles of a micro-service innovation approach
Gebauer *et al.* (2020a)	Empirical (case studies)	- Identifies and describes the digitalization paradox - Depicts three growth paths for industrial product companies during the digital servitization process: commercializing digital solutions, utilizing product connectivity, and establishing an IoT-platform-based application business
Burström *et al.* (2021)	Empirical (case studies)	- Explores how manufacturing companies use AI for enabling business model innovation in industrial ecosystems through four case studies - Suggests that AI business model innovation needs to be aligned with ecosystem innovation - Provides an evolutionary model envisioning how incumbents promote strategic transitions
Zambetti *et al.* (2021)	Empirical (case studies)	- Proposes a holistic view of data-driven product-service-systems and defines four characteristics (data source, data visibility, response mechanism, decision ownership) and six types (product-driven, customer-driven, knowledge-driven, provider-driven, shared-knowledge-driven, network-driven) - Conceptualizes a two-level hierarchical framework for data-driven product-service-systems in a B2B context
Key contributions on platforms and platform ecosystems		
Gawer and Cusumano (2014)	Conceptual	- Identifies and defines two predominant types of platforms: internal or company-specific platforms and external or industry-wide platforms - Summarizes general propositions on design, economics and strategic management of platforms - Identifies challenges of platform leaders and practices associated with effective platform leadership
Eloranta and Turunen (2016)	Empirical (case studies)	- Identifies how companies leverage network-related complexity in their operations - Explores how a platform approach can be used to externalize resources and capabilities, and to provide structure for network orchestration in the service-driven manufacturing context
McIntyre and Srinivasan (2017)	Conceptual (literature review)	- Proposes a future research agenda including strengths and drivers of network effects, platform quality, nature and actions of complementors, and leveraging complementor dynamics for competitive advantage
Cenamor *et al.* (2017)	Empirical (case studies)	- Explores how a platform approach facilitates the implementation of advanced service offerings in manufacturing firms - Argues that a platform approach based on a modular architecture can enable manufacturers to pursue both customization and operational efficiency

Table 1.

(*continued*)

Authors	Research approach	Contribution
		- Highlights the importance of information modules replacing product and service modules as the core modules for successful servitization
de Reuver *et al.* (2018)	Conceptual (literature review)	- Reviews existing research on digital platforms and develops a research agenda - Explores and outlines three main concerns: conceptual clarification of the digital platform concept, scoping of digital platforms and critical methodological issues in the study of digital platforms
Hein *et al.* (2020)	Empirical (case studies)	- Analyzes how B2B platforms utilize value co-creation practices - Identifies three standardized value co-creation practices: integration of complementary assets, ensuring platform readiness and servitization through application enablement
Ardolino *et al.* (2020)	Empirical (case studies	- Summarizes main research findings about multisided platforms - Presents a hierarchical three-level framework for describing multisided platforms - Applies and validates this framework through multiple case studies
Tian *et al.* (2021)	Empirical (case studies)	- Explores how companies successfully leverage platforms for servitization in an Industry 4.0 context - Provides insights into servitization strategies enabled by platforms, implementation approaches for business model adaptation, and pathways dynamics - Constructs a typology for explaining platform-based servitization
Kapoor *et al.* (2021)	Conceptual (literature review)	- Reviews research on both social and technical aspects of platform ecosystems - Focuses on how platform ecosystems function based on a theoretically grounded framework of socio-technical systems: Identifies technical aspects, task aspects, actor aspects, and structure aspects of platform ecosystems - Sets a holistic research agenda
Jovanovic *et al.* (2021)	Empirical (case studies)	- Demarcates three platform archetypes: product platform, supply chain platform, platform ecosystem - Extends the co-evolution perspective of platform ecosystems and argues that platform architecture, platform services and platform governance develop gradually and mirror each other - Identifies specific innovation mechanism for each platform archetype for platform service discovery and platform value expansion
Key contributions on the IoT in the digital servitization context		
Lee and Lee (2015)	Conceptual	- Discusses three IoT categories for enterprise applications to enhance customer value: monitoring and control, big data and business analytics, information sharing and collaboration - Examines the net present value method and the real option approach for IoT investment

(*continued*)

Table 1.

Authors	Research approach	Contribution
Porter and Heppelmann (2014)	Conceptual	- Explores how new smart connected products change the way how product companies compete and provide services - Describes how operations and organizational structures of firms are radically reshaped
Ng and Wakenshaw (2017)	Conceptual	- Reviews the IoT through four conceptualizations: IoT as liquification and density of information of resources; IoT as digital materiality; IoT as assemblage or service system; and IoT as modules, transactions, and service - Defines the IoT and describes its implications - Suggests that physical products are evolving into connected and dynamically reconfigurable service platforms that are socio-cyber-physical
Rymaszewska *et al.* (2017)	Empirical (case studies)	- Addresses how servitization leverages the IoT for innovative product-service-systems - Proposes a framework on how companies can add value to their servitization processes through IoT-based solutions
Tao and Qi (2017)	Conceptual	- Proposes a service-oriented smart manufacturing framework
Tao *et al.* (2018)	Conceptual	- Discusses the role of big data in supporting smart manufacturing
Ng and Wakenshaw (2018)	Conceptual	- Reviews service research and explains the evolution of a service ecosystem view - Promotes a service ecosystem worldview and describes why its application is important in a connected, digital and data-driven world to clarify interactions between actors, within systems and between systems
Raff *et al.* (2020)	Conceptual (literature review)	- Reviews existing studies on smart products - Synthesizes a comprehensive framework delineating four archetypes for the digital age: (1) Digital, (2) Connected, (3) Responsive, (4) Intelligent - Identifies three major conceptual themes and possibilities for future research
Sestino *et al.* (2020)	Conceptual (literature review)	- Investigates the role of the IoT and Big Data in terms of how businesses manage their digital transformation - Reviews literature published from 2008–2019 that analyzes both the IoT and Big Data and identifies multiple, yet inconsistent paths in research - Highlights how the digital transformation enabled by IoT and Big Data can positively impact business
Paiola and Gebauer (2020)	Empirical (case studies)	- Describes the service-oriented impact of IoT technologies on firms' business models with a focus on opportunities and challenges for B2B manufacturing firms - Identifies three progressive levels of digital servitization complexity (product-oriented, process-oriented, outcome-oriented) and proposes a map of digital servitization for understanding technology-caused strategic transitions
Langley *et al.* (2021)	Conceptual	- Develops a vision of how the IoE may alter business models and value creation - Reviews literature on networked business models and service ecosystems and presents a taxonomy of smart things based on their capabilities and their connectivity and derives implications for business models - Concludes a research agenda

Table 1.

Paschou *et al.*, 2020). Servitization refers to the shift from offering products to offering product-service systems, that increase customer's value-in-use rather than value-in-exchange (Baines *et al.*, 2017; Kowalkowski *et al.*, 2017; Frank *et al.*, 2019). *Servitization* changes a product company's value architecture and requires fundamental changes in structure, culture and competences (e.g. Cortimiglia *et al.*, 2016; Kastalli and Van Looy, 2013).

Digitalization is regarded as a major driver of innovation in product companies (Nambisan *et al.*, 2019; Ng and Wakenshaw, 2017; Sestino *et al.*, 2020). Digital technologies are currently triggering changes in companies' business models, creating new revenue and value-creation opportunities. Technologies associated with the term digitalization include the IoT, industry 4.0, cyber-physical systems, cloud computing, big data, artificial intelligence, machine learning, cloud computing, blockchain and so on (Ardolino *et al.*, 2018; Frank *et al.*, 2019; Lee, 2017; Ng and Wakenshaw, 2017; Opresnik and Taisch, 2015; Paschou *et al.*, 2020; Kohtamäki *et al.*, 2020). Recently, digitalization has been closely linked to servitization.

Digital servitization can be defined as *"the transition toward smart product-service-software systems that enable value creation and capture, through monitoring, control, optimization, and autonomous function"* (Kohtamäki *et al.*, 2019, p. 383). This involves transforming processes, capabilities and offerings within companies and their associated ecosystems to create, deliver and capture increased customer value resulting from various digital technologies (Gebauer *et al.*, 2020a; Jovanovic *et al.*, 2021; Kohtamäki *et al.*, 2019; Paschou *et al.*, 2020; Sjödin *et al.*, 2020). Possible pathways for exploring the benefits of digital servitization range from industrialization (cost improvements), commercialization (revenue enhancements) and strategic value (competitive advantage) (Coreynen *et al.*, 2017), or can alternatively be classified through solution customization, solution pricing and solution digitalization into product-oriented service providers, industrializers, customized and integrated solution providers, platform providers and/or outcome providers (Kohtamäki *et al.*, 2019).

Among these technologies and pathways, IoT platforms play a key role in digital servitization. The IoT can be seen as a technology stack that connects physical and virtual objects and creates a world in which "things" communicate automatically with each other (e.g. Sestino *et al.*, 2020). The IoT allows companies to connect their products to a data cloud, to obtain increasing amounts of data (e.g. about product condition and usage, processes, environment, context, location), to enable communication and data exchange to make products and services more intelligent and to explore novel data-driven business opportunities (Leminen *et al.*, 2018; Porter and Heppelmann, 2014; Ng and Wakenshaw, 2017; Raff *et al.*, 2020). IoT platforms bundle a set of technologies (Ardolino *et al.*, 2020) that build the basis for value creation and commercial success. Accordingly, IoT platforms comprise various activities – from connecting products to the data cloud, storing, combining and analyzing data, and sharing resources and responsibilities in the value-creation process with other companies as a key driver for product-service-software systems (Cenamor *et al.*, 2017) or data-driven product-service-systems (Zambetti *et al.*, 2021). For IoT platforms, these opportunities for creating and capturing value, extend far beyond traditional products and services to digital services delivered through ecosystems (Jovanovic *et al.*, 2021; Eloranta and Turunen, 2016; Rajala *et al.*, 2019). To explore these opportunities, IoT platforms impact the business models of product companies.

2.2 Platforms as business models

The literature distinguishes between business models for innovation and transaction platforms. IoT platforms are a specific type of innovation platform (Parker *et al.*, 2016; Cusumano *et al.*, 2019; Van Alstyne *et al.*, 2016). The discussion around IoT platforms actually started with the development of product platforms. Such platforms contain digital functions that enable companies to collect valuable data about product condition and usage by customers and provide new digital (monitoring and/or visualizing) services which, in turn, generate additional revenue (Gebauer *et al.*, 2020b; Zhu and Furr, 2016). Subsequently, more digital functions are added to the core of the platform. These functions may take the form of advanced sensors, data analytics, self-learning and/or autonomous applications, data storage, etc. These functions are provided not only by the company, but also by various external partners (e.g. suppliers, complementors, system integrators, competitors, infrastructure providers, and/or technology specialists). This requires a certain platform and requires an ecosystem approach.

Product companies need to continuously rethink and redesign their business models while gradually advancing their IoT platforms (e.g. Saadatmand *et al.*, 2019; Sandberg *et al.*, 2020; Schroeder *et al.*, 2020). Thus, IoT platforms will drive business-model innovations in product companies. In general, a business model is a holistic description of a company's key business components and how they are linked (Zott *et al.*, 2011), explaining how a company creates and delivers value to customers (Baden-Fuller and Morgan, 2010; Teece, 2010). Although definitions in the literature vary, most scholars agree that business models comprise three core components: value proposition, value creation and/or delivery and profit equation (or value capture) (Ghezzi *et al.*, 2015; Teece, 2010). The value proposition encompasses all aspects of the offering that render value to customers (Chesbrough and Rosenbloom, 2002). Value creation and/or delivery involves all internal and external activities for fulfilling the value proposition. The profit equation, as a financial manifestation, addresses how value is captured for customers or partners and how the costs of value creation are structured (Bowman and Ambrosini, 2000). Accordingly, business model innovation refers to *"designed, novel, nontrivial changes to the key elements of a firm's business model and/or the architecture linking these elements"* (Foss and Saebi, 2017, p. 216). Changes in at least two of the business-model components are considered as business-model innovation (Baden-Fuller and Morgan, 2010; Teece, 2010).

Platforms are considered as a novel business model and/or business-model innovation (Parker *et al.*, 2016; Cusumano *et al.*, 2019; Van Alstyne *et al.*, 2016). Platform-oriented business models encourage companies to shift from firm-centered networks toward an open ecosystem approach emphasizing more collaborative value co-creation and more systemic value capture (Fehrer *et al.*, 2018; Ozalp *et al.*, 2018). IoT platforms create a technological foundation for the platform company and its partners with the platform ecosystem, in order to develop complementary products or services (Evans and Gawer, 2016). Companies build platform ecosystems to incorporate resources, expertise and the innovation capacity of other actors, such as software developers, technology providers, other product companies and service specialists, to co-create value and develop new capabilities (e.g. Nambisan *et al.*, 2019; Rong *et al.*, 2015). As a result, through platform ecosystems, companies are able to develop solutions that address broader value propositions and more complex customer problems, such as guaranteeing outcomes of entire systems of assets (Gebauer *et al.*, 2020a). IoT platforms leverage digital technologies for advanced services, as they offer new ways for creating and capturing value (Jovanovic *et al.*, 2021; Cenamor *et al.*, 2017; Rajala *et al.*, 2019; Wei *et al.*, 2019).

Only recently, research has started to apply a holistic perspective on configurational aspects of platform business models. For example, Ardolino *et al.* (2020) developed and tested a business-model framework to characterize multisided platforms. It encompass variables and configuration items within six dimensions, including platform value proposition, platform sides, a platform revenue model, platform control, platform competition and platform architecture. Furthermore, scholars have begun to explore more deeply how companies utilize platforms. For example, Jovanovic *et al.* (2021) shed light on the co-evolution perspective on platform ecosystems, arguing that platform architecture, services and governance develop gradually and mirror each other. They demarcate three platform archetypes, namely product platform, supply chain platform and platform ecosystem, and they identify specific innovation mechanisms for platform service discovery and platform value expansion. Kapoor *et al.* (2021) focus on how platform ecosystems as socio-technical systems function and identify technical, task, actor and structure aspects of platform ecosystems, based on an extensive literature review. Tian *et al.* (2021) examine how four manufacturing companies successfully leverage platforms for servitization in an industry 4.0 context. They describe servitization strategies enabled by platforms, namely non-digital servitization, digital servitization and smart servitization, providing valuable insights into business-model adaptation and pathway dynamics. Langley *et al.* (2021) focus their concept paper on the impact of the internet of Everything (IoE) and smart things on business models and value creation in service ecosystems.

These contributions suggest that IoT platforms advancement and business-model innovation are interrelated, and that further research is still needed on *what patterns of business-model innovation support product companies in advancing their IoT platforms.*

3. Research approach and methods

3.1 Empirical context

IoT platforms in product companies are the empirical context. The number of IoT platforms has grown rapidly, almost tripling from 260 to about 700 in the last five years (IoT Analytics, 2020). But the term "IoT platform" is still quite fuzzy and has been buzzing around among many practitioners and academics alike. In this study, IoT platforms are defined by connecting products to the internet, making data available about product health and customer usage. This data is in turn transformed into new smart digital services, resulting in new innovative product-service-software systems delivered through ecosystems.

3.2 Research approach

The research approach was structured along a continuum covering product companies with early-stage IoT platforms to those that have already reached an advanced stage. Companies were assumed to move along this continuum as they integrate more and more advanced digital services into their IoT platform. Consistent with the development of grounded theory and the goal of developing a theoretical model of the patterns of business-model innovation followed by companies attempting to advance their IoT platforms, companies were considered and selected along the entire continuum.

To answer the research question, a mixed-methods approach was used with two sequential studies. Study I is a quantitative survey with 81 participating companies covering the entire continuum. Study II consists of qualitative case studies to gain deeper insights into the individual patterns and their actual sequence in the advancement of IoT platforms. Table 2 provides an overview of the sample and company characteristics for Studies I and II.

4. Study I: identifying patterns of business-model innovations

4.1 Research method

Sample and data collection: A survey was conducted among product companies using questionnaires. Five face-to-face interviews were conducted prior to the survey to test a preliminary version of the questionnaire. We then randomly selected 106 companies (written survey was sent to the managers responsible for developing or operating IoT platforms). There were 81 positive responses, resulting in a response rate of 76%. The quality of the information provided was assessed through questions about the length of time the

Study I (n = 81)						
Industry mix[a] (%)	Machine and equipment manufacturing *44%*	Moveable and transportation equipment *31%*	Energy Equipment *5%*	Technology provider *5%*	Software specialist *4%*	Others *11%*
Annual sales	Annual turnover Below €5 billion *50%*	Annual turnover €5–€15 billion *20%*	Annual turnover Above €15 billion *30%*			
Regions (%)	Europe *76%*	North America *19%*	Rest of the world *5%*			

Study II (three case studies)

Use case/ pattern	Interviewee function	Average interviewee experience in IoT platforms or digital services	Industry sector	Number of employees	Region
Aviation specialist	Managers from the digital unit	5+ years	Aircraft industry	25.000+	Europe
Machine manufacturer	Service manager, Manager digital services, Product manager, Chief digital officer	7+ years	Machinery manufacturing	10.000+	Europe
Agricultural specialist	CEO; manager digital unit	10+ years	Agricultural machinery manufacturing	14.000+	Europe

Note(s): [a]Unless otherwise indicated, "%" refers to the percent of the sample respondents

Table 2.
Sample characteristics

respondent had worked at the company, the respondent's knowledge of the IoT platform and their specific work experience at the company (Kumar *et al.*, 1993). Considering these factors, it seems reasonable to assume that the respondents had relevant expertise. To determine the advancement of the platform, questions about platform age (when was the platform launched?) and a subjective assessment of the platform investments (how do you rate the investments in the platform so far? 1 – very low to 7 – very high) were integrated into the questionnaire (Lee and Lee, 2015).

Measuring factors on business-model innovations: Although business models are now an established concept, surprisingly there is still no rigorous reflective scale and/or formative index for measuring and operationalizing business-model innovations. Accordingly, a formative measurement was used to operationalize business-model innovation. Critical for the design of valid indexes with formative indicators are the following criteria: (1) indicator specification and (2) content specification (Diamantopoulos and Winklhofer, 2001). Indicator specification is about indicators that capture the entire scope of each business-model component, namely value proposition, value creation and delivery and profit equation (or value capture) (Ghezzi *et al.*, 2015; Teece, 2010). Some indicators were adopted from previous studies on business-model innovations (e.g. Clauss, 2017). The value proposition was operationalized through six indicators that encompass all aspects of the offering that convey value to the customer. Value creation and delivery was measured by six indicators that encompass all internal and external activities to fulfill this value proposition. The profit equation was operationalized through seven indicators covering different aspects of monetization of IoT platforms.

To achieve content specification, the following dimensions were considered when formulating the actual measurement items for all 19 indicators: (1) *importance* of the business-model innovation in general, (2) *frequency* of the business model innovations and (3) the *emphasis* on these business-model innovations to measure the grade of business-model innovations. As a result, the questionnaire contained 57 items (19 individual indicators with three corresponding items) measured on seven-point scales, where 1 is the lowest value and 7 the highest value (see indicator descriptions in Tables 3 and 4).

Cluster Analysis: A *K*-means cluster analysis was conducted. To reduce possible bias in specifying clusters in advance, the initial decision on the number of clusters was guided by the numbers of factors comprising business-model innovations. This was achieved by limiting the number of clusters between *n*/30 and *n*/60 (*n* is the sample size), by measuring the pronounced increases in the tightness of the clusters, through managerial interpretability of the clusters using ANOVA tables, and by verifying the results of the *K*-means cluster analysis using alternative clustering methods (Ketchen and Shook, 1996).

4.2 Results

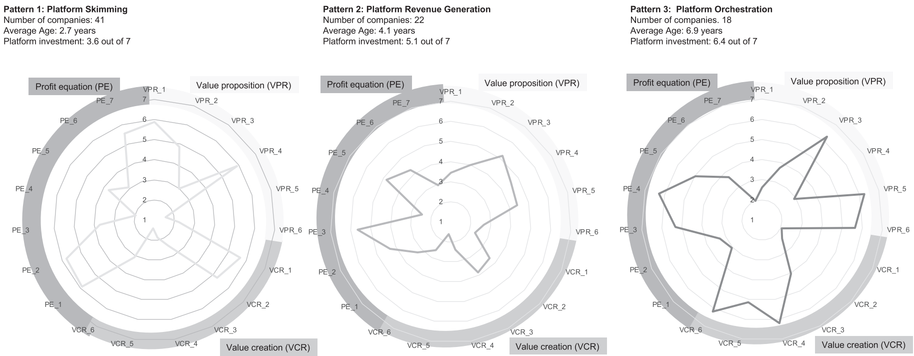
The cluster analysis revealed three clusters. As illustrated in the corresponding ANOVA table (Table 3), all 19 indicators (six for the indicators for value proposition, six for value creation and seven for profit equation) about business-model innovations discriminate between the three clusters. Corresponding cluster means are shown in Table 4. Figure 1

Business model components	Indicators	*F*-test	*p*-value
Value proposition (VPR)	VPR_1: Target customers for the IoT platform	339.655	0.000
	VPR_2: Performance visualization	62.588	0.000
	VPR_3: Performance improvement	409.842	0.000
	VPR_4: Internal cost saving	136.174	0.000
	VPR_5: Modularization	322.368	0.000
	VPR_6: Collaborative benefits	126.009	0.000
Value creation (VCR)	VCR_1: Aligning internal value creation activities to become an IoT-platform company	518.432	0.000
	VCR_2: Building up internal value creation activities on basic applications	446.789	0.000
	VCR_3: Expanding internal value creation activities toward more complex app expertise	123.161	0.000
	VCR_4: Encouraging more collaborations with external partners in the value creation	497.407	0.000
	VCR_5: Maintaining collaborations with external partners in the value creation	548.026	0.000
	VCR_6: Seizing the scope of the value creation activities utilizing the platform (single devices or complex systems)	289.476	0.000
Profit equation (PE)	PE_1: Embedding connectivity cost into products	347.254	0.000
	PE_2: Establishing an investment plan for setting-up the IoT-platform	463.348	0.000
	PE_3: Establishing a clear vision on free and fee elements for the platform	53.122	0.000
	PE_4: Encouraging cost-and-revenue sharing models for platform partners	802.863	0.000
	PE_5: Expanding the value capture toward software applications	37.652	0.000
	PE_6: Embedding IoT value into value capture through existing services	51.712	0.000
	PE_7: Establishing transparency about cost savings	533.717	0.000

Table 3. ANOVA tests associated with the cluster analysis

Business model components	Indicators	Cluster means (1 to 7 – where 1 is the lowest value and 7 the highest value) Pattern 1: platform skimming (n = 41)	Pattern 2: platform revenue generation (n = 22)	Pattern 3: platform orchestration (n = 18)
Value proposition (VPR)	VPR_1: Target customer for IoT platform	5.88	3.45	2.63
	VPR_2: Performance visualization	4.85	3.98	3.74
	VPR_3: Performance improvement	2.97	5.18	6.26
	VPR_4: Internal cost saving	5.91	4.58	2.91
	VPR_5: Modularization	1.57	4.41	6.24
	VPR_6: Collaborative benefits	2.23	2.64	5.65
Value creation (VCR)	VCR_1: Aligning internal value creation activities to become an IoT-platform company	5.66	2.32	2.35
	VCR_2: Building up internal value creation activities on basic applications	5.24	3.64	4.04
	VCR_3: Expanding internal value creation activities toward more complex app expertise	2.45	3.85	6.19
	VCR_4: Encouraging more collaborations with external partners in the value creation	1.89	2.39	5.15
	VCR_5: Maintaining collaborations with external partners in the value creation	1.41	1.62	6.17
	VCR_6: Seizing the scope of the value creation activities utilizing the platform (single devices or complex systems)	3.11	2.58	2.35
Profit equation (PE)	PE_1: Embedding connectivity cost into products	5.89	3.23	3.04
	PE_2: Establishing an investment plan for setting-up the IoT-platform	5.78	4.30	3.28
	PE_3: Establishing a clear vision on free and fee elements for the platform	3.72	5.65	5.33
	PE_4: Encouraging cost-and-revenue sharing models for platform partners	1.96	2.47	6.30
	PE_5: Expanding the value capture toward software applications	3.72	4.83	4.96
	PE_6: Embedding IoT value into value capture through existing services	3.07	4.27	3.69
	PE_7: Establishing transparency about cost savings	5.55	2.94	2.00

Table 4.
Cluster means of discriminating indicators



Notes: Indicators, cluster means where 1 is the lowest value and 7 the highest value.

Value proposition (VPR)	
VPR_1	Target customer
VPR_2	Performance visualization
VPR_3	Performance improvement
VPR_4	Internal cost saving
VPR_5	Modularization
VPR_6	Collaborative benefits
Value creation (VCR)	
VCR_1	Aligning internal value creation activities to become an IoT-platform company
VCR_2	Building up internal value creation activities on basic applications
VCR_3	Expanding internal value creation activities toward more complex app expertise
VCR_4	Encouraging more collaborations with external partners in the value creation
VCR_5	Maintaining collaborations with external partners in the value creation
VCR_6	Seizing the scope of the value creation activities utilizing the platform
Profit equation (PE)	
PE_1	Embedding connectivity cost into products
PE_2	Establishing an investment plan for setting-up the IoT-platform
PE_3	Establishing a clear vision on free and fee elements for the platform
PE_4	Encouraging cost-and-revenue sharing models for platform partners
PE_5	Expanding the value capture toward software applications and subscription model
PE_6	Embedding IoT value into value capture through existing services
PE_7	Establishing transparency about cost savings

Note(s): Cluster means illustrated in the radar plots

Figure 1. Patterns on business model innovations

depicts the cluster means in three radar plots. Each of the clusters can be interpreted as a specific pattern of business-model innovations, since they include consistent modifications in the value proposition, value creation and profit equation. These three patterns can be interpreted as (1) *platform skimming*, (2) *platform revenue generation* and (3) *platform orchestration*. In addition, the two indicators about platform advancement, platform age and platform investment also discriminate between these three patterns.

The first pattern (platform skimming) consists of 41 companies. With an average platform age of only 2.7 years and still relatively low platform investments (average 3.6 out of 7), platform skimming is the early stage of platform development. High means for defining target customers, simple performance visualization and cost savings for the value proposition dominate *platform skimming*. Value creation activities are dominated by high means for aligning internal value creation activities with an IoT platform, building internal value creation activities around basic digital services and applications for value creation and embedding connectivity costs. They hardly make any revenue through the IoT platform. The profit equation is manifested by embedding the costs in existing products and services and to regain the cost reduction potential for its own purposes and customers.

Pattern 2 (*platform revenue generation*) consists of 22 companies. With an average platform age of 4.1 years and median platform investment (average 5.1 out of 7), *platform revenue generation* implies a more advanced phase of platform development. *Platform revenue generation* shows high means for offering customer value through significant performance improvements and customers are willing to pay fees for these more advanced services. The profit equation is characterized by establishing a clear vision about free and paid service elements of the IoT platform. Value creation and value proposition are dominated by high means of delivering value-added services that are closely tied to the installed base as well as digital services that add customer value far beyond existing products.

Pattern 3 (*platform orchestration*) contains 18 companies. With an average platform age of 6.9 years and high platform investment (average 6.4 out of 7), *platform orchestration* has reached the highest level of platform advancement. *Platform orchestration* achieves the highest cluster means on embracing collaboration in the ecosystem for the value proposition. Accordingly, there are high means for fostering more collaborations with new external partners, maintaining collaborations with existing external partners, and leveraging the scope of internal and external activities for value creation as well as fostering cost and revenue sharing models for platform partners. Consequently, this pattern is about working with the surrounding ecosystem to create additional value with digital services.

5. Study II: gaining deeper insights into each pattern

5.1 Research method

For Study II, one company was purposefully selected for each pattern. Study II was guided by typical recommendations for conducting qualitative research (e.g. Voss *et al.*, 2002). Data confidentiality does not permit using the actual company names, but rather company pseudonyms: *Aviation Specialist* for the *Platform Skimming*, *Machine Manufacturer* for the *Platform Revenue Generation*, and *Agricultural Specialist* for the *Platform Orchestration*.

As part of Study II, we conducted semi-structured interviews with these three companies to understand more information about the managerial decisions and organizational structures related to the business-model patterns from Study I. In addition, interviews with ten key executives (two to five for each of the three companies) driving the platform initiatives in their companies were conducted. The interviews lasted between 45 and 120 min. The interviews aimed to understand the objective of the business-model innovations as well as how business model components were modified to increase the maturity of the IoT platform. Questions similar to the "narrative" approach (Yin, 1994) were used to explore key themes (triggers, goals and actions). In particular, the interviewees were asked about the core components of business models (value proposition, value creation and profit equation). In addition, the executives were also asked about the possible obstacles and barriers they perceive in connection with their current situation. At the end of each interview, the participants were asked for additional comments. Questions were phrased in an unobtrusive and non-directive manner to avoid the pitfalls of too active listening (McCracken, 1988). Insights were developed based on the interviewees' own language and/or case study transcripts, rather than using only predefined constructs.

To ensure reliability and validity, this primary data was triangulated with secondary information (e.g. company literature, internal documents). All primary and secondary data were used to develop case studies on patterns of business-model innovation. A content analysis approach was used to analyze these cases to determine how modifications to the value proposition, value creation and profit equation shape the actual pattern of business-model innovations.

5.2 Results

The content analysis resulted in the following insights into the three patterns:

5.2.1 Platform skimming–aviation specialist. The aviation specialist demonstrates the platform skimming approach. Its IoT platform was launched in 2017 and is still in the early stage of development.

Triggers: The advancements on sensors being embedded in aviation assets, on data storage and data analytics trigger the platform skimming pattern. The aviation specialist wanted to leverage the platform to gain more insights into aircraft asset usage from the customer perspective.

Goals: The aviation specialist's goal is to connect as many aviation assets as possible to its IoT platform. The cost of developing the IoT platform is refinanced by reducing the company's own service costs. Therefore, this IoT platform was mainly aimed at improving internal service processes. Increasing cost efficiency was the primary goal of the platform activities.

Actions: Key actions to modify the business-model components began with defining initial pilot customers interested in connecting their assets to the IoT platform. The value proposition was directed toward visualizing the condition and performance of aircraft assets. The resulting IoT platform used data about the use and condition of aviation assets to make aircraft maintenance, repair and operations more cost-effective. For example, aircraft were equipped with sensors to monitor the "health" of critical aircraft components and replace them immediately when certain thresholds were reached. One focus was on digital twins for aircraft assets. Such digital twins improved, for example, the tracking of service history and activities on a particular asset, which in turn made service delivery more cost-efficient. Another focus was on rapid provisioning of critical aircraft components to increase the availability of customers' aircraft assets.

Accordingly, key actions for modifying the value creation were about aligning internal service delivery activities with the emergence of the IoT platform. As for platform skimming, the aviation specialist started to develop basic digital services to easier visualize the aircraft asset condition and/or performance. These digital services were reported to be still descriptive rather than diagnostic and/or predictive. More advanced digital services for further improving aircraft asset performance were still in the early development phase. The aviation specialist bundled all these activities in a small, but agile digital unit. This unit was made responsible for integrating data into the delivery of existing services, developing new advanced digital services and pushing these services throughout the entire organization.

In terms of profit equation, the aviation specialist reported to increasingly invest into the IoT platform development. An investment plan was formulated to mobilize the necessary financial resources. Besides the financial aspects, the investment plan included ways for making the IoT platform more attractive for external customers, for enabling the sales organization to offer the basic and few advanced digital services and for scaling the platform continuously. As part of the investment plan, financial aspects such as cost of connecting aircraft assets, mining, visualizing and analyzing data on aircraft assets as well as possible cost reduction and increased service efficiency were estimated. At the current state, this IoT platform does not aim to increase revenue through monetizing digital services, licensing platform access or offering subscription and/or pay-per-use approaches.

5.2.2 Platform revenue generation – machine manufacturer. The machine manufacturer started its platform in 2015. The platform connects the machines to the data cloud. In the cloud, data about machine usage and condition is processed in two ways. First, the data is used to improve existing services in order to minimize machine downtime. Second, the data is increasingly used for new digital services that open up new business opportunities around machine operation. Compared to the platform skimming pattern, this IoT platform is more advanced. The machine manufacturer reported to already have implemented the actions associated with the platform skimming pattern. It has now turned toward platform revenue generation.

Triggers: This pattern is not triggered by technological advancements, but rather through the high financial demand for expanding the platform.

Goals: The main objective of the machine manufacturer was to increase the number of platform users among its existing customers and to convince these users to pay for the platform services. Accordingly, the machine manufacturer aims to generate more revenue through its IoT platform.

Actions: To generate more revenue through its IoT platform, the machine manufacturer implemented the following measures to modify its business-model components. The value proposition has been extended from pure performance visualization to concrete performance improvements. Typical performance indicators relate to overall equipment effectiveness (e.g. uptime, performance and quality indicators). The value proposition has been modified to allow the machine manufacturer to combine machine and other data to provide advanced digital services. These digital services often include software and/or applications sold and delivered through an industrial application store (app store). Customers can download these applications directly to their machines or other customer devices (e.g. tablets, smartphones). In addition, more sophisticated data analytics enabled the machine manufacturer to evolve its existing services (e.g. repair, inspection and maintenance services) from pure diagnostic services to more predictive and prescriptive services.

All these value creation activities were bundled into one digital unit. But compared to the platform skimming pattern, this digital unit was not just an investment center, but became a revenue center. As a revenue center, this unit was responsible for generating revenue and transforming the initial investment plan into a business plan. This business plan outlines paths for expanding and scaling the IoT platform. These paths illustrate the number of platform users and platform services to match with the necessary IoT infrastructure.

Regarding the profit equation, platform development was considered as a strategic investment to achieve competitive advantages. The costs for the machine connection and operation of the platform are included in the machine price. These costs are refinanced by service cost improvements during the warranty period of the machine. After the warranty period, the machine manufacturer recovers the costs by selling digital services to customers and expanding the number of digital services offered to platform users. To make it easier to convince customers to buy the digital services, the machine manufacturer has simplified pricing by integrating the digital services into existing service contracts. The company is also now experimenting with a subscription approach for some of the digital services. An important measure to change the profit equation is therefore to define the boundary between free services integrated into service contracts and services sold separately via subscription.

5.2.3 Platform orchestration – agricultural specialist. The agricultural specialist launched its platform in 2013. The company invested heavily into the platform development making the platform relatively advanced. The IoT platform already went through the patterns of platform skimming and revenue generation. It connects the agricultural equipment (e.g. harvesters, tractors, planters) to the data cloud. In the cloud, data about usage and condition of the entire farm equipment is combined with a broad range of other data to make agricultural businesses more successful. First, the data is used to optimize the overall equipment effectiveness of the farm equipment. Second, the data is used to embed farm equipment operation more smoothly into the customer operation (e.g. navigation services to drive harvesters, tractors, and planters more carefully on the field). Third, the data is used to optimize additional customer activities (such as making crop planning, water irrigation, seed planting, fertilizing plants, etc.).

Triggers: This pattern is not triggered by technological advancements nor financial demand, but rather through the high competence requirements for advancing the platform.

Goals: The main goals are not just to increase platform users and platform services. Instead, the agricultural specialist aims to compete for customer outcomes. Relevant outcomes range from optimizing the effectiveness of farm equipment, and smoother equipment operation to better planning of crops, irrigation, seed application, or fertilization of plants. Achieving such customer outcomes goes beyond the company's own competencies and requires partnerships with other companies. A key objective was therefore to use an ecosystem approach to make the IoT platform more attractive and to mobilize competence partners.

Actions: Accordingly, key actions for modifying the value proposition were about enabling agricultural businesses to become more successful. This modified value proposition was based on service modules rather than individual services. These service modules can be combined easily in order to customize the value proposition to customers' individual needs.

The value proposition became more collaborative in terms of various partners contributing to achieving actual customer outcomes.

Value creation was extended to incorporate the necessary consulting competences to customize the modular offerings. Value creation is modified in a way utilizing data from all farm management assets and various external data sources (e.g. crop prices, weather, seed, irrigation). This data is converted into more advanced digital services including as many as 50 different applications. These applications are offered through an industrial app store, in which customers can download these applications either on their farm assets or on relevant customer devices (e.g. tablet PCs, smartphones).

As the agricultural specialist does not have all the competencies to develop and deliver all 50 applications, it has incorporated about 20 innovation partners. These applications are increasingly modularized so that they can be more easily adapted to the individual needs of farmers. Value creation activities therefore also comprise mobilizing and managing platform partners, including the coordination and modularization of their own digital service offerings and the complementary service offerings of the innovation partners, in order to increase the attractiveness of the IoT platform.

To manage these value creation activities and facilitate partner mobilization, the agriculture specialist has set up its IoT platform as a new standalone company. Within the standalone company, a stronger ecosystem mindset flourished, making it easier to integrate competitors into the platform ecosystem. Accordingly, platform governance and the establishment and management of partner roles in the platform ecosystem are an essential part of value creation.

Important actions for modifying the profit equation were about introducing cost-and-revenue sharing models for clarifying the costs and revenues for partners when developing and delivering digital services. Furthermore, for keeping the monetization of digital services simple and convenient for customers, the profit equation was adapted toward a freemium approach. For all digital services, there is now a basic level that customers get for free as well as a premium level that requires customers to pay for. A subscription model was used to manage the payments for the premium level. To make it easy for customers to understand the pricing approach, subscription prices simply depend on customers' number of farm acres or livestock.

6. Discussion

6.1 Theoretical implications

The research question addressed in Studies I and II was: *what patterns of business-model innovation support product companies in advancing their IoT platforms?* Answering this research question contributes to the existing literature in three ways.

First, the results extend previous findings from qualitative studies. Thus far, business-model patterns have been described primarily from a static perspective, using qualitative research methods. The combination of qualitative and quantitative methods revealed three business-model patterns, which are sequential in nature. Of course, these three patterns may not be exhaustive and more may be added over time as IoT platforms advance even further. Nonetheless, the three patterns, 1) platform skimming, 2) platform revenue generation, and 3) platform orchestration extend the existing literature. These patterns can be considered as a framework that extends previous frameworks dealing with data-driven service, for example, the digital servitization pathways suggested by Coreynen *et al.* (2017): industrial servitization, commercial servitization and value servitization. Specifically, platform skimming is similar to industrial servitization, while revenue generation is close to the path of commercial servitization. Platform orchestration, with its focus on encouraging partners to develop complementary digital offerings making the platform more attractive, is close to the path of value servitization. The results reveal a sequence of three patterns, with companies seeking cost savings in the first step (platform skimming), revenue generation in a next step and platform orchestration in a further step. Establishing an IoT platform as a revenue driver, and orchestrating an ecosystem from the very beginning is difficult, mainly due to the high initial investments in infrastructure and organizational development. Jovanovic *et al.* (2021) explore the co-evolution of platform architecture, platform governance, and platform services, and distinguish between product platform, supply chain platform, and platform ecosystem as evolutionary archetypes. While Jovanovic *et al.* focus on the position of the company in the value system (or ecosystem), the results of this study apply a more holistic perspective. These three patterns strengthen the theoretical development and validation of IoT platforms by suggesting specific measures to statistically invest in and further test them. In addition, these patterns can be used to set up a model for analyzing the advancement of IoT platforms.

Second, the findings confirm and supplement previous assumptions about IoT platforms challenging companies' value proposition, value creation and profit equation. IoT platforms are new and novel business models (Parker *et al.*, 2016; Cusumano *et al.*, 2019; Van Alstyne *et al.*, 2016). IoT platforms embrace a new business logic, which supplement rather than replace the previous business logic of product companies (Gebauer *et al.*, 2020a; Sjödin *et al.*, 2020; Skylar *et al.*, 2019; Tronvoll *et al.*, 2020). The findings highlight the necessary modifications to business-model components. These modifications are not trivial changes, but imply a fairly wide scope and level of novelty for the business-model innovations (Foss and Saebi, 2017; Ozalp *et al.*, 2018). More specifically, platform skimming is largely about utilizing new and complex technologies, platform revenue generation is about monetizing digital services through more outcome-based models, and platform orchestration is about letting platform ecosystems emerge as a new organizational form for creating value (Jacobides *et al.*, 2018; Jovanovic *et al.*, 2021; McIntyre and Srinivasan, 2017). All these changes are relatively novel modifications to the business model.

Third, the results offer an original process perspective to the existing literature on how business logic and business-model components change over time (e.g. Parker *et al.*, 2016; Cusumano *et al.*, 2019; Van Alstyne *et al.*, 2016). To become more advanced, IoT platforms start with the pattern of platform skimming, continue with revenue generation, to achievethe pattern of platform orchestration (e.g. Ardolino *et al.*, 2018; Paschou *et al.*, 2020; Paiola and Gebauer, 2020; Rymaszewska *et al.*, 2017). This somehow contradicts other contributions suggesting that IoT platforms would directly and from the start require an ecosystem approach. Initially, companies should secure cost savings through the platform skimming pattern. In a further step, revenues can then be increased through the platform revenue-generation pattern within the company's own boundaries, before then taking a larger ecosystem approach that extends beyond the boundaries of their own company. Overall, there is no gradual evolution in the business model, but there are rather three distinctive patterns of business-model innovations. Interestingly, each pattern has a distinct trigger starting with technology advancements for platform skimming, financial requirements for platform revenue generation and competence requirements for platform orchestration. Considering the distribution of companies among these three patterns suggests that half of the companies are still in the early platform-skimming phase ($n = 41$), about one-fourth of the companies have already progressed toward *platform revenue Generation* ($n = 22$) and slightly less than one-fourth has already become a *platform orchestrator* ($n = 18$). From a process perspective, companies still have to go a certain way to further advance their IoT platforms.

6.2 Managerial implications

The findings have two important managerial implications. First, rather than gradually shifting the business model as IoT platform become more advanced, managers should be aware that there seems to be a common sequence of three patterns of business-model innovations: platform skimming towards platform revenue generation and then to platform orchestration (see Figure 2). Accordingly, managers might start their IoT platform journey through the platform-skimming pattern, thus cutting internal service delivery costs. Next,

Pattern 1: Platform Skimming

Trigger(s):
– Technological advancements on sensors, data storage, and data analytics

Goal(s):
– Connecting as many products as possible to the IoT platform
– Improving internal service processes and increasing cost efficiency.

Key actions:
– Defining pilot customers interested in connecting their products to the IoT platform
– Focusing on visualizing product condition
– Utilizing data about the product condition for maintenance, repair, and operations more cost-effective
– Equipping products with sensors to monitor the product "health"
– Aligning internal service delivery activities with the emergence of the IoT platform
– Bundling all activities in a small, but agile digital unit for integrating data into the delivery of existing services, developing new advanced digital services, and pushing these services throughout the entire organization
– Formulating an investment plan
– Enabling the sales organization to offer and sell the basic and few advanced digital services
– Estimate financial aspects such as cost of connecting products, data collections and analysis well as possible cost reductions through increased service

Pattern 2: Platform Revenue Generation

Trigger(s):
– High financial demand for expanding the platform

Goal(s):
– Generating more revenue through its IoT platform by increasing the number of platform users among its existing customers and convincing them to pay for the platform services

Key actions:
– Extending the value proposition toward performance improvements
– Combining machine and other data to develop and provide advanced digital services
– Using sophisticated data analytics to let existing services (e.g., repair, inspection and maintenance services) evolve from pure diagnostic services to more predictive and prescriptive services
– Bundling all value creation activities into digital unit acting as a revenue center
– Starting to set-up an app store
– Formulating and implementing paths for further scaling the IoT platform
– Considering platform development as a strategic investment to achieve competitive advantages.
– Including costs for the machine connection and operation of the platform in the machine price
– Refinancing platform costs by service cost improvements during the warranty period of the machine, selling digital services to customers after warranty and expanding the number of digital services offered to platform users.
– Defining clear boundaries between free services integrated into service contracts and services paid for separately via a subscription

Pattern 3: Platform Orchestration

Trigger(s):
– High competence requirements demand for a more advanced platform

Goal(s):
– Leveraging, improving, and competing on customer outcomes

Key actions:
– Enabling agricultural businesses to become more successful
– Encouraging service modularization
– Setting up procedures for customizing the value propositions to customers' individual needs
– Incorporating the necessary consulting competences to customize the modular offerings
– Utilize data to make customers better in many performance dimensions
– Mobilizing and managing the platform partners, including the coordination and modularization of their own digital service offerings and the complementary service offerings of the platform partners
– Considering setting up the IoT platform as an independent, standalone company
– Establishing platform governance procedures
– Introducing cost-and-revenue sharing models for clarifying the costs and revenues for partners when developing and delivering digital services
– Keeping the monetization of digital services simple and convenient for customers through adapting freemium and/or subscription approach

Figure 2. A guideline for advancing IoT platforms

they can deploy the pattern of platform revenue generation to revise and extend the offering and to develop new revenue streams. Finally, managers move toward the platform orchestration pattern to compete customer outcomes and embrace an ecosystem thinking, so as to enable novel solutions through value co-creation together with platform partners.

Second, the triggers, goals, and actions offer a guideline for managers attempting to increase the advancement of their IoT platforms. This guideline explains the necessary modifications to the business-model components. Managers can assess relevant strengths and weaknesses according to the modifications in the value proposition, value creation, and profit equation for each pattern. Managers can easily assess weaknesses in their IoT platform business models and make better decisions about modifying the business-model components.

6.3 Limitations and future research

Of course, the results have some limitations, but they offer promising directions for future research. First, further research should test and revise the identified three patterns in other industries and/or geographic areas. For example, future research should focus on small and medium-sized companies. Second, both the survey and case study interviews were conducted in 2019. Future research should examine the evolution of business-model innovation through a longitudinal study that tracks companies' attempts to increase platform maturity over time. This would allow for a more detailed examination of how companies move from one pattern to another. Third, the survey and case studies were conducted from the perspective of the IoT platform sponsor and/or provider. It would be helpful to triangulate their perceptions with actual data from platform users and/or customers. This triangulation would provide an interesting contrast and reveal the pros and cons of advancing IoT platforms from both sides. Fourth and finally, this study applied a business-model concept consisting of the three key components of value proposition, value creation and profit equation, in the business model. Future studies can take other, more comprehensive conceptualizations of business models. Although these limitations must be kept in mind when considering the implications, the findings still provide useful new insights for academics and practitioners alike.

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Further reading

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Appendix

Table A1. Indicators and items used in the questionnaire

Business model component	Indicators	Items
Value proposition	*Target customer for the IoT platform*	How important was the definition of target customers?
		How frequent were target customers modified?
		How strongly was trial-and-error learning about most suitable target customers emphasized?
	Performance visualization	How important was value proposition on performance visualization?
		How frequent were performance visualization be modified?
		How strongly was trial-and-error learning about most suitable performance visualization emphasized?
	Performance improvement	How important was value proposition on performance improvement?
		How frequent were performance improvement be modified?
		How strongly was trial-and-error learning about most suitable performance improvement emphasized?
	Internal cost saving	How important was the argument about internal cost savings?
		How frequent were cost saving estimations adapted?
		How strongly was trial-and-error learning about reasonable cost savings emphasized?
	Modularization	How important was the modularization of the value proposition elements?
		How frequent were cost saving estimations adapted?
		How strongly was trial-and-error learning about reasonable cost savings emphasized?
	Collaborative benefits	How important was the establishment of collaborative benefits for all partners?
		How frequent were establishment of collaborative benefits for all partners adapted?
		How strongly was trial-and-error learning about establishment of collaborative benefits for all partners emphasized?
Value creation	*Aligning internal value creation activities to become an IoT-platform company*	How important was the alignment of internal value creation activities to become an IoT-platform company?
		How frequent was, the internal alignment on value creation activities to become an IoT-platform company be modified?
		How strongly was trial-and-error learning about most suitable alignment of internal value creation activities emphasized?
	Building up internal value creation activities on basic apps	How important was building up internal value creation activities on basic apps?
		How frequent were value creation activities on basic apps be modified?
		How strongly was trial-and-error learning about basic apps emphasized?
	Expanding internal value creation activities toward more complex app expertise	How important was the expansion of internal value creation activities toward more complex app expertise?
		How frequent were value creation activities on complex app expertise be modified?
		How strongly was trial-and-error learning about most suitable complex app expertise emphasized?

(*continued*)

Business model component	Indicators	Items
	Encouraging more collaborations with external partners in the value creation	How important was the building of collaborations with external partners in the value creation? How frequent was the development of collaborations with external partners adapted? How strongly was trial-and-error learning about reasonable development steps for collaborations with external partners emphasized?
	Maintaining collaborations with external partners in the value creation	How important was maintaining collaborations with external partners in the value creation? How frequent were ways for maintaining collaborations with external partners adapted? How strongly was trial-and-error learning about ways for maintaining collaborations with external partners emphasized?
	Seizing the scope of the value creation activities utilizing the platform	How important was seizing the scope of value creation activities utilizing the platform? How frequent was the scope of value creation activities adapted? How strongly was trial-and-error learning about the scope of value creation activities encouraged?
Value capture	*Embedding connectivity cost into products*	How important were connectivity cost considerations? How frequent was integration and/or separation of connectivity costs adapted? How strongly was trial-and-error learning about connectivity costs encouraged?
	Establishing an investment plan for setting-up the IoT-platform	How important was established an investment plan? How frequent was the investment plan adapted? How strongly was trial-and-error learning about investments encouraged?
	Establishing a clear vision on free and fee elements for the platform	How important was a clear approach to differentiate between free and fee elements? How frequent was this approach adapted? How strongly was trial-and-error learning about fee and free elements encouraged?
	Encouraging cost-and-revenue sharing models for platform partners	How important were cost-and-revenue sharing models with external partners? How frequent were cost-and-revenue sharing models adapted? How strongly was trial-and-error learning about cost-and-revenue sharing models encouraged?
	Expanding the value capture toward software models	How important were software-oriented revenue mechanisms? How frequent were software-oriented revenue mechanisms adapted? How strongly was trial-and-error learning about software-oriented revenue mechanisms encouraged?
	Embedding IoT value into value capture through existing services	How important was the integration of IoT value capture schemes into the existing services? How frequent were these schemes adapted? How strongly was trial-and-error learning about such schemes encouraged?
	Establishing transparency about cost savings	How important were the transparency and estimation of the cost saving? How frequent were these estimations adapted? How strongly was trial-and-error learning about such cost savings estimations encouraged?

Table A1.