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Digital Platform Ecosystems:

Integrating the Efforts of Autonomous Actors

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Preface

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Brisbane, 02.11.2022 Rob Jago Flötgen

Abstract

Problem Statement: Digital platform ecosystems have emerged and succeeded as the predominant model for leveraging the innovative potential of a multitude of complementors. However, the success or failure of digital platform ecosystems today lies not with any single actor or technical component but with their interactions. Building and leveraging digital platform ecosystems is non-trivial, as platform owners need a holistic understanding of how to integrate the efforts of all autonomous entities in their digital platform ecosystem. From a theoretical standpoint, three issues emerge: First, digital platform ecosystems are understood by the information systems discipline as socio-technical concepts that overlap with several disjointed research domains that still need to be combined into a comprehensive mapping. Second, more needs to be addressed on how and which socio-technical aspects of the technical platform and its ecosystem might be leveraged to develop digital platform ecosystems successfully. Third, more research needs to be done on the attributes that emerge as an outcome of integrated efforts of autonomous actors in digital platform ecosystems.

Research Design: To address this gap, we first reviewed the literature on the various theoretical concepts of digital platform ecosystems, focusing on surveying existing research fields' dependent and independent variables. The remaining publications follow a qualitative research strategy and utilize various research methodologies: We build on case surveys, case studies, and taxonomy development to analyze announcements or partner-related documents (but not limited to) of digital platforms regarding (1) actions taken to leverage their platform-based nature and the ecosystem, (2) the financial regulatory reporting ecosystem, and (3) business-to-business app stores. To derive conclusions from our extensive qualitative data collection, we employed a systematic inductive theorizing method to data analysis and repeatedly contrasted our findings with the emergent theoretical conceptions.

Results: This dissertation connects the isolated concepts of digital platform ecosystems to provide nomological networks of digital platform ecosystem research and digital platform ecosystem performance. Moreover, we highlight how digital platforms in different industries leverage and combine socio-technical characteristics of their platform-based nature and their ecosystem by presenting archetypes of digital platform ecosystem resilience, archetypes of digital platform ecosystem structures, dimensions & types of B2B app store governance, and an e^3-value model of emerging financial regulatory reporting frameworks for digital platform ecosystems. Based on this, we develop a novel understanding of the digital platform ecosystem attributes resilience, structure, and performance as outcomes of the integrated efforts of autonomous actors.

Contribution: Our research findings make significant contributions to the existing literature on digital platform ecosystems in three distinct ways. First, we offer a comprehensive and interconnected overview of constructs and causal relationships within digital platform ecosystem(s) (performance), effectively synthesizing empirical knowledge from disparate domains and highlighting boundary constructs that can bridge theoretical gaps. Second, we integrate resilience theory, actor-network theory, and performance theory into the context of digital platform ecosystems. Third, we extend these theories by introducing novel concepts such

as digital platform ecosystem resilience, characterizing digital platform ecosystem structures, and delineating digital platform ecosystem performance. Additionally, we provide valuable taxonomies related to B2B app store governance. Managers can effectively leverage these research outcomes to prioritize actions, conduct fit-gap analyses, and develop strategic roadmaps to foster the growth and success of their platform ecosystems.

Limitations: This dissertation acknowledges certain limitations that warrant critical examination, encompassing three key aspects. First, despite an extensive data set derived from numerous empirical studies, surveyed cases, interviews, and diverse secondary data, it is essential to recognize that the data may not be exhaustive. The evolving nature of the phenomena under investigation hinders complete coverage, as new cases, and data, which were not previously disclosed or officially announced, might emerge, and necessitate consideration in future research endeavors. Second, the qualitative methods employed in this study possess certain constraints on generalizability and applicability, confined within their specific economic, social, and technical contexts. Last, due to the qualitative nature of this dissertation, the theoretical constructions are subject to a degree of interpretative stance. To mitigate this concern, we have taken measures such as ensuring inter-coder reliability, employing data triangulation, and adhering to established research methodologies to uphold scientific rigor.

Future Research: In addition to the avenues for future research within the embedded publications, this dissertation provides three additional starting points for further investigation. First, researchers should shed light on the tensions and emerging emancipation movements of digital platform ecosystem complementors to uncover the mechanisms behind unequal power relationships among platform actors and to increasingly regain the balance of ecosystem power dynamics in the long term. Second, we want to encourage future digital platform ecosystem research to leverage system dynamics modeling as a new methodological framework for an emergent dynamic perspective of digital platform ecosystems. Third, we argue to understand further the effects of external triggers on spontaneous and disorganized action of ecosystem actors and related consequences.

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List of Abbreviations

ACIS	Australasian Conference on Information Systems
AMCIS	Americas Conference on Information Systems
B2B	Business-to-Business
CON	Conference
DPE	Digital Platform Ecosystem
ECIS	European Conference on Information Systems
EJIS	European Journal of Information Systems
HICSS	Hawaii International Conference on System Sciences
IS	Information System
JN	Journal
Lit. Rev.	Literature Review
NR	Not Ranked
P	Publication
PACIS	Pacific Asia Conference on Information Systems
RQ	Research Question
Tax. Dev.	Taxonomy Development
VHB	Verband der Hochschullehrer für Betriebswirtschaft

Part A

1 Introduction

Almost 30 years ago, the first pioneers discussed the role of IT in designing organizations (Baroudi & Lucas, 2015). They envisioned a future where an "[...] organization [...] may not be an organization at all" (p. 22) but might be powered by "an amalgamation of independent agents" (p. 16) and enabled by contemporary IT. By their forecast, digital platforms, as an instance of modern IT, have made thriving ecosystems possible today as an established socio-technical (inter-)organizational structure. Conversely, these ecosystems have become essential to the business models of digital platform enterprises, as reflected by Satya Nadella, the CEO of Microsoft Corporation:

> *"[…] we fundamentally wouldn't exist as a company if not for the [...] ecosystem taking what we build, adding value to it and then, most importantly, jointly being as obsessed about how do the outcomes of it help the world get better […]"* (CRN, 2021).

In this dissertation, we learn how and why digital platform ecosystems can be successful along three schools of thought. First, we connect isolated digital platform ecosystem research. Second, we analyze how digital platforms leverage the interplay of their technical nature and their ecosystem. In a third step, we shed light on selected attributes as outcomes of the integrated efforts of autonomous actors in digital platform ecosystems.

1.1 Motivation

Digital platforms change how companies run their business today (de Reuver et al., 2018; Jacobides et al., 2018). Whereas in the past, a company's success was determined by its mastery of the value chain, today, the ability to attract or add generative activities within the product or business model of a digital platform is becoming the criterion for success (de Reuver et al., 2018). Digital platform owners thus face the challenge of managing the ecosystem of so-called platform complementors and customers to ensure the success of their digital platform (Boudreau, 2010; Ghazawneh & Henfridsson, 2013).

A digital platform ecosystem consists of a technical platform (in its elementary reduction, an extensible code base that provides the core functionality), its software extensions/complements (modular services), and its stakeholders, namely (but not limited to) the platform owner, complementors, customers, and competitors (Tiwana, 2013). The platform complementors use digital platforms' boundary resources to generate new value in products, modular services, or even new businesses (Autio et al., 2018; Lusch & Nambisan, 2015). By doing so, they become an inherent part of the value-creation process of the digital platform (Adner & Kapoor, 2010; McIntyre & Srinivasan, 2017). Therefore, digital platforms allow owners to utilize innovation capabilities and resources outside their firm's boundaries (Eaton et al., 2015; Ghazawneh & Henfridsson, 2013). As such, they are increasing the economic value of the platform beyond what they would achieve on their own (Parker & Van Alstyne, 2018).

However, building and utilizing a digital platform ecosystem is not trivial; less than 15% of the 57 ecosystems examined in a recent study across 11 industries were found to be sustainable

(Reeves et al., 2019). Platform owners face several challenges, from becoming unattractive to complementors to platform exploitation (Chen et al., 2020; Wareham et al., 2014). To counteract this, digital platform owners employ governance mechanisms to balance the diverse interests of all platform stakeholders and channel their activities to increase the overall value of the platform within their digital platform ecosystem (Parker & Van Alstyne, 2018; Wareham et al., 2014). Therefore, platform owners require a holistic understanding of the integration of the efforts of all autonomous entities in their digital platform ecosystems as its success and failure today do not lie with a single actor or technical component but in their interrelations (Zhu & Iansiti, 2019).

While the actors and the technology artifacts are the fundamental parts of a platform owner's digital platform ecosystem, we can distinguish between different levels of ecosystems that function as both 'part' and 'whole', depending on the perspective (Wang, 2021). For example, a single complementor / application developer only sees his 'part' product/service ecosystem, whereas the platform owner sees a bigger or the 'whole' business ecosystem. From a theoretical perspective, there are two streams: On one hand, digital platform research extends digital platform ecosystem research through the integrated role that architecture and governance play in these socio-technical constructs (Tiwana et al., 2010). On the other hand, digital platform ecosystem research fuels platform research by analyzing the complex networks of their actors to identify patterns of behavior that shape the focal platform's growth or decline (Tsujimoto et al., 2018). Looking at both research streams together, there is an imbalance within the literature on ecosystems that prioritizes the parts over the whole, which has led to the conduct of single-level or firm-centric studies that view the ecosystem as an exogenous influence beyond the control of the actors (Wang, 2021). However, this is fraught with issues from a theoretical perspective: First, the focus on single actors may undermine the mutual dependency of an ecosystem, with studies possibly advocating for a "winner-takes-all" mentality instead of balanced approaches. Second, this may lead to typical logical fallacies when abstracting from findings of single-level research (Klein & Kozlowski, 2016). Finally, this is also a practical strategic problem, as stated by Adner (2022): "Defining ecosystems around companies blind everyone involved to alignment hurdles and limits their ability to craft appropriate strategies. The presumption of centrality makes it harder to establish the relationships needed to achieve their goals: It's harder for ecosystem leaders to create strategies that attract followers and for ecosystem partners to know which leaders to follow and where to place their bets". In sum, little has been learned about how autonomous actors' efforts, i.e., the ecosystem's parts (or a single platform research stream), can be integrated into a successful coherent whole (or digital platform ecosystem research). To address this disparity, we have identified three research gaps which we address in this dissertation to improve our understanding of how to integrate the efforts of autonomous actors in digital platform ecosystems:

First, digital platform ecosystems are understood by the information systems discipline as a socio-technical concept that overlaps with several disjointed research domains, including information systems, economics, marketing, strategy, and technology management (McIntyre & Srinivasan, 2017; Schreieck et al., 2016). Naturally, each of these domains introduces its foci and lenses when studying various problems and effects for varying settings (Hein et al., 2020). This knowledge, however, has yet to be combined into a comprehensive mapping, making it difficult to understand the interrelationships between the main concepts of digital platform ecosystems through causal links. This represents a loss of potential to integrate several isolated fragments of digital platform ecosystems research into a cohesive and comprehensive nomological network of established empirical evidence. The resulting interrelated nomological network of digital platform ecosystem research provides an essential basis for this dissertation and will guide future theory development.

Second, due to digital platform ecosystems' efficient capability to leverage the innovative potential of many complementors beyond the focal enterprise, they have emerged and succeeded as the predominant model for designing, organizing, and promoting digital innovation (Jacobides et al., 2018). In the past decade, platform-based technology enabled both the accommodation of the increased demand and the expansion of service offerings (Parker & Van Alstyne, 2018), while digital platform owners have learned to leverage their ecosystem (Foerderer, 2020). The allocation of tasks within digital platform ecosystems has been a significant subject of investigation in previous research. Surprisingly, there has been limited discussion concerning the ways in which socio-technical aspects of the technical platform and its ecosystem can be harnessed and integrated to effectively cultivate digital platform ecosystems (Wang, 2021). This dissertation seeks to surpass the conventional focus of Information Systems (IS) studies, which assess the strength of the "sword" (referring to the IS system), by delving into how the "sword" (in this context, the technical platform and ecosystem) can be effectively employed to construct successful digital platform ecosystems (Floetgen, Strauss, et al., 2021). The findings of this research gap shed light on the third research gap, which centers on the emergence of attributes resulting from these efforts.

Third, digital platform ecosystem researchers have often examined what relationships and interactions among which actors in digital platform ecosystems interact without considering any resulting attribute as an outcome of the integrated efforts of autonomous actors (Wang, 2021). For example, many studies have examined the interactions between a platform owner and the different participants in the platform ecosystem (Riasanow, Jäntgen, et al., 2020) or emphasized firm-level outcomes such as sales or profitability (Floetgen, Novotny, et al., 2021). However, only a few papers in information systems and organizational science literature on ecosystems include attributes of the ecosystems in the analysis, and even fewer treated the ecosystem attributes as outcomes (Wang, 2021). By examining attributes of successful digital platform ecosystems, we can directly address the part-whole mismatch (Wang, 2021) while lowering the likelihood of studies possibly advocating for a "winner-takes-all" mentality instead of balanced approaches. A similar lack of attention for emergent attributes has been criticized in other areas, such as collective system usage (Burton-Jones & Gallivan, 2007; Nan, 2011), representing an overall need to conduct further multi-level research within the information systems discipline.

1.2 Research Questions

This dissertation shifts the focus from finding what autonomous actors and interactions in digital platform ecosystems explain the success (Riasanow, 2020) to seeking explanations for how and why digital platform ecosystems can be successful. In this dissertation, we address three research questions using the hourglass model of reporting research findings. This model is employed to enhance coherence and concentration throughout the dissertation (Bem, 2003).

RQ1: *What does the literature contribute to our understanding of digital platform ecosystems by connecting the different digital platform ecosystem research streams?*

This research question entails an extensive review of the literature (Okoli, 2015) on the various theoretical concepts of digital platform ecosystems with a focus on surveying the dependent and independent variables of existing research fields, for example, but not limited to, IS (e.g., governance mechanisms and boundary resources), economics (e.g., network externalities and competition), marketing (e.g., electronic word of mouth), strategy (e.g., multi-homing), technology management (e.g., technology leadership or transitions). The extracted variables are then aggregated into recurring boundary constructs on different levels of analysis, and the causal links between them are summarized within nomological networks of digital platform ecosystem research and digital platform ecosystem performance. Thus, the results of the first research question lay the foundation for the subsequent research questions by providing a deep understanding of the theoretical concepts of digital platform ecosystem research and future research opportunities.

RQ2: *How can the socio-technical combination of the technical platform and its ecosystem be leveraged to build digital platform ecosystems?*

With the second research question, we empirically analyze announcements or partner-related documents (but not limited to) of digital platforms regarding (1) actions taken to leverage their platform-based nature and the ecosystem, (2) the financial regulatory reporting ecosystem, and (3) business-to-business app stores. We build on case surveys (Larsson, 1993) by applying the Eklund and Kapoor (2019) approach, case studies (Yin, 2014), taxonomy development (Nickerson et al., 2017), and qualitative methods (Lincoln et al., 2005) such as semi-structured interviews (Fontana & Frey, 1994). These methods allow us to compile individual case reviews (Yin, 2014) and spot cross-case patterns without sacrificing scientific rigor (Larsson, 1993). We focus on the application areas: mobility and financial platforms in the context of the COVID-19 pandemic, emerging regulatory reporting frameworks within the banking industry, and business-to-business app stores in the software industry.

RQ3: *Which attributes as outcomes of digital platform ecosystems arise by integrating the socio-technical efforts of autonomous actors?*

As existing theories for broader socio-technical attributes as outcomes of the integrated efforts of autonomous actors neither cover the degree of detail, nor the context of platform ecosystems, new definitions for attributes as outcomes of platform ecosystems become necessary. We use the data gathered in response to the second research question and the insights from research question one about the different theoretical digital platform ecosystem lenses to draw inferences from a substantial collection of varied qualitative data. This dissertation employs a systematic inductive methodology for data analysis, wherein a process of iterative comparison between the collected data and the evolving theoretical concepts forms the foundation of the research (Corbin & Strauss, 2008; Locke, 2003; Miles et al., 2019).

In sum, we connect the isolated theory of digital platform ecosystems and develop an empirical understanding of how digital platforms leverage socio-technical characteristics of their platform-based nature and the ecosystem. Based on this, we combine the insights from the first two research questions towards novel digital platform ecosystem attributes as outcomes of the integrated efforts of autonomous actors in digital platform ecosystems.

1.3 Structure

This publication-based dissertation is divided into three parts A, B, and C (see Figure 1). Part A begins with the overall motivation of the research problem, followed by the introduction of the three research questions and an explanation of the structure of this dissertation (see Part A: Chapter 1). Next, we introduce the theoretical concepts of digital platforms and explain the fundamentals of digital platform ecosystems (including business ecosystems, innovation ecosystems, service ecosystems, platform ecosystems, and an integrative perspective on digital platform ecosystems), and provide a summary of the literature of the governance of digital platform ecosystems (see part A: Chapter 2). We finish Part A with the presentation of our research design comprised of the research paradigm and the applied research methodologies (see Part A: Chapter 3).

Part B contains the information on our six primary published and peer-reviewed publications (P) related to the three research questions. Some publications provide results across different research questions: The publication P6 provides results for RQ1 and RQ3, while publications P2, P3, and P5 contribute to the results of RQ2 and RQ3. Concerning the first research question, the publications P1 and P6 review and connect isolated digital platform ecosystems research streams and derive a research agenda (see part B: Chapter 1 and 6). The publications P2, P3, P4, and P5, analyze and explore the utilization of the socio-technical efforts of various autonomous actors in digital platform ecosystems across multiple empirical investigations (see part B: Chapter 2, 3, 4, and 5). Regarding the third research question, P2, P3, P5, and P6 contribute with attributes as an outcome of the integrated socio-technical efforts of autonomous actors in digital platform ecosystems (see part B: Chapter 2, 3, 5, and 6).

In part C, we provide an overview of the findings from the six embedded papers (see part C: Chapter 1). Additionally, we discuss the articles' results (see part C: Chapter 2), point out theoretical and practical implications (see part C: Chapter 3), draw attention to the dissertation's limitations (see part C: Chapter 4), outline potential directions for further research (see part C: Chapter 5), and end with a conclusion of this dissertation (see part C: Chapter 6).

In the following paragraphs, we give an overview of the publications embedded in this dissertation (Table 1) and an overview of additional publications (Table 2). Moreover, we summarize the theoretical and practical problem, the research method, and the contributions of the six publications embedded in part B.

Figure 1. Structure of the Dissertation

(Publications with an asterisk (*) provide results on multiple research questions)

Part A — **Introduction, conceptual background, research approach**

Part B — **Connecting digital platform ecosystem research streams**

RQ1: What does the literature contribute to our understanding of digital platform ecosystems by connecting the different digital platform ecosystems research streams?

P1: Connecting the Dots of Digital Platform Ecosystem Research: Constructs, Causal Links and Future Research

Method: Systematic literature review, nomological network development

P6*: Digital Platform Ecosystem Performance: Antecedents and Interrelations

Method: Systematic literature review, nomological network development

Analysis of the socio-technical efforts of autonomous actors to build digital platform ecosystems

RQ2: How can the socio-technical combination of the technical platform and its ecosystem be leveraged to build digital platform ecosystems?

P2*: Introducing platform ecosystem resilience: leveraging mobility platforms and their ecosystems for the new normal during COVID-19

Method: Case survey

P3*: Platform Ecosystem Structures: Leveraging Platform-based Technology and the Finance Ecosystem for the New Normal

Method: Case survey

P4: Implications of Emerging Financial Regulatory Reporting Frameworks for Digital Platforms Boundary Resource

Method: structured content analysis / inductive category development, e^3-value method, expert interviews

P5*: B2B App Store Governance in Software Platform Ecosystems: Dimensions and Types

Method: Multiple case study, taxonomy development

Attributes as outcomes of the integrated efforts of autonomous actors in digital platform ecosystems

RQ3: Which attributes as outcomes of digital platform ecosystems arise by integrating the socio-technical efforts of autonomous actors?

P2*: Introducing platform ecosystem resilience: leveraging mobility platforms and their ecosystems for the new normal during COVID-19

Method: Systematic inductive approach to data analysis, theorizing

P3*: Platform Ecosystem Structures: Leveraging Platform-based Technology and the Finance Ecosystem for the New Normal

Method: Systematic inductive approach to data analysis, theorizing

P5*: B2B App Store Governance in Software Platform Ecosystems: Dimensions and Types

Method: Qualitative cluster analysis

P6*: Digital Platform Ecosystem Performance: Antecedents and Interrelations

Method: Inductive theorizing

Part C — **Summary of results, discussion, limitations, implications for theory and practice, future research, and conclusion**

Table 1. Overview of Publications Embedded in this Dissertation

#	Authors	Title	Outlet	Type (Ranking)	RQ
P1	Floetgen, R. J. Novotny, M. Urmetzer, F. Böhm, M.	Connecting the Dots of Digital Platform Ecosystem Research: Constructs, Causal Links and Future Research	ECIS 2021	CON (VHB: B)	RQ1
P2	Floetgen, R. J. Strauss, J. Weking, J. Hein, A. Urmetzer, F. Böhm, M. Krcmar, H.	Introducing platform ecosystem resilience: leveraging mobility platforms and their ecosystems for the new normal during COVID-19	EJIS	JNL (VHB: A)	RQ2, RQ3
P3	Floetgen, R. J. Mitterer, N. Urmetzer, F. Böhm, M	Platform Ecosystem Structures: Leveraging Platform-based Technology and the Finance Ecosystem for the New Normal	PACIS 2021	CON (VHB: C)	RQ2, RQ3
P4	Floetgen, R. J. Gomm, S. Böhm, M. Krcmar, H.	Implications of Emerging Financial Regulatory Reporting Frameworks for Digital Platforms Boundary Resource	AMCIS 2020	CON (VHB: D)	RQ2
P5	Floetgen R. J. Ziegler, U. Weking, J. Hoeffler, M. Riasanow, T. Böhm, M	B2B App Store Governance in Software Platform Ecosystems: Dimensions and Types	HICSS 2022	CON (VHB: C)	RQ2, RQ3
P6	Floetgen, R. J. Novotny, M. Weking, J. Hein, A. Urmetzer, F. Böhm, M. Krcmar, H.	Platform Ecosystem Performance: Antecedents and Interrelations	ACIS 2022	CON (NR)	RQ1, RQ3

Outlet:
ACIS Australasian Conference on Information Systems
AMCIS Americas Conference on Information Systems
ECIS European Conference on Information Systems European
EJIS European Journal of Information Systems
HICSS Hawaii International Conference on System Sciences
PACIS Pacific Asia Conference on Information Systems

Type:
CON: Conference
JNL: Journal
VHB: German Academic Association for Business Research
NR: Not ranked

*All publications are published and peer reviewed.

P1: Connecting the Dots of Digital Platform Ecosystem Research: Constructs, Causal Links and Future Research. The first publication (Floetgen, Novotny, et al., 2021) addresses the expanding yet fragmented research landscape of digital platform ecosystems, which represents an intersection of various academic disciplines, including IS, economics, marketing, strategy, and technology management. While preliminary studies have primarily focused on individual constructs and their isolated interrelationships, there has been a lack of comprehensive synthesis of empirical evidence in this field. However, this body of academic literature constitutes the most comprehensive, rigorous, and dependable collection of evidence in this domain. To fill this gap, the first paper conducts a literature review of 97 empirical studies published in esteemed IS and management journals. It extracts all variables and causal relationships among them, leading to the aggregation of 51 recurrent constructs across seven micro (complement, complementor, owner, platform, user) and macro (ecosystem, market) levels of analysis, along with summarizing their causal links. The article contributes a nomological network of digital platform ecosystem research and concludes by identifying three promising future research avenues: an emergent multi-level perspective, the exploration of complex dynamics, and the study of heterogeneity within digital platform ecosystems.

P2: Introducing Platform Ecosystem Resilience: Leveraging Mobility Platforms and their Ecosystems for the New Normal during COVID-19. In the second publication (Floetgen, Strauss, et al., 2021), the focus lies in examining the enhanced resilience of mobility platforms and their ecosystem actors compared to non-platform competitors. Although contemporary resilience research encompasses organizational resilience, community resilience, and IT resilience, the socio-technical aspects of digital platforms have remained relatively unexplored. This paper adopts a case survey technique and incorporates a diverse set of qualitative evidence derived from 266 actions spanning 171 examined mobility platforms. We contribute the five digital platform ecosystem resilience archetypes (1) diversification, (2) business model adaptation, (3) serving the public good, (4) creating a meta-platform, (5) optimizing service operation of how mobility platforms leverage their ecosystem and platform-based characteristics to become resilient. Further, this paper contributes with a definition of platform ecosystem resilience as "frugally leveraging socio-technical factors of digital platforms and ecosystems to design, deploy, and use situation-specific responses to prepare for, endure, and adapt by capturing new opportunities and engaging in transformative activities to cope with exogenous shocks and become resilient for future disruptions."

P3: Platform Ecosystem Structures: Leveraging Platform-based Technology and the Finance Ecosystem for the New Normal. The third publication (Floetgen, Mitterer, et al., 2021), analyzes the efforts of digital financial platforms to capture new opportunities and engage in transformative activities during the COVID-19 pandemic. We follow a case survey approach and analyze a qualitative data set of 152 actions of 61 different financial platforms. Based on this, we reveal the six archetypes (1) exchange-oriented service expansion, (2) banking core service extension/improvement, (3) taking social responsibility, (4) innovation promotion, (5) e-commerce acceleration, and (6) cyber security advancement of how platforms can use digital technology and their ecosystem to develop platform ecosystem structures. Our assessment of the solution space may help practitioners identify, pick, and schedule appropriate digital platform coping activities to prepare for upcoming difficulties, maintain competitiveness, and offer innovation.

P4: Implications of Emerging Financial Regulatory Reporting Frameworks for Digital Platforms Boundary Resource. The fourth publication (Floetgen et al., 2020), explores a novel holistic and harmonized platform approach for financial regulatory reporting between regulators and banks to decrease the reporting burden on the banking industry. Towards this goal, this paper models and visualizes the platform ecosystem of financial regulatory reporting of significant European banks using the e3-value model based on 34 publicly available documents, i.e., laws, directives, guidelines, other publicly available articles, and studies.

Furthermore, five semi-structured interviews with experts for regulatory reporting of banks were conducted. This work highlights that emerging, comprehensive platform reporting frameworks create a shift of the significant value creation processes within the ecosystem leading to more standardized regulatory reporting solutions across the banking industry. The standardization enables a platform-based approach for regulatory reporting of banks to foster innovation for value-added services by opening the platform to third-party developers. The boundary resources for financial regulatory reporting platforms will need to be jointly developed with the emerging regulatory reporting framework itself as the foundation for the boundary resources and the regulated entities (i.e., banks) as they require the control over their sensitive data. Thereby, this work extends Ghazawneh and Henfridsson (2013) conceptualizations of boundary resources.

P5: B2B App Store Governance in Software Platform Ecosystems: Dimensions and Types. The fifth publication (Floetgen, Ziegler, et al., 2022), reflects on the trend that software vendors continue to implement business-to-business (B2B) app stores as a novel channel to distribute and sell software applications built by their ecosystem. A substantial body of information system (IS) research has addressed the mechanisms that platform owners exert to orchestrate the ecosystem of actors on top of their core-product platform. However, platform ecosystem research provides limited guidance for specific B2B app store governance. Therefore, this publication uses a multiple case study to broaden the understanding of B2B app store governance while examining successful cases of app store implementations in the enterprise software space. The derived insights are used to develop B2B app store governance taxonomies of (1) architecture, (2) control mechanisms, and (3) demand generation to provide an overview of the solution space. Moreover, this study derives the three robust B2B app store governance types: (1) platform play, (2) transaction channel, and (3) community platform by aggregating different taxonomy characteristics. To maintain their competitiveness and offer innovation for their B2B app store, managers may use this article to help them discover and choose governance characteristics.

P6: Digital Platform Ecosystem Performance: Antecedents and Interrelations. The sixth publication (Floetgen, Novotny, et al., 2022), puts forward a gap in the literature about no consensus on the measurement of digital platform ecosystem performance due to disintegrated perspectives for antecedents of digital platform ecosystem performance. The current theoretical evidence within digital platform ecosystem research relies heavily on numerous dependent variables to evaluate the performance of individual actors in isolation, often focusing solely on the economic gains of these individual actors. We fill this void by performing a systematic literature review of empirical research papers to develop an interconnected set of constructs (heterogeneity, competition, engagement, governance, quality, network size, generativity, architecture, cost, and motivation/satisfaction) that can be used to reflect digital platform ecosystem performance and the interrelationship among those constructs. Building on this finding, we argue that digital platform ecosystem performance should be considered an interrelated, socio-technical, and dynamic concept.

In addition to the key publications P1-P6, this dissertation also points to nine publications (see Table 2) that are tangentially related to the three research questions (see chapter 1.2):

Related to RQ1, we provide a structured overview of literature about the co-evolution of business ecosystems in management, organizational science, and information systems literature (Riasanow, Floetgen, et al., 2020).

Related to RQ2, we studied how the industry-leading companies Porsche (Maier-Borst et al., 2022), PricewaterhouseCoopers (Kazmi et al., 2022), ZF (Farr et al., 2022), ARRI (Nguyen et al., 2022), Wacker Chemie (Burckhardt et al., 2022), and the Charité Berlin (Engel et al., 2022) are leveraging digital technologies - primarily digital platforms - to transform their organizations and ecosystems successfully. In addition, we modeled the digital platform ecosystem of the financial industry and identified innovation patterns (Riasanow et al., 2018).

Related to RQ3, we investigated overreaching characteristics of business models of innovative companies in different innovation ecosystems that enabled them to excel in such innovations (Böttcher et al., 2021). Moreover, we illustrate governance characteristics of different ownership structures and the influence of internal factors and the surrounding ecosystem on their governance decisions (Floetgen et al., 2023).

Although publications P7-P16 provide comprehensive insights about integrating the efforts of autonomous actors in digital (platform) ecosystems, publications P1-P6 represent the central results and main building blocks of this publication-based dissertation.

Table 2. Overview of Additional Publications

#	Authors	Title	Outlet	Type (Ranking)
P7	Floetgen, R. J. Winder, P. Field, E. Weking, J. Hein, A. Schreieck, M. Böhm, M. Krcmar, H.	Ownership Structures and Governance Strategies for Digital Platform Ecosystems: An Empirical Study	ECIS* 2023	CON (VHB: B)
P8	Böttcher, T.P. Phi, D.A. Floetgen, R. J. Weking, J. Krcmar, H.	What Makes an Innovative Business Model? Evidence From the 70 Most Innovative Firms	AMCIS* 2021	CON (VHB: D)
P9	Riasanow, T. Flötgen, R. J. Soto Setzke, D. Böhm, M. Krcmar, H.	The generic ecosystem and innovation patterns of the digital transformation in the financial industry	PACIS* 2018	CON (VHB: C)
P10	Riasanow, T. Flötgen, R. J. Greineder, M. Möslein, D. Böhm, M. Krcmar, H	Co-evolution in Business Ecosystems: Findings from Literature	EMISA* 2019	CON (VHB: D)

Table 2. Overview of Additional Publications

P11	Engel, P. Hong, S. L. Mielenz, M. Vrettos, K. Floetgen, R. J. Krcmar, H.	Digitale Transformation an der Charité Berlin – ERIC: Enhanced Recovery after Intensive Care	Book* 2022	Chapter
P12	Farr, A. Oberaigner, L. Stadler, A. Wetzel, J.-P. Floetgen, R. J. Krcmar, H.	Erfolgreiche digitale Transformation von HR bei ZF	Book* 2022	Chapter
P13	Maier-Borst, M. Gassert, P. Adrianowytsch, K. Floetgen, R. J. Krcmar, H.	Hebel und Handlungsfelder für die digitale Transformation in der Automobilindustrie am Beispiel der Porsche AG	Book* 2022	Chapter
P14	Kazmi, A. Kazmi, H. Sri Laxmi Akhani, A. Floetgen, R. J. Krcmar, H.	Digitale Transformation bei PricewaterhouseCoopers anhand der Initiative Your Tomorrow	Book* 2022	Chapter
P15	Burckhardt, F. Mirlach, T. Auer, U. Ziegler, U. Floetgen, R. J. Riasanow, T. Krcmar, H.	Digitale Transformation bei der Wacker Chemie AG	Book* 2022	Chapter
P16	Nguyen, M.-L. Faltermeier, F. Schäffner, M. Möslein, D. Pfister, D. Floetgen, R. J. Krcmar, H.	Digitale Transformation bei ARRI – Das Beispiel der Filmdistribution in der Kinobranche	Book* 2022	Chapter

Outlet:
AMCIS Americas Conference on Information Systems
PACIS Pacific Asia Conference on Information Systems

Type:
CON: Conference
VHB: German Academic Association for Business Research
NR: Not ranked

*All publications are published and peer reviewed.

2 Theoretical Background

The following chapter consolidates findings from several research streams to provide the conceptual background for the primary phenomenon of this dissertation – digital platform ecosystems. It consists of key definitions, characteristics of digital platforms, and related findings from platform ecosystem research. We conclude with an overview of digital platform governance literature, as it contains essential knowledge for managing digital platform ecosystems.

2.1 Digital Platforms

Perspectives on digital platforms stem from a variety of different research fields, including technology management with a technological perspective (Baldwin & Woodard, 2009; Tiwana et al., 2010), economics with a market-based perspective (McIntyre & Srinivasan, 2017; G. G. Parker et al., 2016), and information systems research with a socio-technical perspective (Constantinides et al., 2018; de Reuver et al., 2018).

The technical perspective sees digital platforms as software-based systems. These software-based systems consist of an extensible codebase that provides core functionality and standardized interfaces (Tiwana et al., 2010). The standardized interfaces of software-based systems allow for easily adding, removing, recombining, or replacing modular services (Yoo et al., 2010). Modular services or platform complements are software subsystems that extend the platform's functionality through standardized interfaces (Baldwin & Woodard, 2009). Standardized interfaces, also called boundary resources, can be, for example, APIs or open code (Ghazawneh & Henfridsson, 2013). The design of standardized interfaces defines the platform's openness, as it can exert restrictions on participation, development, or use across different platform members (Parker & Van Alstyne, 2018). New services, like applications, can be introduced by either an ecosystem of loosely tied external complementors or by strategically aligned partners, depending on how open the system is (Ghazawneh & Henfridsson, 2013). The standardization of interfaces and modularity of the architecture simplifies the addition of new modules to a digital platform (Tiwana & Konsynski, 2010), which accelerates the pooling of additional value complementors (Katz & Shapiro, 1985).

Digital platforms are seen from a market-based viewpoint as two-sided markets (Rochet & Tirole, 2003). As two-sided markets bring together several user groups, they facilitate network externalities, implying that the market value rises with the number of its users (Katz & Shapiro, 1985). Digital platforms, in this perspective, represent the intermediary between the group of users trying to facilitate network effects (Thomas et al., 2014). However, this process is not trivial, as prospective platform owners face several challenges and opportunities. One of these challenges is the "chicken-and-egg" problem, describing the need for a platform to have both sides in place to ensure a valid value proposition (Caillaud & Jullien, 2003; Parker & Van Alstyne, 2005). Examples of this are manifold; search engines would not have this high popularity if only a few websites were on the internet (Caillaud & Jullien, 2003). Conversely, network effects can also increase the early advantage of incumbents, as they have the most extensive customer and complementary base at the outset. In specific circumstances, robust network effects have the potential to foster competition among various platforms, resulting in a scenario where a single platform emerges as the ultimate victor, taking the lion's share of the market (Eisenmann et al., 2006).

The socio-technical approach establishes a link between digital platforms and the broader ecosystem they operate within, with particular emphasis on the seamless integration and governance of various actors within that ecosystem (de Reuver et al., 2018). In the realm of information systems, digital platforms play a pivotal role by offering boundary resources, such as app stores, which serve as facilitators for the integration and empowerment of an ecosystem comprising diverse actors. These actors are thereby enabled to collaboratively present complementary products or services to the market (Ghazawneh & Henfridsson, 2013; Karhu et al., 2018). By adding their products or services to the platform, this ecosystem of actors becomes part of the inherent value-creation process of the platform (Adner & Kapoor, 2010; McIntyre & Srinivasan, 2017). In contrast to other perspectives, the output of this process is not designed upfront by a central platform authority (Henfridsson et al., 2014). Standardized interfaces combined with the highly modular architecture allow for recombining and creating value-adding solutions long after the platform's initial launch (Yoo et al., 2010). As such, digital platforms can postpone decisions regarding their value proposition and allow for a late-binding of capabilities from ecosystem actors, characterized by high autonomy (Jacobides et al., 2018; Svahn & Henfridsson, 2012).

In summary, digital platforms refer to a particular type of platform that utilizes digital technologies to facilitate interactions between autonomous agents (Chen et al., 2022, p. 151). Because of its modular design principles, an ecosystem of actors can easily extend the digital platform’s functionality (Baldwin & Woodard, 2009; Gawer & Cusumano, 2014). The actors leverage the platforms’ standardized interfaces and components to create complementary products and services (Tiwana et al., 2010). The standardized interfaces and components design can define who can build additions or what complements can be built (Parker & Van Alstyne, 2018). In this context, digital platforms possess the capability to efficiently coordinate and structure the value-generating endeavors of a complementary ecosystem of actors, all without necessitating explicit contractual agreements or hierarchical structures (Chen et al., 2022). Hence there is a need to assess digital platforms from an ecosystem perspective (Eaton et al., 2015; Foerderer et al., 2018). Table 3 provides an overview of digital platforms’ core concepts and descriptions.

Table 3. Overview of Core Concepts of Digital Platforms

Concept	Description	Reference
Digital Platform	Digital platforms comprise of technical and socio-technical components that together facilitate value creation among different agents. • The technical components refer to an extensible codebase to which complementary applications can be added. • The socio-technical components refer to boundary resources that enable and govern an ecosystem of actors in value-creation on a platform.	Chen et al. (2022); Constantinides et al. (2018); de Reuver et al. (2018); McIntyre and Srinivasan (2017); Tiwana et al. (2010)
Digital Platform Architecture	"A conceptual blueprint that describes how the ecosystem is partitioned into a relatively stable platform and a complementary set of modules that are encouraged to vary, and the design rules binding both."	Constantinides et al. (2018, p. 382); Tiwana et al. (2010, p. 677)
Digital Applications / Complements	Digital Applications (also called modules, add-on software subsystems, or complements) are "executable pieces of software that are offered as applications, services, or systems to end-users" and "add functionality to the platform."	Ghazawneh and Henfridsson (2013); McIntyre and Srinivasan (2017, p. 143); Tiwana et al. (2010, p. 675)
Actors	Actors refer to the agents that interact with each other on a digital platform. Actors evolve over time and take on different roles regarding digital platforms. • *Owner*: "Focal platform actor/organization enabling value co-creation among complementors and users through provision of the technical platform and governance mechanisms." (Floetgen, Novotny, et al., 2021) • *Complementor*: "Suppliers of complementary products and services (complements), including developers and sellers. Single actors or organizations." (Floetgen, Novotny, et al., 2021) • *User*: "Service beneficiaries of platform and complements, sometimes provision of user generated content (complements). Single actors or organizations." (Floetgen, Novotny, et al., 2021)	Adner (2016, p. 44); Gawer (2014, p. 1245); Jacobides et al. (2018); Kapoor (2018); McIntyre and Srinivasan (2017)
Boundary Resources	The interfaces and resources that enable actors to source capabilities, exchange information, develop applications, and coordinate activities. They serve as the foundation for a platform's governance.	Constantinides et al. (2018); de Reuver et al. (2018); Yoo et al. (2010)
Network Externalities	Digital platforms can be subject to direct and indirect network effects. Direct network effects imply that "the value of the platform depends on the number of users in the same user group". Indirect network effects imply that "the value the platform depends on the numbers of users in a different user group."	de Reuver et al. (2018, p. 127); Katz and Shapiro (1985)

Table 3. Overview of Core Concepts of Digital Platforms

Concept	Description	Reference
Modularity	Modularity refers to the degree to which a system can be decomposed into components, the tightness of coupling between the components and the capacity for their recombination. Digital platforms are characterized by a modular architecture allowing the extension of the platform and recombination of complements because of its standardized interfaces.	Baldwin and Woodard (2009); Constantinides et al. (2018); Schilling (2000, p. 312)
Generativity	Generativity refers to a "technology's overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences." A platform's generativity results from the layered modular architecture that allows for platform expansion and evolution after manufacture.	Cennamo and Santaló (2019); Yoo et al. (2010); Zittrain (2009, p. 1980)

2.2 Digital Platform Ecosystem Fundamentals

The term ecosystem refers to interacting entities characterized by mutual interdependence (Jacobides et al., 2018). The term recently increased in popularity in research and management practice to depict competitive environments (Jacobides et al., 2018). Ecosystem research streams include information systems, strategic management, and economics (Jacobides et al., 2018). The most influential concepts are "business ecosystems," "innovation ecosystems," "service ecosystems," and "platform ecosystems." Each concept highlights different aspects of ecosystems that also hold for digital platform ecosystems (Constantinides et al., 2018; Jacobides et al., 2018). The most significant difference between the streams lies in their unit of analysis. "Business ecosystems" focus on a firm and its environment, "innovation ecosystems" concentrate on groups of actors that jointly create new value propositions, "service ecosystems" on the value-creation process itself, and "platform ecosystems" assess how actors organize around platforms (Jacobides et al., 2018; Lusch & Nambisan, 2015). We conclude and summarize related ecosystem definitions in Table 4.

2.2.1 Business Ecosystems

The first research stream sees ecosystems as communities of organizations, institutions, and individuals that impact each other through their activities (Teece, 2007). It provides the broadest scope on ecosystems by focusing on the affiliation of organizations to ecosystems that influence their business success. This concept builds on top of Moore (1993), who advocated that entities co-evolve their capabilities and roles inside business ecosystems and tend to align themselves with the direction set by one another. Participants of business ecosystems work cooperatively to deliver a joint value proposition to customers which exceeds what a single company can offer (Moore, 1993).

However, the relationships between ecosystem participants are not static, span different industries, and are not directly materialized in contracts as they would be within networks and supply chains (Clarysse et al., 2014; Iansiti & Levien, 2004). Instead, business ecosystems are characterized by loose coupling and an alignment structure consisting of shared sets of standards or cognitive schemata (Thomas & Autio, 2020). Hence, they are usually characterized by a dynamic change of participants, shifting roles, and the emergence of new values, which Thomas and Autio (2020) refer to as fluidity. However, Iansiti and Levien (2004, p. 8) stress that participants “depend on each other for their mutual effectiveness and survival,” which ties the performance of individual members to the overall performance of the ecosystem and vice versa. Thus, ecosystem members must monitor and react to their environment and build dynamic capabilities to gain a sustainable competitive advantage (Teece, 2007).

Literature on business ecosystem strategy points to keystone organizations that try to assure the success of the business ecosystem. According to Dhanaraj and Parkhe (2006), they do so by managing knowledge mobility, innovation appropriability, and ensuring ecosystem stability. However, due to the broad lens of business ecosystems, validating these mechanisms remains open (Jacobides et al., 2018). On the contrary, Jacobides et al. (2018) and Helfat and Raubitschek (2018) contend that innovation capabilities, environmental scanning and sensing capabilities, and integrative capabilities at the firm level are of paramount importance when it comes to harnessing the potential of business ecosystems.

2.2.2 Innovation Ecosystems

Research on innovation ecosystems focuses on the focal value proposition resulting from an ecosystem’s activities (Adner, 2016). As such, Adner (2016, p. 42) describes ecosystems as “the alignment structure of the multilateral set of partners that need to interact for a focal value proposition to materialize.” Innovation ecosystems thus include various actors that jointly create, deliver, and appropriate value; however, together create a focal value proposition for an end-user (Adner, 2016; Nambisan & Sawhney, 2011). From the viewpoint of a focal firm, the value proposition is made up of one’s offering, and contributions of others, also called complements (Adner & Kapoor, 2010). As such, end customers first decide which offerings of innovation ecosystems fulfill their value expectations and how they must be combined. This “full package,” the focal value proposition, exceeds what a single firm could achieve on its own (Adner, 2006). Actors within innovation ecosystems are thus dependent on each other but are not necessarily hierarchically linked (Jacobides et al., 2018). Instead, they rely on an alignment structure to unite actors’ activities and ensure that the ecosystem’s output remains viable (Adner, 2016).

As posited by Adner (2016) in the "ecosystem-as-structure" concept, innovation ecosystems consist of four fundamental structural elements: activities, actors, positions, and links. Activities pertain to the specific actions required to actualize the focal value proposition (Adner, 2016). Actors encompass the entities responsible for performing these activities, including actors that the focal firm may not have direct control over (Adner, 2016). Positions denote the roles assumed by actors during the value creation process and determine the structure of value transfers between them (Adner, 2016). Links define the contents exchanged among actors, encompassing resources, capabilities, funds, and other relevant factors (Adner, 2016). Particularly, positions and links play a vital role in ensuring the success of the collaborative value creation process by providing the alignment structure (Adner, 2016).

Positions and links result from relationships between the actors' activities in creating the central value proposition (Adner, 2016). Relationships between a focal firm’s activities and its complements can be present on an economic and system-level (Kapoor, 2018). Kapoor (2018) refers to these relationships as complementarities and interdependencies. Complementarities describe the economic relationship of one offering to another. As such, offering A might only be valuable when combined with offering B, or more of B could increase A's value (Kapoor, 2018). Interdependencies refer to relationships between actors resulting from the links between their offerings required to create value. For example, offering A, B, and C could provide users with value independently; however, C could require A and B to be created. As such, the actors producing A, B, and C are complementors in the first case, and in the other case, the producers of A and B are suppliers to producer C (Kapoor, 2018). Kapoor (2018) stresses architectures as another structural element of innovation ecosystems to coordinate the different relationships. Architectures refer to the underlying sociological, technological, and organizational foundations that embed the actors' activities, positions, and links within a materialized construct, allowing an ecosystem leader to govern the value creation process (Kapoor, 2018).

Research on innovation ecosystems strategy adopts the perspective of a focal actor, distinguishing between ecosystems leaders and complementors (Adner, 2016; Adner & Kapoor, 2010). Most of the literature in this regard deals with strategies for ecosystem leaders. The focus here is on the ecosystem leader's ability to align and orchestrate the ecosystem's activities to be successful (Adner & Kapoor, 2010; Nambisan & Sawhney, 2011; Williamson & De Meyer, 2012). Ecosystem leaders can do so by creating, altering, or renewing the architecture of the innovation ecosystem (Nambisan & Sawhney, 2011). Options include defining the modularity of the ecosystem (Nambisan & Sawhney, 2011), facilitating transparency within the ecosystem (Alexy et al., 2013), searching for additional complementors to include in the ecosystem (Williamson & De Meyer, 2012), or create platforms to manage the actor's interdependencies (Kapoor, 2018).

2.2.3 Service Ecosystems

Research on service ecosystems focuses on the value creation process (Vargo & Lusch, 2011). Here, service ecosystems are actor-to-actor networks that exchange and integrate resources and capabilities through services to create value (Vargo & Lusch, 2011). One of the particular elements of service ecosystems is that customers are co-creators of value as they adapt offerings to their needs and provide feedback (Vargo & Lusch, 2015). Often customers use their knowledge of the combinatorial value of services to create new services and thus change their role to a primary service provider (Vargo, 2008). Like business ecosystems, service ecosystems are characterized by dynamism and fluidity as actors gain more access to resources and capabilities, thus changing their activities and roles (Vargo & Lusch, 2011). Hence, actors within service ecosystems must sense and act on their environment to ensure the ecosystem's success (Lusch & Nambisan, 2015; Teece, 2007).

Lusch and Nambisan (2015) propose that service ecosystems necessitate possessing structural flexibility and integrity, a shared worldview, and an architecture of participation. Structural flexibility refers to the ability of individual ecosystem participants to adapt to changing external influences or internal competition to exploit new service innovation opportunities in changing constellations (Lusch & Nambisan, 2015). Lusch and Nambisan (2015) point to knowledge sharing between actors to increase transparency and support fellow actors to adapt. In the context of service ecosystems, structural integrity denotes the robustness and strength of connections and relationships among the various actors involved (Lusch & Nambisan, 2015). Strong ties, for example, ease knowledge sharing between actors. However, strong ties might simultaneously restrict structural flexibility because they reduce an actor's adaptive capacities (Uzzi, 1996). Because of this tension field, a shared worldview between actors is beneficial, as it helps ecosystem actors to overcome information gaps without the need for contractual binding (Lusch & Nambisan, 2015). Boland and Tenkasi (1995) show how IT-based communication channels can facilitate shared worldviews between actors. Lastly, service ecosystems require an architecture for participation that orchestrates the service exchange. This architecture has to fulfill two properties; create transparency about the exchange rules and implement mechanisms to share value among actors (Lusch & Nambisan, 2015).

Institutions, technology, and language provide the foundations for these organizational structures and principles (Vargo & Lusch, 2011). Vargo and Akaka (2012) refer to institutions as social norms and standards that actors draw on to create value for themselves and others. These include, for example, monetary systems, laws, or cultural habits (Vargo & Lusch, 2015). For the technological dimensions, Lusch and Nambisan (2015) point to service platforms that facilitate actors' interactions and resource exchanges on a modular IT-enabled architecture (Yoo et al., 2010). These IT-enabled platforms fulfill the two properties mentioned for an architecture of participation. They allow actors to easily share information and create standard rules for interaction and value exchange (Hein et al., 2019). As such, service ecosystems are defined as "self-adjusting systems of mostly loosely coupled social and economic (resource-integrating) actors connected by shared institutional logics and mutual value creation through service exchange" (Lusch & Nambisan, 2015, p. 161).

2.2.4 Platform Ecosystems

The fourth research stream reflects how closely platforms are related to ecosystems (see Thomas et al., 2014). Platforms serve as the architecture that exerts governance rules and mechanisms over a group of actors to orchestrate their activities and facilitate value creation (Constantinides et al., 2018; G. G. Parker et al., 2016). Next to the platform owner, the ecosystem includes complementors who contribute to the platform's value by extending its functionality and offerings (Jacobides et al., 2018). From an ecosystem perspective, the actors leverage the affordances offered by a platform to align their interdependences and create viable offerings (Jacobides et al., 2018). This ecosystem leverage is enabled by platforms' capacity to provide standards and rules, help transactions between dispersed actors, and facilitate recombinant innovation through modularity (Ceccagnoli et al., 2012; McIntyre & Srinivasan, 2017; Thomas et al., 2014). In turn, the influence of a platform's architecture on its ecosystem's activities and behavior plays a central role in this research stream (McIntyre & Srinivasan, 2017; Tiwana, 2013; Wareham et al., 2014).

Thomas et al. (2014) describe how platform ecosystem actors use three different architecture-related affordances of platforms to create appropriate value through production, innovation, and transaction leverage. Production leverage refers to using stable assets and resources provided by platforms' interfaces and standards that reduce the time needed to create new offerings and enable the specialization of ecosystem actors (Boudreau, 2010; Thomas et al., 2014). Platforms enable this mechanism by providing boundary resources, for example, APIs (Ghazawneh & Henfridsson, 2013). Innovation leverage refers to the openness of those boundary resources, enabling an ecosystem of actors to source additional capabilities, use shared assets, and create new offerings (Boudreau, 2010; Parker & Van Alstyne, 2018). Lastly, transaction leverage refers to the ability of platforms to develop multi-sided markets and help ecosystem players receive a share of the value creation for their contributions (Ceccagnoli et al., 2012).

2.2.5 The Integrative Perspective on Digital Platform Ecosystems

Based on an integrative perspective, digital platform ecosystems incorporate characteristics of business, innovation, service, and platform ecosystems (de Reuver et al., 2018). They rely heavily on autonomous agents contributing to the platform's value creation process; hence, they are characterized by actors' socio-technical interdependence (Teece, 2018). On the one hand, the stability of software-based platforms and their boundary resources allows the ecosystem of actors to easily develop and integrate services without extensive knowledge of platform architecture. On the other hand, the configuration of boundary resources allows the platform owners to control the platform's ecosystem (Parker & Van Alstyne, 2018; Tiwana et al., 2010). Utilizing boundary resources, digital platform owners can access the innovation capabilities outside of their organizational boundaries and improve the focal value proposition of the platform (Yoo et al., 2010). As such, the economic value of the digital platform ecosystem exceeds what the platform owner could achieve on its own (Parker & Van Alstyne, 2018). However, ecosystem actors find themselves in an environment characterized by co-opetition (Adner & Kapoor, 2010). The success of a digital platform ecosystem does thus reside in the platform governance, trying to balance the different interests of ecosystem actors and channel the activities of those autonomous actors in a way that the overall value of the platform rises (Parker & Van Alstyne, 2018; Wareham et al., 2014).

Table 4. Overview of Definitions of Ecosystems

Concept	Definitions	Reference
Business Ecosystem	"In a business ecosystem, companies coevolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations."	Moore (1993, p. 76)
	"The community of organizations, institutions, and individuals that impact the enterprise and the enterprise's customers and supplies."	Teece (2007, p. 1325)
Innovation Ecosystem	"The collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution."	Adner (2006, p. 2)
	"The alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize."	Adner (2016, p. 42)
Service Ecosystem	"a relatively self-contained, self-adjusting system of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange."	Lusch and Nambisan (2015, p. 162); Vargo and Lusch (2015, p. 11)

Table 4. Overview of Definitions of Ecosystems

Concept	Definitions	Reference
Platform Ecosystem	"The collection of the platform and the modules specific to it"	Tiwana et al. (2010, p. 676)
	"The platform and its network of complementors that produce complements to enhance platform value."	McIntyre and Srinivasan (2017, p. 143)
	"The platform's sponsor plus all providers of complements that make the platform more valuable to consumers."	Jacobides et al. (2018, p. 2257)
Digital Platform Ecosystem	Technical view: "A collection of complements (apps) to the core technical platform, mostly supplied by third-party." Organizational view: "Collection of firms interacting with a contribution to the complements."	de Reuver et al. (2018, p. 127)
	"A digital platform ecosystem comprises a platform owner that implements governance mechanisms to facilitate value creating mechanisms on a digital platform between the platform owner and an ecosystem of autonomous complementors and consumers."	Hein et al. (2020, p. 90)

2.3 Governing Digital Platform Ecosystems

Platform governance describes strategies developed and executed by platform owners to orchestrate the value creation process (Chen et al., 2022). Platform governance revolves around design decisions, overarching rules and values, constraints, and inducements that platform owners use to orchestrate the value creation process on their platform (Boudreau, 2010; Constantinides et al., 2018). The ownership of the digital platform, including its central resources, enables the enforcement of the respective platform ecosystem strategy (Kretschmer et al., 2020).

Platform governance and design determines what value-creating activities are enabled on the platform, who can contribute to or perform those activities, how the platform enables or controls contribution, and how platform owners capture a share of the value co-created with complementors (Hagiu & Wright, 2019; Wareham et al., 2014). The critical challenge for platform governance is to find the balance between controlling ecosystem participants and providing incentives to contribute to the value creation process (Chen et al., 2022; Hagiu & Wright, 2019). To achieve this, platform owners use governance mechanisms, ranging from designing standardized interfaces in a certain way to protect against platform exploitation (Karhu et al., 2018) to hosting a developer conference (Foerderer, 2020).

To control the digital platform's ecosystem, platform owners can implement measures and design features that control the access, output, behavior, and external relationship of complementors (Chen et al., 2022). Table 5 provides an overview of those measures. Access control entails the implementation of measurements and design elements that establish the criteria for determining which individuals or entities are granted entry into the digital platform, as well as access to its digital interfaces and boundary resources (Ghazawneh & Henfridsson, 2013). Platform owners use access control to enforce complementors' adaption and contain opportunistic behavior (Boudreau, 2010). As an illustration, platform owners have the option to establish screening mechanisms, which may involve application or selection processes, aimed at identifying actors who meet the platform's standards and can actively contribute to its ecosystem (Song et al., 2018; Tiwana, 2015). Platform owners can also restrict the usage of a platform's boundary resources by design, such as prohibiting APIs' access to prevent competitors' exploitation (Gawer, 2021).

Output control describes measures and design features that evaluate and monitor complementors' outputs and outcomes (Chen et al., 2022). Critical to the platform's success is that complementors develop desirable offerings that customers value (Zhu & Iansiti, 2012). Digital platform owners try to ensure this by implementing output control measures that allow them to easily access the quality of platform contributions (Chen et al., 2022). Feedback systems have proven effective in this respect (Bolton et al., 2013). Customers can share their personal experiences or opinions on complementors' outputs using feedback systems integrated into app stores (Qiu et al., 2017). Based on the feedback, platform owners exclude low-quality or fraudulent complementors and promote high-quality complements. At the same time, poorly rated complementors are encouraged to improve their offerings, as they fear the consequences of slow-selling or platform exclusion (J. Huang et al., 2018).

Behavioral control defines what kind of interactions are allowed on the platform and helps platform owners prevent misconduct by complementors. While delegating more decision rights to complementors might persuade them to join the platform, it also increases the risk of them not behaving in a way anticipated or desired by the platform owner (O'Mahony & Karp, 2020). If given unsupervised freedom, complementors might execute platform strategies that negatively influence the platform's value creation and decrease platform attractiveness for others (Chen et al., 2020; Wareham et al., 2014). Platform owners use behavioral control to protect against unforeseen contingencies, opportunism, or exploitation. One option is to implement antimanipulation mechanisms, for example, by analyzing reviews for their truthfulness and penalizing attempts to gain an illicit advantage (Siering et al., 2016). Another option is to redesign the technical features of the platform interfaces to prevent complementors from bypassing the platform and interacting directly with users (Zhu & Iansiti, 2019).

External relationship control pertains to the degree of autonomy bestowed by digital platform owners upon complementors when it comes to their interactions with other platforms (Chen et al., 2022). Since platforms often compete with each other, platform owners want to tie complementors exclusively to their platform, as they can be the critical competitive advantage over rivals (Cennamo, 2021; Kretschmer et al., 2020). Complementors might find multi-homing more attractive as it allows them to access more customers and increase their bargaining power over platform owners (Koh & Fichman, 2014). One strategy is to alter the compatibility with competing platforms to increase the cost of multi-homing (Karhu et al., 2018); however, this can also lead to the own platform becoming unattractive to potential complementors (L. Chen, Yi, Li, & Tong, 2020. Another strategy is establishing exclusive partnerships with complementors (Rochet & Tirole, 2003). However, complementors often demand guarantees limiting the owner's scope of action on the platform (Cennamo & Santalo, 2013; Zhu & Liu, 2018).

While it might be necessary to limit platform contribution on the one hand side, platform governance should also include measures and design features to increase the platform's attractiveness for complementors. As the number of complementors increases, the platform benefits from network effects and gains access to more skills and resources, leading to more technical innovations and new offerings for customers (Boudreau, 2010; Cennamo, 2016; West, 2003). To incentivize contributions to their platform ecosystem, platform owners can drawback on several governance mechanisms, which can be structured into the following four themes: sharing of resources, provision of information, conferring autonomy, and giving rewards (Chen et al., 2022).

One way to fuel value creation on a platform is to share resources with complementors, making it easier and worthwhile to contribute to the platform or support them in creating new value offerings on the platform (Parker & Van Alstyne, 2018; von Hippel & Katz, 2002). Sharing of resources can be realized by platforms boundary resources, for example, through the provision of APIs, SDKs, code libraries, reference designs, technical specifications, or even curated development environments (Ghazawneh & Henfridsson, 2013). Several studies show that sharing resources contributes significantly to a platform's value creation as it incites the engagement of complementors and enhances the throughput and quality of additions (Kankanhalli et al., 2015; G. Parker et al., 2016; Ye & Kankanhalli, 2018). As such, well-designed boundary resources can become a competitive advantage of digital platforms if they reduce the coordination costs when interacting with the platform (Tiwana, 2015) or stimulate further platform-specific investments of complementors (Wulf & Blohm, 2020).

Digital platform owners can also provide information to complementors to evoke desired behavior or draw them into joining the platform. Without sufficient information, complementors may underestimate the potential of a platform and be discouraged from investing in it (Dattée et al., 2018). To address this information gap, platform owners can provide knowledge about interfaces or customers that show the platform's potential for complementors (Chen et al., 2022). One measure is establishing conferences, workshops, or online communities to facilitate knowledge-sharing and relationship-building between a platform sponsor, complementors, and customers (Foerderer, 2020; P. Huang et al., 2018). While this might come with coordination costs, the measures can simultaneously help channel complementors' efforts to areas that offer synergy potential or solve customer problems that platform owners currently do not want to address (Huber et al., 2017). As such, providing the information is also an effective tool to foster entrepreneurial interest and activities in a digital platform's ecosystem (Eckhardt et al., 2018).

Moreover, the adoption of and contribution to a platform depends on the autonomy that platform owners grant complementors in carrying out value-adding activities on the platform (Parker & Van Alstyne, 2018). Decision-making rights allow complementors to develop new offerings, set prices, and receive a fair share of the revenue (Hagiu & Wright, 2019). As such, handing-over decision rights encourage complementors to join the platform, add local knowledge, or own intellectual property (Boudreau, 2010; Chen et al., 2020). While opening up one's platform can result in more innovation (Ye & Kankanhalli, 2018), it may also raise platform complexity and make it more difficult for actors to capture value (Karhu et al., 2018). Another way to confer autonomy is to ensure the platform's modularity, as it reduces the complementor's investment in understanding how other components work (Saadatmand et al., 2019). Instead, the standards resulting from the modular design ensure interoperability of complements and recombination of value at the customer's side, facilitating economies of scale and scope for complementors (Shapiro & Varian, 1998; Tiwana, 2013).

Another way of incentivizing complementors to join the platform and contribute to its value-creation process is to give rewards (Chen et al., 2022). The prerequisite for motivating complementors to join the platform is that they believe their investments will be profitable (Nambisan & Sawhney, 2011). To ensure this, platform owners set up intellectual property protection mechanisms, revenue-sharing arrangements, promotional programs, or even free entry programs (Miric et al., 2019; Rietveld et al., 2019). Often these mechanisms are implemented into the platform by design and do not include contractual agreements, as the value of contributions of complementors cannot be specified upfront (Foerderer, 2020). In addition, platform owners often award promotional rewards to provide a continuous incentive. One option is implementing platform features such as recommendation, certification, endorsement, or features, which can help selected complementors attract more customers or increase sales (Rietveld et al., 2019).

Table 5. Digital Platforms Governance Mechanisms following Chen et al. (2022)

Governance Mechanism	Description	Measure	Exemplary Literature
		Control	
Access Control	Defining who can use the platform in which way to contain opportunistic behavior	• Screening mechanisms • Restriction of boundary resource usage	• Tiwana (2015) • Gawer (2021)
Output Control	Evaluating complementors outputs to ensure customer satisfaction and regulate competition with the platform owner	• Feedback systems	• Bolton et al. (2013)
Behavioral Control	Defining which interactions are allowed to protect against platform exploitation	• Antimanipulation mechanisms	• Siering et al. (2016)
External Relationship Control	Defining how much complementors are allowed to engage with other platforms	• Exclusive partnerships • Compatibility reduction	• Rochet and Tirole (2003) • Karhu et al. (2018)

Table 5. Digital Platforms Governance Mechanisms following Chen et al. (2022)

Governance Mechanism	Description	Measure	Exemplary Literature
Incentive			
Resource Sharing	Sharing of resources through boundary resources to support complementors at creating new valuable offerings	• APIs, SDKs, reference designs, curated development environments	• Ghazawneh and Henfridsson (2013); Ye and Kankanhalli (2018)
Provision of Information	Providing information to reduce complementor's uncertainty regarding value appropriation	• Conferences • Online communities	• Foerderer (2020) • P. Huang et al. (2018)
Conferring Autonomy	Increasing the autonomy of complementors to allow them more freedom in creating value	• Decision rights • Platform openness • Modularity	• Hagiu and Wright (2019) • Boudreau (2010) • Saadatmand et al. (2019)
Giving Rewards	Providing rewards to ensure that contributions of complementors are profitable	• Revenue sharing • Recommendation	• Miric et al. (2019) • Rietveld et al. (2019)

3 Research Strategy and Methodological Approach

To investigate the integration of the efforts of autonomous actors in digital platform ecosystems, we rely on a mixed-method qualitative research strategy. “To ensure a strong research design, researchers must choose a research paradigm that is congruent with their beliefs about the nature of reality” (Mills et al., 2016, p. 2). This dissertation chooses the constructionist research paradigm and includes aspects of critical ontological realism with epistemological subjectivism (Levers, 2013), where the interpreter and the interpreted interact to generate meaning (Crotty, 1998). Table 6 explains the conceptual terms of ontology, epistemology, and a research paradigm for clarification.

Table 6. Conceptual Terms of Ontology, Epistemology, and Research Paradigm

Concept	Definitions	References
Ontology	“The study of being” and “raises basic questions about the nature of reality and the nature of the human being in the world”	Crotty (1998); Denzin and Lincoln (2005, p. 183)
Epistemology	Study of knowledge or “a way of understanding and explaining how I know what I know”	Crotty (1998, p. 3); Levers (2013)
Research Paradigm	“[…] a system of ideas, or world view, used by a community of researchers to generate knowledge. It is a set of assumptions, research strategies, and criteria for shared rigor, even taken for granted by that community.”	Fossey et al. (2002, p. 718)

Therefore, we – as we identify ourselves as critical realists - maintain the ontological perspective of identifying phenomena and developing consensus on describing the whole from glimpses or incomplete fragments (Bergin et al., 2010). From an epistemology point of view, subjectivism is the belief that knowledge is “always filtered through the lenses of language, gender, social class, race, and ethnicity” (Denzin & Lincoln, 2005, p. 21).

3.1 Research Methods

Following a constructionist paradigm with a mixed-method qualitative research strategy, Table 7 displays the main methods of this dissertation, namely, case surveys (**P2**, **P3**), case studies with taxonomy development (**P5**), the e3-value way (**P4**), and literature reviews (**P1**, **P6**). The context for each strategy is discussed more below. Furthermore, each article includes a full discussion of how the methodologies were leveraged.

Table 7. Research Methods of the Publications

#	Title	Lit. Rev.	Case Survey	Case Study	Tax. Dev.	e^3-value Method
P1	Connecting the Dots of Digital Platform Ecosystem Research: Constructs, Causal Links and Future Research	●				
P2	Introducing platform ecosystem resilience: leveraging mobility platforms and their ecosystems for the new normal during COVID-19	○	●			
P3	Platform Ecosystem Structures: Leveraging Platform-based Technology and the Finance Ecosystem for the New Normal	○	●			
P4	Implications of Emerging Financial Regulatory Reporting Frameworks for Digital Platforms Boundary Resource	○		○		●
P5	B2B App Store Governance in Software Platform Ecosystems: Dimensions and Types	○		●	●	
P6	P6: Platform Ecosystem Performance: Antecedents and Interrelations	●				

Legend:

● Primary method used in the publication — Lit. Rev.: Literature Review
○ Secondary method used in the publication — Tax. Dev.: Taxonomy Development

3.1.1 Structured Literature Review

Conducting literature reviews is critical for expanding knowledge and understanding the breadth of research on a specific topic. We follow Okoli (2015) and use the definition of Fink (2005, p. 3) for our operative definition of a systematic literature review: "A systematic, explicit, [comprehensive], and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners." In particular, we leveraged literature reviews to summarize the empirical evidence of digital platform ecosystem research, to develop novel theoretical insights (e.g., novel insights into platform ecosystem performance), and to provide a conceptual foundation for our subsequent study (**P1, P6**). Our reviews of digital platform ecosystems follow established guidelines of the IS research community and adapt elements from systematic (Okoli & Schabram, 2010) and integrative (Webster & Watson, 2002) literature review methods. We aligned our literature review process with the four stages, planning, selection, extraction, and execution, proposed by Okoli and Schabram (2010).

Setting our publications **P1** and **P6** in the context of existing frameworks for review and theory development papers, our approach has evolved from a solely organizing and descriptive to a broad theorizing / theoretical review (Leidner, 2018; Paré et al., 2015), describing and synthesizing prior work to develop a new theory. We follow in the footsteps of previous foundational theoretical reviews of the information system community (Clark et al., 2007;

William & Ephraim, 2014). While we included only studies grounded in empirical data, we merged insights from both process and variance theories for a more holistic understanding of digital platform ecosystems. Thus, we contribute to the frequent calls for advanced theory development within the information systems community (Burton-Jones et al., 2021; Rowe, 2017) and study the conceptual, structural, and temporal dimensions of digital platform ecosystems (Phillips & Ritala, 2019).

3.1.2 Case Survey

An effective way to find trends or patterns across different studies is to use case surveys. Case surveys can "bridge the gap between nomothetic surveys and idiographic case studies to combine their respective benefits of generalizable, cross-sectional analysis and in-depth, processual analysis" (Larsson, 1993, p. 1515).

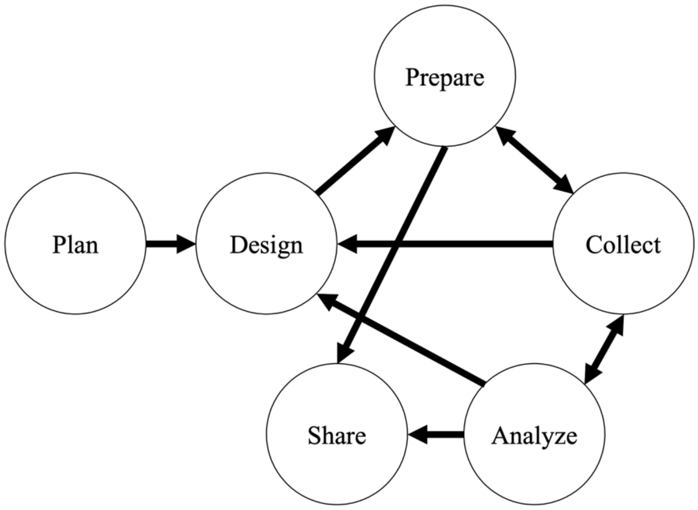
To inductively derive the socio-technical aspects of mobility and financial platform ecosystems, we used a case survey technique in this dissertation (**P2**, **P3**). The case survey technique makes it easier to learn from a vast body of qualitative information that is varied and represented by case studies. Moreover, case surveys allow for collective assessments of individual case instances (Yin & Heald, 1975) and detection of trends between cases without sacrificing scientific rigor (Larsson, 1993). The comprehensive implementation of the case survey method follows the four-step process of selecting a relevant case data set, design of the coding scheme, multiple coding ensuring interrater reliability, and the analysis. This dissertation used the approach of Eklund and Kapoor (2019) and collected, e.g., company announcements showing how mobility and financial platforms have coped with the COVID-19 pandemic (**P2**, **P3**). An extensive understanding of each research activity and appendices with examples of our open/axial coding to show how the results emerged can be found in each publication.

3.1.3 Case Study

The case study approach is well-established in IS literature (Tsang, 2014) and is frequently used to investigate real-life phenomena in fields with little to no previous research (Yin, 2014). Generally, case study research is "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2014). However, Eisenhardt (1989) suggests that conducting case studies is a holistic research approach and strategy rather than a simple research method. Therefore, this dissertation has adopted Gibbert and Ruigrok (2010) guidelines to "talk the walk" within our publications to explain the research process, including data collection and analysis to ensure methodological rigor.

This dissertation leverages the case study approach within publication **P5** to analyze B2B app store governance in software platform ecosystems. Next, we summarize how the general case study procedure (Figure 2) is aligned with Yin (2014).

Figure 2. Case Study Procedure (Yin, 2014)



The first phase of the case study procedure is the **planning** phase. Here, researchers must identify whether the case study method suits their research problem (Yin, 2014).

The case study **design** explains the research question's derivation that guides the study. Case studies can be designed with either a single or multiple case study design (Yin, 2014). If necessary, researchers must select case providers for their numerous case studies and justify them based on predefined criteria.

In the (data) **preparation** phase, scholars must screen and select their case candidates and conduct a pilot case study (Yin, 2014).

In line with Yin (2014), several data sources should be included in the **data collection** phase to facilitate data triangulation and ensure data quality. The data sources can be, e.g., interviews, observations, internal presentations, and information found on internal and publicly available websites. As Edmondson and McManus (2007) recommended, a researcher might use a flexible approach to data collection since new insights are obtained within each step of data collection.

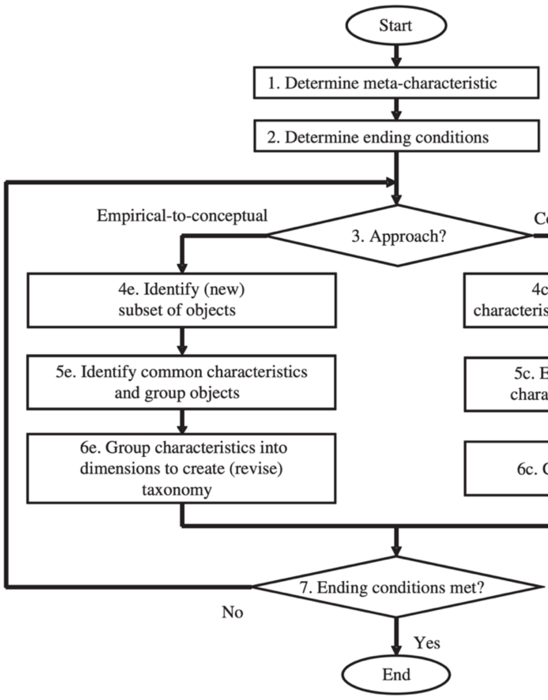
To **analyze** the data, researchers might leverage an iterative coding strategy. To identify B2B app store governance dimensions and characteristics (**P5**), open, axial, and selective coding was utilized (Corbin & Strauss, 2008).

Finally, researchers report their case study in the **sharing** phase. It is essential to define the audience and display enough evidence for the readers to reach their conclusions. The process should be reviewed and re-composed until its done well (Yin, 2014).

3.1.4 Taxonomy Development

We applied the taxonomy development method (Figure 3) within publication **P5** to build the B2B app store governance taxonomy based on our multiple case study insights. Following the approach of Nickerson et al. (2017), we performed three iterations with alternating inductive and deductive cycles to develop and evaluate the taxonomy. Before starting the first step, the meta-characteristics (Architecture, Control Mechanisms, and Demand Generation) were determined to guide the selection of governance concepts. Furthermore, the objective and subjective end conditions were defined, which terminated the iterative process when their criteria were met (Nickerson et al., 2017).

Figure 3. Taxonomy Development Method (Nickerson et al., 2017)



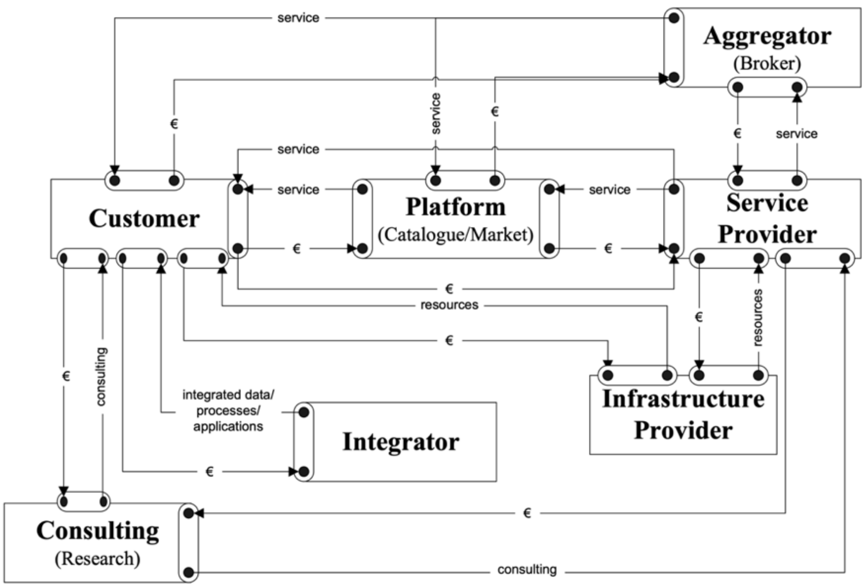
The first iteration followed the conceptual-to-empirical approach (Figure 3), resulting in an initial taxonomy for app store governance based on a systematic literature review (see chapter 3.1.1). Given the meticulousness of the established meta-characteristics, an extensive examination of the literature concerning existing governance dimensions and characteristics was conducted, and from this analysis, pertinent concepts were amalgamated to create an initial taxonomy. The second iteration followed an empirical-to-conceptual approach (Figure 3) and refined the initial taxonomy with additional data sources (i.e., semi-structured interviews, publicly accessible documents from partner portals, or the vendor's website). Thereby, we could add more characteristics and group them into the dimensions of our taxonomy (Nickerson et al., 2017). This process was performed until all our cases were included. Here, we did not only have characteristics to differentiate the cases but also relied on the rich case study data to create in-depth characteristics and increase the degree of detail within the taxonomy (Nickerson et al., 2017). Next, the characteristics and dimensions were synthesized to keep the taxonomy lean without losing discriminative power. The resulting taxonomy was evaluated in an empirical-to-conceptual approach in the third iteration. Therefore, the taxonomy was applied to a tenth case that was not used in the previous inductive step. This was done to validate the taxonomy for relevance and reliability for unseen cases.

3.1.5 e³-value Method

The e3-value methodology has been developed by Gordijn and Akkermans (2001) to model and analyze e-business models with a focus on a value-based approach. The purpose of the e3-value model is to bridge the gap between business and IT-focused modeling approaches for business areas that require a strong integration of business and IT systems. Furthermore, this modeling approach allows the analysis of multi-enterprise relationships for e-business scenarios. In sum, the e3-value method offers an integrated framework for business and IT activities, which is particularly appropriate for the socio-technical phenomenon of digital platform ecosystems (Gordijn & Akkermans, 2001).

The ontology of the e3-value method allows the identification of objects with economic value, which are created, exchanged, and consumed (Gordijn & Akkermans, 2001). The e3-value method allows the representation of value exchanges between different actors within a network and the identification of how economic value is created. Furthermore, the ontology is capable of modeling power elements of actors due to new technological or economical possibilities or the impact of new players within the network. An example of the adopted implementation of the method is illustrated in Figure 4 with the main elements of the e3-value ontology defined by Gordijn and Akkermans (2001):

Figure 4. Example of an e³-value Model (Leimeister et al., 2010)



- Actor: An actor is an independent economic or legal entity that is carrying out value activities to increase profit or its utility within the network.
- Value object: Products, services, money, or intangible goods like user experience are value objects that are exchanged between different actors.

- Value port: An actor's provision or request of value objects is represented by value ports. This allows the focus on the interaction between external actors independently from internal processes.
- Value interface: The value interface describes the willingness of each actor to exchange value objects through its value ports.
- Value exchange: The value exchange connects two value ports of different actors and represents one or more potential transactions of value objects.
- Composite actor: Several actors can collaborate to offer joint value objects. The composite actor represents this partnership.
- Value activity: This activity represents the value-creating process that a (composite) actor performs.

This dissertation leverages the e3-value method to model the digital platform ecosystem of novel regulatory reporting frameworks for banks within the European Monetary Union (**P4**). Within the ecosystem of banking supervision, many different actors are involved, i.e., regional, and multinational banks or banking groups, national competent authorities, European supervisory authorities, national central banks, the European central bank, and software providers. As regulatory reporting requirements are generally defined as business requirements, which must be translated into IT requirements as the basis for an IT/IS solution, the framework provides the ability to model the value exchanges in this multi-actor digital platform ecosystem.

Part B

1 P1: Connecting the Dots of Digital Platform Ecosystem Research: Constructs, Causal Links and Future Research

Table 8. Fact Sheet Publication P1

Authors	**Floetgen**, Rob Jago[1] **Novotny,** Marcus[2] **Urmetzer**, Florian[2] **Böhm,** Markus[1]
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Outlet	**ECIS 2021** 29th European Conference on Information Systems, 2021, Virtual
Status	**Published**
Contribution of First Author	Problem Definition, Research Design, Data Collection, Interpretation, Reporting

Abstract. Digital platform ecosystems are at the core of several of the world's most valuable companies and constitute a strongly growing but fragmented research area at the intersection of multiple research streams such as IS, economics, marketing, strategy, and technology management. To date, prior research mainly examines individual constructs and their interrelations in an isolated fashion, with no holistic synthesis of the field's empirical evidence. Addressing this gap, we surveyed 97 empirical studies in top IS and management journals, extracting all variables and causal links between them. Variables were then aggregated to 51 recurring constructs on seven micro (individual entity) and macro (ecosystem and market) levels of analysis and causal links between them were summarized. We contribute a nomological network of DPE research and present three future research avenues: an emergent multi-level perspective, complex dynamics, and studying the heterogeneity of the field to further bridge its isolated insights.

2 P2: Introducing Platform Ecosystem Resilience: Leveraging Mobility Platforms and their Ecosystems for the New Normal during COVID-19

Table 9. Fact Sheet Publication P3

Authors	**Floetgen**, Rob Jago[1] **Strauss**, Jana[2] **Weking,** Jörg[1] **Hein,** Andreas[1] **Urmetzer**, Florian[2] **Böhm,** Markus[1] **Krcmar**, Helmut[1]
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Outlet	**EJIS** European Journal of Information Systems
Status	**Published**
Contribution of First Author	Problem Definition, Research Design, Data Collection, Interpretation, Reporting

Abstract. COVID-19 has created many constraint-related challenges for humans in general and organisations in particular. Specifically, businesses that require physical contact, such as mobility providers, have been severely impacted by the crisis. This paper reveals how mobility platforms and their ecosystem of actors have adapted faster than their non-platform competitors to become resilient. Whereas current research on resilience explicitly deals with the concept of organisational resilience, community resilience, or IT resilience, socio-technical characteristics of digital platforms have not been investigated. We build on a case survey approach, including heterogeneous qualitative evidence of 266 actions of 171 analysed mobility platforms. The results show five archetypes of how mobility platforms leverage their platform-based nature and the ecosystem to build resilience. Based on this, we develop the concept of platform ecosystem resilience as leveraging socio-technical factors of digital platforms and ecosystems frugally to design, deploy and use situation-specific responses to prepare for, endure and adapt by capturing new opportunities and engaging in transformative activities to cope with exogenous shocks and become resilient for future disruptions. Our results emphasise the importance of platform ecosystems for practitioners and policy planners to develop the "new normal" rather than resuming existing practices.

3 P3: Platform Ecosystem Structures: Leveraging Platform-based Technology and the Finance Ecosystem for the New Normal

Table 10. Fact Sheet Publication P2

Authors	**Floetgen**, Rob Jago[1] **Mitterer**, Nathalie[2] **Urmetzer**, Florian[2] **Böhm**, Markus[1]
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Outlet	**PACIS 2021** 25th Pacific Asia Conference on Information System, 2021, Virtual
Status	**Published**
Contribution of First Author	Problem Definition, Research Design, Data Collection, Interpretation, Reporting

Abstract. The fierce competition in the finance sector in general, which was reinforced by uncertainty that the COVID-19 pandemic brought along, turned into a race for capturing new opportunities and engaging in transformative activities. In particular, structures of financial platforms and their ecosystems thus far provided competitive advantages compared with non-platform businesses. This paper reveals six archetypes of how finance firms achieve platform ecosystem structures by using platform-based technology and the ecosystem. We follow a case survey approach and analyze a qualitative data set of 152 actions of 61 financial platforms. We further demonstrate that platform ecosystem structures reinforce themselves, enable a sense of cohesiveness, and contribute to a "new normal" instead of a "preserving-the-past" reality. Our overview of the solution space might support practitioners in identifying, selecting, and planning relevant coping actions of digital platforms to prepare for future challenges, stay competitive, and provide innovation.

4 P4: Implications of Emerging Financial Regulatory Reporting Frameworks for Digital Platforms Boundary Resources

Table 11. Fact Sheet Publication P4

Authors	**Floetgen**, Rob Jago[1] **Gomm**, Sebastian[2] **Böhm**, Markus[1] **Krcmar**, Helmut[1]
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Outlet	**AMCIS 2020** Americas Conference on Information Systems, 2020, Virtual
Status	**Published**
Contribution of First Author	Problem Definition, Research Design, Data Collection, Interpretation, Reporting

Abstract. Regulators and banks have identified the necessity of a more holistic and harmonized approach for financial regulatory reporting than the current approach of "just" adopting new regulations to decrease the reporting burden on banking industry. Thus, new platform-based reporting frameworks for supervisory and statistical reporting of banks are being discussed to foster more efficient processing and reporting of data in Europe. Toward this goal, we use the e3-value method to model the ecosystem of emerging financial regulatory reporting frameworks based on publicly available laws, legal documents, guidelines published, consultations and industry surveys by supervisory authorities. Extending Ghazawneh & Henfridsson (2013) conceptualizations of boundary resources, the paper reveals that the boundary resources for financial regulatory reporting platforms will have to be co-created with the emerging regulatory reporting framework itself as foundation for the boundary resources and the regulated entity (i.e., banks) as they require the control about their sensitive data.

5 P5: B2B App Store Governance in Software Platform Ecosystems: Dimensions and Types

Table 12. Fact Sheet Publication P5

Authors	**Floetgen**, Rob Jago[1] **Ziegler**, Ulrich[2] **Weking,** Jörg[1] **Hoefler,** Matthias[2] **Riasanow**, Tobias[1] **Böhm**, Markus[1]
Author Affiliations	**1** - Technical University of Munich, Garching, Germany **2** – Celonis SE, Munich, Germany
Outlet	**HICSS 2021** 55[th] Hawaii International Conference on System Sciences, 2021, Virtual
Status	**Published**
Contribution of First Author	Problem Definition, Research Design, Data Collection, Interpretation, Reporting

Abstract. The ever-increasing customer demand for use case- specific B2B software puts platform owners into a challenging situation where integrating a B2B app store into their digital platform becomes a necessity to manage the dynamics of software platform ecosystems. However, platform owners face uncertainty and experiment, while platform ecosystem research provides limited guidance for specific B2B app store governance. Closing this gap, we use multiple case studies and develop three taxonomies for architecture, control mechanisms, and demand generation to provide an overview of the solution space for B2B app store governance. We further derive three robust B2B app store governance types: platform play, transaction channel, and community platform. This paper enriches the B2C-driven and core-offering related research on digital platform governance with tangible B2B app store governance dimensions and types. We envision to guide practitioners in identifying and selecting governance characteristics to remain competitive and provide innovation for their B2B app stores.

6 P6: Digital Platform Ecosystem Performance: Antecedents and Interrelations

Table 13. Fact Sheet Publication P6

Authors	**Floetgen**, Rob Jago[1] **Novotny**, Marcus[1] **Hein,** Andreas[1] **Weking,** Jörg[1] **Urmetzer**, Florian[2] **Böhm,** Markus[1] **Krcmar**, Helmut[1]
Author Affiliations	**1 -** Technical University of Munich, Garching, Germany **2** – University of Cambridge, Cambridge, United Kingdom
Outlet	**ACIS 2022** Australasian Conference on Information Systems, 2022, Melbourne, Australia
Status	**Published**
Contribution of First Author	Problem Definition, Research Design, Data Collection, Interpretation, Reporting

Abstract. The success of many of the world's most valuable companies is based on digital platform ecosystems (DPEs). Their performance depends on integrating autonomous, individually incentivized but highly entangled actors using digital platforms to cocreate values. Extant research uses numerous dependent variables to measure the performance of different actors in isolation. These variables are often limited to the (economic) gains of single actors, where an interconnected perspective on the performance of the whole DPE is lacking. This study extracts all variables and causal links from 132 empirical articles in top information system, management, and economic outlets and aggregates them into ten interconnected antecedents of DPE performance, namely: Heterogeneity, Competition, Engagement, Governance, Quality, Network Size, Generativity, Architecture, Cost, and Motivation/Satisfaction. Based on a nomological network, we contribute an understanding of DPE performance as an interrelated, sociotechnical, and dynamic construct. Our findings aim to support practitioners in effectively navigating and steering their DPEs.

Part C

1 Summary of Results

This dissertation entails six embedded publications, which address the research questions of first connecting the fragmented research field of digital platform ecosystems, second describing how to build digital platform ecosystems by leveraging platform-based technology and the ecosystem, and third identifying attributes as outcomes of the integrated efforts of autonomous actors in digital platform ecosystems. This chapter summarizes the results for each of the three research questions.

RQ1: *What does the literature contribute to our understanding of digital platform ecosystems by connecting the different digital platform ecosystem research streams?*

Connecting the dots of digital platform ecosystem research and building an interconnected perspective of digital platform ecosystem performance. Following a systematic literature review (**P1**), we identified 51 digital platform ecosystem research boundary constructs. We grouped these constructs by nine levels of analysis: complement, complementor, owner, platform, user, ecosystem, and market. Based on this, we built a frequency matrix and nomological network showing causal links between the levels of analysis and the key constructs. By synthesizing the digital platform ecosystem boundary constructs and causal relationships, we provide an integrative review of the research area.

Moreover, we demonstrate how our perspective might contribute to future theory development by establishing three digital platform ecosystem research avenues. In the second publication (**P6**), we inductively discovered ten interconnected antecedents of digital platform ecosystem performance studied across individual actors, technology entities, and its collective ecosystem. Based on this, we built a nomological network of the antecedents and interrelations of digital platform ecosystem performance. The findings for RQ1 are highlighted in Table 14.

Table 14. Overview of Key Results of Research Question 1

P	Findings *
P1	▪ A list of 51 recurring constructs grouped by seven micro and two macro (ecosystem and market) levels of analysis. Most studies with constructs at the complement level measured its Performance through sales, sales ranking or usage, and demand measures such as downloads, primarily operationalized as dependent variables. - The most prevalent constructs for the complementor level were platform engagement and performance, which were generally studied with dependent variables. - At the owner level, only performance was primarily analyzed as a dependent variable, comprising financial measures such as revenue, market share, or firm survival. - The platform level contained primarily constructs studied as independent variables concerning technical aspects (architecture, type, and features), access (openness), or quality (word of mouth). - At the user level, constructs are operationalized as dependent variables focused on platform usage, purchasing, or content creation behavior.

Table 14. Overview of Key Results of Research Question 1

	- Within the macro layer, studies analyzed constructs pertaining to the study's platform ecosystem and its encompassing market. - At the ecosystem level, constructs described the networks of complementors and users interacting by providing or utilizing complements on the platform. ▪ A frequency matrix detailing the number of studies analyzing links within and between levels of analysis. - Some levels of analysis exhibit a clear tendency to be studied more often with either independent or dependent variables. - Levels of analysis can be split into those utilized to explain intra-level and extra-level behavior. - Only about half of our studies bridge the two layers of analysis, thus analyzing how individual digital platform ecosystem actors and artefacts shape their ecosystem or market, and vice versa. ▪ A nomological network visualizing the causal links (edges) between individual constructs (nodes) - Causal links explaining constructs that ultimately drive economic digital platform ecosystem success (performance, platform engagement, platform usage, purchasing and content creation) are predominant as these make up 40 of the 49 causal links.
P6	▪ Identification of the 10 higher-level categories of heterogeneity, competition, engagement, governance, quality, network size, generativity, architecture, cost, and motivation / satisfaction as antecedents of digital platform ecosystem performance. - more than 40% of our data on empirical relationships, relate to influences on performance itself. ▪ A Table of the direct influences on digital platform ecosystem performance by the 10 antecedents ▪ A Nomological network of the antecedents of digital platform ecosystem performance - Antecedents of performance are not only direct antecedents of performance but also antecedents of each other, thereby contributing to value realization in various ways and mediating their effects. - Several dimensions show self-reinforcing feedback loops, the most prevalent being competition, network size, motivation / satisfaction, and performance. - Dimensions can also strongly moderate the causal links between them.
* Extracted from the respective embedded and published publications.	

RQ2: *How can the socio-technical combination of the technical platform and its ecosystem be leveraged to build digital platform ecosystems?*

Archetypes of actions taken by platform owners. We used case surveys to deduce the socio-technical aspects of mobility platform ecosystems (**P2**) and financial platform ecosystems (**P3**) to understand their potential to respond to the COVID-19 epidemic. We propose five archetypes, each of what mobility or financial platform owners can do to develop this platform- and ecosystem-induced resilience (**P2**) and structure (**P3**). Our findings reveal the distinct ways in which each archetype leverages platform- and ecosystem-specific attributes to effectively navigate the structural changes brought about by the COVID-19 pandemic. This knowledge equips managers with a comprehensive understanding of how to harness digital platform ecosystems to address the challenges posed by the COVID-19 crisis, prepare for potential future external disruptions, and foster both resilience and robustness within the platform ecosystem structure.

The introduction of a standardized platform reporting framework. Upon the advent of harmonized and all-encompassing platform reporting frameworks that encompass both statistical and supervisory reporting necessities, along with IT-ready specifications, a noticeable transformation in the regulatory reporting ecosystem has been observed. Our e3-value model, which depicts the platform ecosystem in Europe, illustrates the potential effects of introducing a standardized reporting framework. For instance, platform owners may diversify their business model by collaborating with third-party developers and sharing revenues, thereby expanding the platform through additional components (**P4**). Banks can also leverage the platform to construct applications tailored to their specific needs.

B2B platform ecosystem app store governance. App store owners must pay close attention to complementors' specialized needs and customers' generally high expectations if they want to run a successful B2B platform. Therefore, we provide a detailed understanding of the control concepts (influencing the platform and the ecosystem) for B2B app stores (**P5**). In addition to that, we derive three lessons learned: First, to increase overall engagement and utilization, it is essential to communicate the platforms' identity to users and complementors. Second, to attract complementors, it is crucial to provide free development tools, documentation, and enablement resources that are free and open to the public. Third, platform owners should restrict quality assurance to functional and security levels while leaving other levels untested. This ensures the overall rigor of the applications.

The findings for RQ2 are highlighted in Table 15.

Table 15. Overview of Key Results of Research Question 2

P	Findings *
P2	▪ Five platform ecosystem resilience archetypes of diversification, business model adaptation, serving the public good, creating a meta-platform, and optimizing service operation. - All five archetypes leverage the digital platform to strengthen their organizational resilience. - The adaptability of a system's outcome, such as the business model change (system as an interplay of platform and ecosystem factors), can achieve organizational resilience. - The interdependence between the focal platform owner and ecosystem actors (cascading effects, intertwined actions) can lead to community resilience. - Digital platforms influence resilience within the mobility ecosystem and at an inter-industry level.
P3	▪ Six archetypes of how platforms can use digital technology to drive platform ecosystem structures: exchange-oriented service expansion, banking core service extension/improvement, taking social responsibility, innovation promotion, e-commerce acceleration, and cyber security advancement.
P4	▪ An e3-value model of the ecosystem in Europe with the introduction of a standardized platform reporting framework

Table 15. Overview of Key Results of Research Question 2

	- Banks and platform owners consolidate all legislative acts to derive the respective regulatory reporting requirements and specify the IT-ready requirements for reporting solutions shifts to the reporting framework specification. - The different competent authorities lay down their legislative acts, including the reporting requirements, which will be incorporated in the standardized reporting framework by the work of expert groups. - The currently existing lock-in effect for traditional regulatory reporting solutions will be diminished by this standardization. ▪ Boundary resources for financial regulatory reporting platforms will have to be co-created with the emerging regulatory reporting framework itself as foundation for the boundary resources and the regulated entity (i.e., banks) as they require the control about their sensitive data.
P5	▪ A taxonomy on B2B app store governance which is divided into three sub-taxonomies that relate to architecture, control mechanisms and demand generation. - Architecture covers the infrastructure and solution-related governance components and resources that form the fundamental and operational basis of each app store. - Control mechanisms establish operating principles and exert fundamental directives on all participants in the ecosystem. - Demand generation describes the governance principles employed to incentivize complementors and end users to participate, contribute, and consume content through the app store.
* Extracted from the respective embedded and published publications.	

RQ3: *Which attributes as outcomes of digital platform ecosystems arise by integrating the socio-technical efforts of autonomous actors?*

Digital platform ecosystem resilience, structure, and performance. Our results showcase three attributes as outcomes of the integrated efforts of autonomous actors in digital platform ecosystems. First, we define digital platform ecosystem resilience (**P2**). Second, we discuss how platform ecosystem structures can be extended (**P3**). Third, we provide an interrelated, socio-technical, and dynamic understanding of digital platform ecosystem performance (**P6**).

Digital platform ecosystem B2B app store governance types. We identify the three robust app store types “Platform Play,” “Transaction Channel,” and “Community Platform.” Each offers a different reasoning for how governance features should be interpreted and expressed (**P5**). Based on the chosen components, all app store types can be differentiated along the dimensions of our B2B app store governance taxonomy.

The findings for RQ3 are highlighted in Table 16.

Table 16. Overview of Key Results of Research Question 3

P	Findings *
P2	▪ We coin the term digital platform ecosystem resilience as “Leveraging socio-technical factors of digital platforms and ecosystems frugally to design, deploy and use situation-specific responses to prepare for, endure and adapt by capturing new opportunities and engaging in trans- formative activities to cope with exogenous shocks and become resilient for future disruptions”.
P3	▪ Platform-based technology is essential for the platform ecosystem structure as platform properties enable its creation in several ways. ▪ A three-part understanding of how the established platform ecosystem structures can be extended: - A (new) actor can split a connection of a pair of other actors and thereby gain betweenness centrality. - Extensions on the intra-ecosystem level, such as banks cooperating with fintech’s to launch a new platform. - Extensions on the inter-ecosystem level, thus opening completely new business opportunities. ▪ Platform ecosystem structures reinforce themselves as actions on the platform level to support the ecosystem and vice versa. ▪ We observed a unique “spirit” of mutual help and strengthening or a sense of cohesiveness within the platform ecosystem structures that exceed known network effects of actor-network theory. ▪ Due to the platform actions, all the platform ecosystem structures spawn changed practices with short- and long-term impacts on the ecosystem.
P5	▪ We reveal three robust digital platform ecosystem app store governance types, i.e., Platform Play, Transaction Channel, and Community Platform. - App store owners run a “Platform Play” app store to increase the adoption of the core offering, enhance the stickiness of the platform and differentiate the offering from competitors. - A “Transaction Channel” app store is characterized by offering non-platform native solutions hosted on their infrastructure alongside solutions that also extend the core offerings of the platform. - Within the “Community Platform” app store the external expertise is considered internal expertise that is productized and listed on the app store by partners, customers, or employees.
P6	▪ We realize the need to study digital platform ecosystem performance as an interrelated, sociotechnical, and dynamic concept. - Interrelated: The ten antecedents of digital platform ecosystem performance affected value realization directly and indirectly (Figure 1); thus, all of them should be considered when analyzing a digital platform ecosystem’s current Performance and future potential. - Sociotechnical: Our dimensions comprised variables measuring social actors’ behavior (e.g., governance mechanisms and user engagement) and technical properties (e.g., platform or complement architecture) influencing value realization. - Dynamic: Introducing changes in single antecedence is likely to set off different effects, which are difficult to anticipate.

* Extracted from the respective embedded and published publications.

2 Discussion

Based on the summary of results, we discuss our findings along with three emerging themes that are of interest regarding the related body of knowledge. First, we discuss power relations in digital platform ecosystems. Second, we discuss a generativity perspective on digital platform ecosystems. Third, we discuss multi-level theory building within digital platform ecosystems.

2.1 Power Relations in Digital Platform Ecosystems

As compared to traditional organizations, digital platform ecosystems involve "a platform owner that implements governance mechanisms to facilitate value-creating mechanisms on a digital platform between the platform owner and an ecosystem of autonomous complementors and consumers" (Hein et al., 2020). Due to strong network effects (**P1**) and a "winner-takes-all/most" dynamic (Cusumano et al., 2019; Noe & Parker, 2000), only a few platforms dominate digital markets, and even more platform consolidation is expected in the future (Cusumano et al., 2019). As digital platforms provide foundational infrastructure for many industries and in crises (**P2, P3)**, the dominant platforms often become key orchestrators of their respective sectors (Kenney et al., 2021). Meanwhile, platform actors find themselves in "coopetition" as platform owners coordinate the participants' activities in the ecosystem (**P1, P4, P5)** but may also enter the competition with complementors (Jiang et al., 2011; Kretschmer et al., 2020; Lai et al., 2018; Zhu, 2019; Zhu & Liu, 2018). Further, platform owners' ability to control the ecosystem's technical setup, data, and terms and conditions (**P1**, **P3, P5**) inherently creates information asymmetry. It assigns additional power to them (Cutolo & Kenney, 2021), being able to design the structure to their own advantage (Tschang, 2021). Our results (**P1, P6)** strengthen the observation that the increasing threat of research has been interested in the relationships of multiple actors within an ecosystem (Jacobides et al., 2018; van Angeren et al., 2013). However, picking significant relationships between the platform owner and platform complementors within our nomological network (**P1),** we observe that mostly unidirectional power relationships towards platform complementor have been investigated (**P1, P6)**: By depicting complementors such as Uber drivers as relatively passive or reactive actors within a digital platform ecosystem (**P2)**, previous research is based on the assumption that a more powerful actor (platform leader/owner) is imposing its will upon a less powerful actor (Hurni et al., 2021; Wen & Zhu, 2019). Exemplarily, **P1** indicates which boundary constructs affect power relations between platform owners and complementors. Consistent with our findings (**P6**), Rietveld et al. (2020) highlight the presence of unequal power dynamics within platform ecosystems, emphasizing the inquiry into how a platform's growing dominance in the market influences the performance outcomes of complementors.

However, there is a lack of actors' perspectives other than from the platform owner's point of view (Hurni et al., 2021; Kapoor & Agarwal, 2017). Especially platform complementors, accounting for the greater majority of critical value creation within platform ecosystems **(P1)**, have been mainly overlooked so far (McIntyre et al., 2021). Our results unbox that understanding power mechanisms within platform ecosystems as comprehensively as possible requires an adequate investigation of existing interdependencies (**P1, P2, P3, P4, P6**), far beyond hierarchical command-and-control structures (Wang, 2021). By investigating holistic platform ecosystem relations among, e.g., platform owners and complementors (**P1**, **P4, P6**), our results are not limited to single-sided effects and do justice to the multiple levels of social actors and technological mechanisms a platform is offering (Markus & Rowe, 2018). Therefore, we propose in chapter 5 to conduct further research regarding the emancipation of complementors in software platform ecosystems.

2.2 Generativity Perspective of Digital Platform Ecosystems

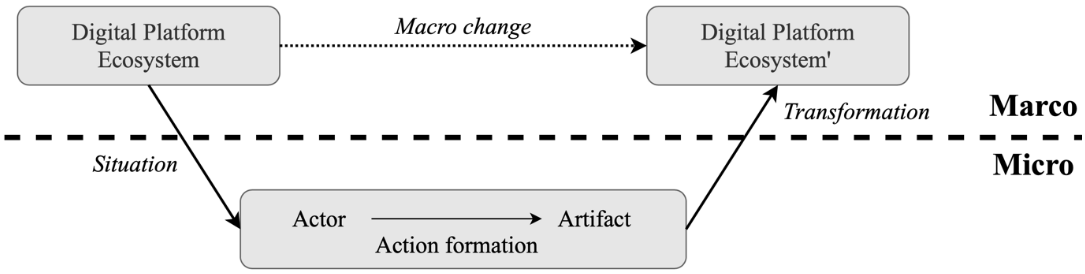
Platform ecosystems are characterized by generativity (Cennamo & Santaló, 2019; Constantinides et al., 2018), referring to their “overall capacity to produce unprompted changes driven by large, varied, and uncoordinated audiences” (Zittrain, 2009, p. 1980). Platform architectures offer infinite opportunities for value contributions (e.g., **P2, P3, P5**) that can be created by a diverse set of autonomous actors (Wareham et al., 2014). Thus they evolve and expand without the need for hierarchical intervention of platform owners (Cennamo & Santaló, 2019; Yoo et al., 2012). However, several challenges come with an infinite number of complements on a platform, ranging from difficulties ensuring the platform's stability to a reduced capability of ecosystem actors to capture value (Cennamo & Santaló, 2019). Therefore, the design of the platform and its governance mechanisms (**P4, P5**) is critical to the success of the ecosystem (Cennamo & Santaló, 2019; Jacobides et al., 2018). The central goal in this regard is to balance the control over the actors’ activities and the platform’s generativity (Parker & Van Alstyne, 2018; Wareham et al., 2014; Yoo et al., 2012). Thus, our nomological networks (**P1, P6**) provide an overview of the interrelations between the different entities of digital platform ecosystems, which allow, for instance, platform owners, as well as complementors, to anticipate activities based on influencing factors effectively.

In addition, generativity is applicable for analyzing central structural aspects of digital platform ecosystems and digital innovation (Tilson et al., 2010; Yoo et al., 2010). Generativity can be viewed from two perspectives. The concept of 'generative properties' is concerned with identifying the specific attributes of digital artifacts integrated within the social structure that facilitate actor creativity and lead to unforeseen consequences (generativity stemming from intentional system design). Conversely, the 'generative patterns' perspective investigates the patterns of events that initiate an evolutionary dynamic, giving rise to unexpected changes (generativity emerging as a consequence of system evolution). While the first perspective primarily revolves around artifacts and social structure, the second perspective places greater emphasis on the role of actors and events in the generative process. These lenses and the results of this dissertation (**P2, P3, P5**) contribute to the explanation of digital platform ecosystems that are characterized by the possibility of evolution in an emergent way (Cennamo & Santaló, 2019). Our results contribute to both generative perspectives of digital platform ecosystems. For example, in the light of generativity as a consequence of system evolution, we show that “the adaptability of a system’s outcome, such as the business model change (system as an interplay of platform and ecosystem factors) can achieve organizational resilience” (**P2**). Regarding generativity as a consequence of system design, we reveal the emergence of three robust digital platform ecosystem app store governance types, i.e., Platform Play, Transaction

Channel, and Community Platform within the platform ecosystem of the B2B software industry as a consequence of different combined governance and technical platform characteristics (**P5**).

To investigate how the ecosystem produces changes on the macro level driven by actions on the entity level, Eck and Uebernickel (2016) developed a model of digital platform ecosystem change (Figure 5) where the aggregation of triggered individual behaviors or actions leads to an (unintended) new ecosystem state (Eck & Uebernickel, 2016). Our results also add to this model as we show that the ecosystem situationally influences individuals that consequently take actions (**P2, P3**). Moreover, our identified attributes as outcomes of the integrated efforts of autonomous actors provide an additional perspective/outcome next to the result of a new ecosystem state (**P2, P3, P6**). In sum, we argue that according to this perspective digital platform ecosystems have to be considered on multiple levels to explain ecosystem generativity (Eck & Uebernickel, 2016) which we will discuss next.

Figure 5. Macro-Micro-Macro Model of Digital Platform Ecosystems Change (Eck & Uebernickel, 2016)



2.3 Multi-level Theory Building within Digital Platform Ecosystems

“The primary goal of the multilevel perspective […] is to identify principles that enable a more integrated understanding of phenomena that unfold across levels […]” (Kozlowski & Klein, 2000, p. 7). Multi-level research, according to Kozlowski and Klein (2000), is based on the general systems theory (von Bertalanffy, 2003) with the common goal of establishing principles that generalize across phenomena and disciplines, and represent “an ambitious effort that is aimed nothing less than promoting the unity of science” (Kozlowski & Klein, 2000, p. 6). As digital platform ecosystems represent a fragmented (**P1**, **P6**) and multi-level research field (Wang, 2021), this dissertation’s results contribute to an integrated understanding of autonomous actors' efforts across different analysis levels. In this chapter, we want to discuss our results concerning multi-level theory building.

In the realm of multi-level theory building, a fundamental tenet emphasizes the hierarchical nesting of multi-level systems, wherein micro-events are situated within macro contexts, and these contexts generally evolve through dynamics at lower levels. The primary objective of multi-level theories is to examine individual-level phenomena that form the foundation of organizational-level characteristics or outcomes, thereby enhancing our understanding of how individual and collective behaviors can contribute to organizational advancement (House et al., 1995; Klein et al., 1999). Considering the interconnections between various levels of analysis within digital platform ecosystems (**P1, P2, P3, P6**), acknowledging and incorporating multi-level influences (**P1, P2, P3, P6**) becomes imperative. Following Burton-Jones and Gallivan (2007), single-level investigations of multi-level phenomena, such as ecosystem performance (**P6**), can result in a variety of fallacies, compromising construct or internal validity. For example, when a change in a shared cause at the ecosystem level (also known as a confounder) is not controlled, the contextual fallacy can lead to misleading connections at the individual level. Even more significantly, failing to define the mechanism by which collective ecosystem performance emerges from the performance of its parts is a cross-level fallacy that undermines construct validity if a meaningful aggregation for parts-level measurements is not chosen. Consequently, by establishing a nomological network, our research enriches the comprehension of digital platform ecosystem performance as an interconnected, sociotechnical, and ever-changing construct (**P6**), with the aim of mitigating these fallacies.

This dissertation strengthens the observation that higher-level phenomena (such as (**P2**) platform ecosystem resilience) emerge from characteristics, cognition, behavior, affect, and interactions among individuals (Kozlowski & Klein, 2000). As multi-level theorizing requires the definition of collective constructs at higher levels of analysis (**P2, P3, P6**), such as the ecosystem level, this dissertation analyses ecosystem attributes as an outcome of the integrated efforts of autonomous actors. Moreover, our results show that these attributes emerge from the dynamic interactions among lower-level elements, as highlighted by our archetypes of how to leverage platform technology and the ecosystem (**P2, P3**). Building on Morgeson and Hofmann (1999), the notion of collective constructs refers to phenomena that arise from a continuous series of events and interactions among individual actors. Hence, the collective construct is shaped by the actions of individuals (or the collective as a whole) and not vice versa. The findings of this dissertation reveal three key characteristics of digital platform ecosystems, which can be regarded as collective constructs. Firstly, we elucidate the concept of digital platform ecosystem resilience (**P2**). Secondly, we provide insights into how platform ecosystem structures can undergo expansion (**P3**). Lastly, we present digital platform ecosystem performance as an intricate, socio-technical, and dynamic construct (**P6**).

3 Implications

Our results contribute to the theory of digital platform ecosystems and multiple sub-theories. First, we **build** a holistic and connected overview of constructs and causal links of digital platform ecosystem(s) (performance) to combine the empirical knowledge across largely unconnected areas and showcase boundary constructs that can bridge theories. Moreover, we contribute detailed measures of leveraging the technical platform and the ecosystem to develop digital platform ecosystems. Second, we **integrate** resilience, actor-network, and performance theories into the digital platform ecosystem context. Third, we **extend** those theories by introducing digital platform ecosystem resilience, characterizing digital platform ecosystem structures and performance, and providing B2B app store governance taxonomies. This chapter summarizes the most important theoretical and practical implications in line with our research questions.

3.1 Implications for Theory

From a theoretical perspective, we **build** a holistic and integrated overview of digital platform ecosystem research boundary constructs (**P1**) and an understanding of the antecedents of digital platform ecosystem performance (**P6**) in a rapidly evolving and fragmented study field of digital platform ecosystems (i.e., the "What's" and "How's" of theory (Whetten, 1989)). As a result, we synthesize empirical knowledge from isolated studies and showcase build boundary constructs that potentially bridge theories. To illustrate, the ten identified antecedents of digital platform ecosystem performance have a direct or indirect impact on value realization. Therefore, it is crucial to investigate these antecedents collectively to minimize confounding variables and enhance the comparability of research outcomes (**P6**). We demonstrate how our perspective on digital platform ecosystems might contribute to future theory development by building three future research avenues (1) an emergent multi-level perspective, (2) complex dynamics, and (3) the possibility of learning from heterogeneity (**P1**). Furthermore, our research uncovers reinforcing effects within digital platform ecosystems, which go beyond the established network effects. This underscores the importance of differentiating between platform ecosystem research and non-platform ecosystem research to gain a comprehensive understanding of these dynamics (**P1**). Each archetype (**P2, P3**) exemplifies how the inherent characteristics of platform ecosystems can significantly amplify the capacity to bolster collaborative endeavors among independent actors. The central actors, platform owners, effectively facilitate access for previously unconnected participants from non-platform ecosystems through adeptly designed, facilitated, and adaptable modular architecture and governance, thereby promoting enhanced coordination and collaboration. For platform complementors, engaging in multiple platform ecosystems grants them access to a diverse array of complementors, leading to mutual benefits. Consequently, this reciprocal strengthening between solid complementors and platform ecosystems is evident (**P2**). In addition to these cross-theory implications, this dissertation also provides specific contributions to existing sub-concepts of platform ecosystems: We contribute to the existing body of knowledge regarding platform ecosystem governance through the development of three taxonomies encompassing dimensions and characteristics of B2B app store governance (**P5**).

This dissertation **integrates** resilience research, actor-network theory, and performance theory into the digital platform ecosystem context. Thereby, we contribute with archetypes that show how mobility platforms (**P2**) and financial platforms (**P3**) leverage their technical platform and ecosystem to build resilience and structure. All our presented archetypes may be easily extended and reconceptualized by previously unknown aspects of platform ecosystem structure or resilience. This establishes the groundwork for developing other artifacts, such as platform ecosystem structure or resilience maturity models. We (**P2)** demonstrate that a combined and multi-level approach to organizational and community resilience is required in platform ecosystems. We show, for example, that archetypes interact and favorably affect the different levels of analysis. Accompanying this, we contribute by understanding platform ecosystem structures at the firm and intra- and inter-ecosystem levels (**P3**).

The findings of this dissertation **extend** multiple theories, with a focus on four key aspects: First, we introduce the novel concept of platform ecosystem resilience (**P2**), making us pioneers in the field of information systems research to recognize the influence of platform ecosystems and their resilience during crises. Second, we present a new perspective on structures in the context of digital platforms (**P3**). Unlike prior studies that were limited to non-platform or single-level viewpoints, our analysis reveals that the implemented measures can lead to a lasting transformation of the financial industry's status quo, ushering in a "new normal" reality. Third, our understanding of digital platform ecosystem performance offers a comprehensive and novel view (**P6**), highlighting its intricate, sociotechnical, and dynamic nature. We enrich the sociotechnical perspective of information systems research on digital platform ecosystems by exploring the interactions between social actors and technological elements and encompassing both instrumental and humanistic performance objectives. Fourth, our publication **P4** extended the boundary resources model (Ghazawneh & Henfridsson, 2013) regarding our financial regulatory reporting platform ecosystem.

3.2 Implications for Practice

From a practical standpoint, our research elucidates the causal relationships and effect chains existing in digital platform ecosystems (**P1, P6**). Prior studies have highlighted the challenges faced by managers in accurately assessing outcomes within intricate socio-technical systems (Sterman, 1989). By demonstrating the interconnectedness of various constructs within digital platform ecosystems, our work empowers managers to proactively anticipate the potential consequences of their actions. To tackle the intricacies of this domain, our model enables platform owners to measure the drivers that contribute to value realization in their ecosystem. Additionally, users and complementors can utilize our approach to enhance their value realization within digital platform ecosystems, while also gaining insights into the attractiveness of a given digital platform ecosystem when making decisions related to adoption, multi-homing, or continued usage and development.

Our findings give practitioners a thorough understanding of how to utilize the ecosystems and the underlying technology to handle crises (like COVID-19), specifically, prepare for other exogenous shocks, and build ecosystem resilience and structure more generally (**P2, P3**). Managers may utilize our solution space to organize tasks, do fit-gap analysis, and create roadmaps to strengthen their platform ecosystem resilience and structure. Finally, governments should investigate how they may promote long-term investments or ease rules for platform ecosystems supporting the public good, which may encourage their positive social effect.

Our modeled digital platform ecosystem (**P4**) serves as a valuable foundation for innovative and comprehensive reporting solutions, particularly beneficial for banks. We strongly advocate for active participation and collaboration from all stakeholders within the financial regulatory reporting ecosystem, as we discuss the emergence of regulatory reporting frameworks that promise a harmonized and holistic approach to financial regulatory reporting.

We establish comprehensive principles for effective B2B app store management (**P5**) by amalgamating insights derived from case studies and platform governance theory, while also considering crucial aspects specific to B2B app stores. These guidelines emphasize the significance of communicating the platform's identity to both users and complementors, providing free and publicly accessible development tools, documentation, and enablement assets, maintaining a rigorous standard for applications, and focusing quality assurance efforts on functional and security aspects.

4 Limitations

While each publication contains an extensive analysis of its limitations, we will highlight the most important limitations for interpreting the results regarding our research methods, data sources, and scope.

We want to mention two limitations regarding our **literature reviews**. First, our literature datasets are not exhaustive despite our large sample of 97 (P1) and 132 (P6) empirical studies. While, e.g., a more extensive forward/backward search could have been performed, we could allocate publications released after our cutoff date to our results. Second, generalizability concerns might affect our literature reviews. On the one hand, categorizing variables into constructs is a partially subjective effort that simplifies study results to make them comparable while possibly sacrificing detailed insights. By adhering to the principles of grounded theory and debating our clusters within the author team (**P1 & P6**), we were able to address this subjectivity. On the other hand, a frequently mentioned drawback in our study sample was the generalizability of causal linkages to different digital platform ecosystem contexts. Therefore, it is essential to consider carefully if a particular causal relationship may be applied to one's study or organization, which may need more assessment.

The nature of our **case surveys** yields four limitations. First, as our case surveys comprise 171 cases of mobility providers with 266 relevant individual actions (P2) and 152 cases of 61 financial platforms (P3), we cannot investigate each case in depth. Second, we chose mobility and financial platforms as a sample to examine digital platform ecosystem resilience and structure development in depth. The study must be extended to different platform contexts for generalizability to validate the generalizability of our archetypes of digital platform ecosystem resilience and structure. Third, the unprecedented nature of the crisis limited our data sources as it was still developing. New or previously unannounced examples may have emerged that should be examined in future research. We attempted to address this issue by collecting data over a seven-month (**P3**) and a 15-month (**P4**) period. Finally, because the qualitative character of our case survey allows for interpretation (Walsham, 2017), we used data triangulation and iterative team discussions.

In the context of the **e3-value method**, it is important to acknowledge a specific limitation. Our e3-value model (**P4**) is inherently bound by the information available from the analyzed documents and our entity coding process. Nevertheless, we took measures to address this limitation by demonstrating inter-coder reliability through the collaboration of two independent coders. Moreover, to further validate our models, we conducted five semi-structured interviews with financial industry professionals.

Regarding our **data sources,** we exemplary point out two limitations**.** First, some information about control methods (**P5**) is only available to business customers or platform users. To fill this need, we, e.g., conducted interviews with industry professionals. Second, our results only represent the status quo of a specific point in time. Longitudinal research to acquire a process view of possible changing paradigms within the quickly evolving area of digital platform ecosystems could be intriguing.

5 Future Research

In the context of the embedded publications about the integrated efforts of autonomous actors in digital platform ecosystems, we have identified versatile opportunities for further research (Table 17). In addition, three overreaching directions for further research are presented in this chapter.

Table 17. Avenues for Future Research

P	Exemplary Research Question *
P1	**Connecting the isolated parts for an emergent multi-level perspective:** ▪ How do collective constructs in digital platform ecosystems emerge because of an ongoing series of events and interactions of individual entities (process perspective)? **Looking ahead: Complex dynamics in digital platform ecosystems:** ▪ What does a dynamic systems approach contribute to our understanding of digital platform ecosystems to consider emergent dynamics and the function of digital platform ecosystems as a whole? **Learning from heterogeneity: Towards new insights from generalizing across digital platform ecosystem contexts:** ▪ What can we learn about the difference of digital platform ecosystems based on causal links between boundary constructs with conflicting evidence? ▪ How do different sources of heterogeneity across digital platform ecosystems (e.g., maturity stages, complementor types: in-house, 3rd party, etc., or even the combination of various sources) affect the evolution of the digital platform ecosystem?
P2	**Digital platform ecosystem resilience from a platform perspective:** ▪ How does platform ecosystem resilience unfold based on a process perspective and longitudinal investigations? ▪ How are digital platforms mobilizing and switching their resources to target crisis-related bottlenecks? **Digital platform ecosystem resilience from an ecosystem perspective:** ▪ What digital platform ecosystem resilience effects and mechanisms can be observed from a platform complementor perspective? ▪ How does the structure and type of an ecosystem (e.g., its homogeneity, complexity, innovation ecosystems, technology ecosystems) influence resilience? ▪ How does ecosystem compatibility contribute to platform ecosystem resilience?
P4	**Influences of emerging financial regulatory frameworks on digital platform ecosystems:** ▪ What are the influences of emerging financial regulatory frameworks and banks on reporting platforms' boundary resources in other countries, such as the American financial regulatory reporting ecosystem? ▪ How are boundary resources co-created between different actors in digital platform ecosystems in further contexts and across industries?

Table 17. Avenues for Future Research

P6	**Digital platform ecosystem performance:** ▪ What emergent dynamics beyond a single digital platform ecosystem's performance (e.g., by studying, e.g., the coevolution of digital platform ecosystems and their environments) can be observed? ▪ Which antecedents of digital platform ecosystem performance are especially imperative for the performance of transaction, innovation, or hybrid digital platform ecosystems? ▪ How do effect sizes for causal links between the performance antecedents affect the evolution of digital platform ecosystems?
* Extracted from the respective embedded and published publications.	

Emancipation of Complementors in Software Platform Ecosystems. The omnipresence of digital platforms has far-reaching effects on all involved platform ecosystem actors. Balancing the power by establishing fair frameworks and rules among all actors involved is desired and needed. Future research should observe platform power dynamics from a complementor perspective as the nature of platform design and its morally questionable exploitation disbalances power dynamics between actors within the digital platform ecosystem. Existing research does not adequately analyze digital platform ecosystems to recent developments, such as Epic's lawsuit against Apple demanding a fair app market (Tagesschau, 2021). This example illustrates that complementors attempt to overcome the oppression experienced by platform owners by emancipating themselves. Due to the socio-technical and holistic nature of platform ecosystems, social and technical emancipation must be considered to understand the underlying dynamics. On the one hand, existing research only applies either social or technical (Young et al., 2021) aspects but lacks to combine both within one framework: a socio-technical analysis. On the other hand, critical researchers point out the need to clarify the structure of emancipation to enhance the purposeful execution of such actions in the long term (Adam, 2001). Therefore, shedding light on those tensions and emerging emancipation movements is a promising direction for future research to uncover the mechanisms behind unequal power relationships among platform actors to increasingly regain the balance of ecosystem power dynamics in the long term.

System dynamics modeling as a new methodological framework for an emergent dynamic perspective of digital platform ecosystems. Digital platforms introduce a paradigm shift in how we perceive value creation, as value is no longer confined to a single company's supply chain (Hein et al., 2019). Instead, although a single owner may oversee the governance of platforms, the actual value emerges from the interactions among an extensive ecosystem of independent social actors. For example, the iOS App Store, with its 20 million registered developers, is estimated to generate over a billion US dollars in revenue per week on the platform through the interactions of complementors, users, competitors, and other digital platforms (Lunden, 2018). Consequently, platform owners are motivated to foster a vast ecosystem of complementors and users that fuel their platform's generativity and growth. The ecosystem of a digital platform is inherently dynamic, characterized by the interactions of autonomous agents that evolve over the ecosystem's lifecycle. Due to this interactivity, changes within the ecosystem cannot be solely attributed to the actions of individual actors, making coevolution and responses to governance mechanism alterations challenging to predict. To address this observation, we suggest that future research should explore the application of adaptive systems and system dynamics modeling to digital platform ecosystem studies (Arzoglou et al., 2019; Ruutu et al., 2017). These frameworks account for the temporal dimension of ecosystems, which represents a crucial area for future research (Phillips & Ritala, 2019). By translating digital platform ecosystems into mathematical equations and running simulation analyses with varying input parameters, researchers can test alternative behavioral assumptions or governance policies (Abar et al., 2017). This approach not only sheds light on the temporal dimension of digital platform ecosystems but also enhances the rigor of this research area, addressing current methodological concerns arising from limited data-driven techniques (de Reuver et al., 2018).

Understand the effects of external triggers on spontaneous and disorganized action of ecosystem actors and related consequences. Various factors contribute to the failure of digital platform ecosystems (Zhu & Iansiti, 2019). Often, these failures are not directly linked to specific actions or decisions but rather stem from external market factors beyond the company's control, managerial inaction, or inadequate response to critical situations. It is essential to evaluate such failures in the context of competitors and the impacts resulting from ecosystem interactions, rather than viewing them as isolated occurrences in the development of a digital platform (Reeves et al., 2019). A deeper examination of conflicting elements within digital platforms and their broader ecosystems, which may seem sensible individually but display inconsistency when compared, might unveil potential solutions for understanding these complex, non-linear dynamics of platform ecosystems (Lewis, 2000). Tensions can arise when contradictory demands become apparent and persistent, particularly during times of crisis or when new challenges emerge, necessitating immediate action from ecosystem actors (Smith & Lewis, 2011). To overcome these challenges, it becomes crucial to make the dynamics stemming from existing tensions more discernible and comprehensible. Consequently, future research should systematically elucidate the tensions that commonly arise in such situations but often remain obscured behind the scenes. Exemplary research inquiries may include: What are the mechanisms behind the emergence of tensions within digital platform ecosystems, and what are the underlying reasons for their occurrence? How can these tensions be proficiently self-managed through organic and spontaneous actions taken by various actors within the ecosystem, and what specific roles do digital platforms play in facilitating this process?

6 Conclusion

As the global reliance on digital platform ecosystems grows, encompassing employees, complementors, users, and shareholders, it becomes imperative to ascertain how to effectively harness the collaborative endeavors of autonomous actors within these ecosystems. We noticed that existing research on digital platform ecosystems has primarily focused on identifying isolated actors and their interactions responsible for the ecosystem's success, rather than exploring the collective value and benefits generated by the entire ecosystem. This provides the opportunity for us to learn how to leverage the results of an integrated perspective of autonomous actors' actions in digital platform ecosystems. This dissertation builds a comprehensive understanding of this integrated perspective by combining isolated research on digital platform ecosystems and scrutinizing how digital platforms capitalize on their technical nature and the broader ecosystem. By doing so, novel attributes resulting from the integrated efforts of autonomous actors are developed and examined. The outcomes of this research contribute to the existing literature on digital platform ecosystems and offer practical guidance to practitioners in effectively developing their platform ecosystems.

We hope our findings not only make for interesting reading, promote bold ideas, and exude an interdisciplinary flair, but also kindle practice with "the spark of science".

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Appendix A: Embedded Publications in Original Format

CONNECTING THE DOTS OF DIGITAL PLATFORM ECOSYSTEM RESEARCH: CONSTRUCTS, CAUSAL LINKS AND FUTURE RESEARCH

Research Paper

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Abstract

Digital platform ecosystems are at the core of several of the world's most valuable companies and constitute a strongly growing but fragmented research area at the intersection of multiple research streams such as IS, economics, marketing, strategy and technology management. To date, prior research mainly examines individual constructs and their interrelations in an isolated fashion, with no holistic synthesis of the field's empirical evidence. Addressing this gap, we surveyed 97 empirical studies in top IS and management journals, extracting all variables and causal links between them. Variables were then aggregated to 51 recurring constructs on seven micro (individual entity) and macro (ecosystem and market) levels of analysis and causal links between them were summarised. We contribute a nomological network of DPE research and present three future research avenues: an emergent multi-level perspective, complex dynamics, and studying the heterogeneity of the field to further bridge its isolated insights.

Keywords: digital platform ecosystems, nomological network, constructs, causal links.

1 Introduction

Whether it is Apple, Amazon, Alibaba, Tencent, or SAP–several of the world's most valuable companies in our largest economies are centred around digital platform ecosystems (DPE). Thereby a digital platform as an extensible codebase enables the co-creation of value between autonomous networks of complementors and users forming an ecosystem under the orchestration of a platform owner (Hein et al., 2019; Tiwana et al., 2010). Enticed by the growth prospects of network effects and low marginal costs, and under competitive pressure from new digital players, also companies across traditionally supply-chain oriented industries such as manufacturing are now faced with questions of adopting, joining or building their own platform ecosystems (Jacobides et al., 2019; Urmetzer et al., 2018). Thus, it is no surprise that platform ecosystems literature is growing substantially, with its cumulative volume in top journals having doubled over the past four years.[1]

The IS discipline understands DPEs as socio-technical phenomena, which lie at the intersection of various fragmented research fields, including IS, economics, marketing, strategy and technology management (Hein et al., 2019; McIntyre and Srinivasan, 2017; Schreieck et al., 2016). Naturally, each of these fields brings their own foci and lenses to the scene, studying diverse issues such as governance mechanisms and boundary resource design (Floetgen et al., 2020; Karhu et al., 2018), network externalities and competition (Katz and Shapiro, 1986; Rochet and Tirole, 2003), electronic word of mouth (You et al., 2015), multi-homing (Landsman and Stremersch, 2011), and technology leadership or transitions

[1] In our literature search, 654 of 1324 studies within the AIS Senior Scholars' Basket of Journals and the Financial Times Research Rank with the *platform* or *ecosystem* term in their Abstract, Title or Keywords have been published since 2017.

(Kretschmer and Claussen, 2016; Ozalp et al., 2018). However, there is, as yet, no holistic overview of the key DPE constructs and their interrelations through causal links that shape their evolution over time. This constitutes a missed learning opportunity to aggregate the knowledge across the different research areas for the emerging DPE field, as their various constructs are likely connected.

Consider the following example: A platform owner aims to grow the market size of its ecosystem. This growth is based on value co-creation between complementors and users, which the owner can influence through governance mechanisms (Schreieck et al., 2016). To attract more complementors, it could develop boundary resources to simplify complement development (Xue et al., 2019), or relax input control (Wessel et al., 2017), thus extending the platform's value proposition and hopefully enticing additional users to join through cross-side network effects (Chu and Manchanda, 2016). Yet, it is possible that such profound governance changes have effects beyond their intended impact, as a rising number of complements has also been shown to negatively impact single complement sales (Taeuscher, 2019) or user purchasing behaviour (Li and Netessine, 2020). Additionally, the perceived effectiveness of the mechanisms from the owner's point of view will affect its future behaviour as part of a decision-making feedback loop (Sterman, 2000). While prior studies have analysed several of these effects during a DPE's evolution in isolation and for varying contexts, their insights have not yet been connected into a coherent picture. As such, inducing change at one end of a DPE could have unexpected, non-linear effects across the landscape of its complex ecosystem. This is also relevant from a practical perspective, as prior research has shown that managers frequently tend to misjudge cause-effect relationships in complex systems, leading to unexpected dynamics, policy resistance or even systematic mistakes in decision-making (Meadows, 2008; Sterman, 1989, 2000).

In essence, the DPE field lacks a holistic overview of its constructs and causal links as a summary of its established empirical evidence. Prior reviews aiming to holistically survey constructs and causal links for specific IS areas have been vital to advancing our understanding of the fields, e.g. of IS success (DeLone and McLean, 1992) and management support systems (Clark et al., 2007). Over the past 15 years, a promising review approach for this endeavour has also been pioneered by Jeyaray et al. (2006) and Lacity et al. (2010, 2011, 2016), who systematically aggregated and organised the empirical knowledge for the fields of IT innovation and business services sourcing. In line with this research approach and the conceptual multiplicity of the research object 'digital platform ecosystem', our research question is as follows: *Which constructs have been studied empirically at what levels of analysis in DPE research, and what are the causal links between them?*

Starting from a broad keyword search, we analyse 97 empirical studies from top IS and management journals and extract all variables with causal links among them. Through constant comparison, we identify 51 recurring constructs with distinct causal links across seven micro (individual entity) and macro (ecosystem and market) levels of analysis. Aggregating causal links between the levels, we identify foci and gaps of the field and connect the repeatedly analysed empirical constructs. Thus, we combine and structure the fragmented empirical knowledge across DPE research streams, and connect their dots for future theory development. We contribute a nomological network of the DPE field and present three future research avenues, highlighting the importance of an emergent multi-level perspective, arising complex dynamics, and learning from the heterogeneity of the field to further bridge its isolated insights.

2 Background

DPEs are the subject of several disciplines with differing perspectives (Hein et al., 2019; McIntyre and Srinivasan, 2017). From a technical point of view, digital platforms are extensible codebases providing core functionality that is complemented by an ecosystem of third-party software modules leveraging the platform's interfaces (Tiwana et al., 2010). Following a market-based view, these platforms mediate transactions between two or more market sides, laying the focus on pricing and competition instead of architecture (Eisenmann et al., 2006; Rochet and Tirole, 2003). Integrating both points of view, the socio-technical perspective focusses on how value creation is facilitated in the ecosystem by platform owners leveraging governance mechanisms such as input control or the provisioning of boundary resources and incentives (De Reuver et al., 2018). Thereby, the ecosystem is not only seen as a network of software modules, but of loosely-coupled autonomous agents creating and implementing innovations (Wang, 2021), moving the locus of value creation outside the firm (Parker et al., 2017). In sum, “a digital platform ecosystem comprises a platform owner that implements governance mechanisms to facilitate value-creating mechanisms on a digital platform between the platform owner and an ecosystem of autonomous complementors and consumers.” (Hein et al., 2019)

Following Hein et al. (2019), there are three recurring actor roles across DPEs: Platform owners, complementors and users.[2] Thereby, platform owners are the focal ecosystem actors, who are responsible for the platform’s architecture and facilitate access and value creation through governance mechanisms. Ownership may be centralised within a single organisation, such as in the case of Facebook or SAP, divided between multiple actors in consortia, as in open source ecosystems, or even decentralised, such as in peer-to-peer platforms. Complementors, which can be individuals, organisations or even other digital platforms compatible with the DPE, extend the focal platform’s value proposition by providing products or services (complements). Users encompass both individuals and organisations that participate in the DPE as service beneficiaries. Additionally, actors can take up both complementor and user roles, as in the case of user innovators (Ye and Kankanhalli, 2018). Considering this wide range of actor roles, there is considerable ambiguity around the concept of DPEs, extending to the utilisation of the overall *platform* term (De Reuver et al., 2018). Thereby, many authors don’t clearly distinguish whether they are referring to technological platforms or the marketplaces facilitated by them, e.g. Apple’s iPhone and iOS operating system or its iOS App Store (Porch et al., 2015). Throughout our review, we follow the IS perspective of DPEs as socio-technical phenomena (De Reuver et al., 2018), gathering empirical evidence on interactions amongst actors, and between actors and technology.

By aggregating DPE constructs and causal links across empirical studies, our approach builds theory from prior literature, as constructs and the relationships between them are regarded as central elements of theory (Gregor, 2006; Levy and Ellis, 2006; Whetten, 1989). Thereby, constructs are thought of as unobservable concepts with a specific scientific purpose, that can be operationalised through one or several variables (Bacharach, 1989; Kerlinger and Lee, 2000). Constructs that are analysed in several causal links across studies can serve as boundary spanners between theories (Bacharach, 1989), allowing us to connect the empirical knowledge of the field in a larger network (Furneaux and Wade, 2009). For this purpose, constructs studied as both dependent and independent variables are of particular interest, as they can mediate causal link chains across multiple studies. However, a holistic review of empirical relationships between constructs for DPE research is missing. Importantly, our approach does not analyse the theoretical reasoning for causal effects and the boundary conditions cited in original studies (Whetten, 1989). Yet, in studying whether and how constructs are interrelated through causal links across the different DPE research streams, we aim to showcase an existence or lack of cumulative evidence as a foundation for future research.

3 Research Approach

In this descriptive review (Paré et al., 2015), we surveyed the literature on DPEs to aggregate the empirical knowledge of the field. Thereby, we adopt the empirical study as our unit of analysis, and uncover prevalent DPE constructs, and causal links through frequency analysis. We followed a systematic literature review approach (Okoli, 2015) organised into four phases (Figure 1): Planning the review, selecting literature, extracting data and synthesising results. In the first step, we developed a review protocol within the research team, defining the purpose of the review and ensuring a systematic implementation of our approach, including search, data extraction and synthesis strategy.

Second, literature for the study was selected using the Web of Science and SCOPUS databases. To minimise the risk of excluding relevant studies, we started with the broad search string <<platform* OR ecosystem*>> in the Abstract/Title/Keywords fields, limiting our search to journals within the AIS Senior Scholars' Basket of Journals and the Financial Times Research Rank.

[2] Although Hein et al. (2019) refer to *users* as *consumers*, we opt for the *user* terminology in this study, due to the wider range of both consumption and content creation behaviours represented by it.

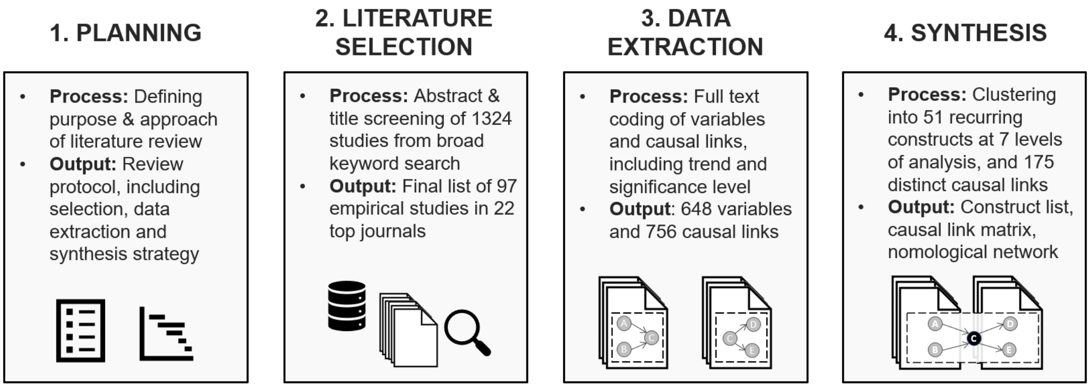

Figure 1. Research Approach

We limited the journal set to only include articles which had passed the highest quality standards during peer review without further quality appraisal. All resulting studies' titles and abstracts were then manually screened for two criteria: (1) the article centrally encompasses a DPE according to the definition by Hein et al. (2019) and (2) there has been an empirical analysis of variables and their causal links which relate to DPE research. If we could not tell whether a study analyzed a DPE from the abstract, we skimmed the full text. This removed 877 studies from our list which did not refer to DPEs (e.g. ideological, organisational or internal IT platforms and business ecosystems without an IT focus; n=619), or where the platform was not central to the article (n=258). Another 326 articles were excluded as they did not report empirical research. Of the remaining 121 studies, 24 had to be dropped from our sample during data extraction, as they did not clearly specify their involved variables or the directions of causal links between them. Thus, our final sample is composed of 97 studies from 22 journals, which are marked with an asterisk (*) in the References section.[3]

Code	Meaning
Independent Variable	Exogenous variable, explains change in the dependent variable.
Dependent Variable	Endogenous outcome variable, is influenced by the independent and moderator variable(s).
Moderator Variable	Exogenous variable, influences the strength of the causal link between an independent and dependent variable. Only defined for some causal links.
Level of Analysis	Level at which each variable was measured (see Table 2).
Causal Link	Directed empirical relationship between an independent and dependent variable.
Trend (positive/negative)	Coded for each causal link. Refers to whether an increase in the independent variable (or the interaction of independent and moderator variable) had a positive/negative effect on the dependent variable.

Table 1. Coding Scheme

Third, we coded every full text to extract all empirically studied causal links and their involved variables, as well as the DPE and methodology. Therefore, we created a master list that includes a description of the dependent, independent and moderator variables, including their level of analysis, and their relationships to one another expressed as causal links (Table 1). Variables were coded multiple times if utilised in several roles by a study, e.g. mediating variables were included as both independent and dependent

[3] At least three articles were included for ten journals: Information Systems Research (n=16), MIS Quarterly (n=11), Strategic Management Journal (n=11), Management Science (n=10), Journal of Information Technology (n=7), Organization Science (n=5), Journal of Management Information Systems (n=5), Marketing Science (n=4), Journal of Marketing (n=4), Journal of Marketing Research (n=3).

variables. Following these guidelines, we extracted a total of 648 variables with 756 causal links between them. For each causal link, we also coded its trend (negative or positive), along with the involved independent, dependent and up to one moderator variable. For quantitatively-studied links, we also documented whether the original authors deemed them to be significant (true for 670 links), for which the significance level varied between 5% and 10% across authors. As we wanted to focus on each study's central insights, we only extracted causal links that were referenced in the text body, omitting control variables and auxiliary or non-empirical analyses (e.g. simulation).

Level of Analysis		**Description**
Micro Layer	Complement	Digital artefacts extending the value proposition of the focal platform, including software applications, product/service listings and user generated content.
	Complementor	Suppliers of complementary products and services (complements), including developers and sellers. Single actors or organisations.
	Owner	Focal platform actor/organisation enabling value co-creation among complementors and users through provision of the technical platform and governance mechanisms.
	Platform	Extensible codebase hosting digital complements and mediating interactions between complementors and users.
	User	Service beneficiaries of platform and complements, sometimes provision of user generated content (complements). Single actors or organisations.
Macro Layer	Ecosystem	The socio-technical network of actors (complementors, users, owners) and complements spanned up by the focal platform.
	Market	Everything outside the respective study's DPE, including industries and markets with competing or neighbouring DPEs, as well as regulatory institutions.

Table 2. Description of our constructs' micro and macro levels of analysis

Fourth, we synthesised our results by aggregating our dataset to a list of distinct DPE constructs and causal links, following grounded theory coding protocols for open coding, axial coding and constant comparison (Corbin and Strauss, 2008). As each variable was assigned to a level of analysis, variables intended to measure the same construct for a common level were clustered into constructs. For example, variables such as a complementor's revenue (Li et al., 2019), market share (Tanriverdi and Chi-Hyon, 2008) or IPO likelihood (Ceccagnoli et al., 2012) were grouped into a *Performance* construct at the complementor level. We distinguished constructs at seven levels of analysis (Table 2) according to the research objects studied by the original authors, further divided into a micro and macro layer (Bélanger et al., 2014). Within the micro layer, levels describe single entities, meaning the individual actors (*complementors*, *users* and *owners*) or technological artefacts (*platform, complements)* of a DPE. The macro layer describes socio-technical collectives that result from interactions between individual entities, spanning up the *ecosystem* level of a DPE and the *market*-level influences outside of it. Thus, micro levels are embedded into macro contexts, whereas macro levels emerge from interactions at the micro levels (Kozlowski and Klein, 2000). Clustering was undertaken as an explorative, bottom-up approach without an initial coding scheme to avoid a priori judgements. Thereby, a list of 51 recurring DPE constructs that were utilised in at least three studies emerged through constant comparison, covering 606 of our 648 extracted variables.[4] This also combined our set of 756 causal links between all variables into 175 distinct causal links between recurring constructs, covered in one to five studies (excluding moderators). Following clustering, we again reviewed all causal links to assure that the relationships between

[4] Though the cut-off point at three studies may seem arbitrary, it allowed us to condense our results to the most relevant constructs, while still reporting over 93% of our data. Similarly to Furneaux & Wade (2009, p. 5), we recognise that some degree of inference is necessary for the task of clustering due to varying naming conventions and partly ambiguous reporting in primary studies. However, we aim to increase transparency of the included variables per construct throughout Section 4.2.

clustered constructs were still true to the meaning of the underlying variables. We then created a frequency matrix detailing the number of studies that analyse causal links within or between levels of analysis. In addition, we built a nomological network (Cronbach and Meehl, 1955) to organize the causal links with repeated empirical evidence in a logical and integrated fashion.

4 Findings

In the following, we present a descriptive overview of the studies included in our sample, followed by two findings: (1) a list of recurring DPE constructs grouped by level of analysis and (2) a frequency matrix and nomological network showing causal links between levels of analysis and key constructs.

4.1 Overview of our sample

Our empirical studies cover a large variety of different platform ecosystems that all fit the definition of DPEs as extensible codebases enabling value co-creation between complementors and consumers, governed by a platform owner (Hein et al., 2019; Tiwana et al., 2010). We sketch an overview of the platforms included in our sample according to the *transaction* and *innovation platform* typology developed by Cusumano et al. (2019): Thereby, transaction platforms primarily serve as intermediaries for exchanges of products, services, or information, whereas innovation platforms provide a technical foundation for which complementors can develop software extension. Our sample includes 52 studies covering transaction platforms such as multi-sided marketplaces (Amazon, Taobao) or social networks and online communities (Facebook, Wikipedia, or TripAdvisor), and 47 studies analyzing innovation platforms such as smartphone operating systems (Android, iOS), video game consoles (Microsoft Xbox, Sony Playstation) or other software platforms (SAP, Mozilla Firefox). Some platforms take up a hybrid role in that they offer complementors both an extensible codebase to generate and a marketplace to distribute new innovations (e.g., the iOS and Android smartphone app stores).

Regarding methodology, included articles relied predominantly on quantitative data analysis, with most studies utilising econometric analyses (n=79), structural equation modeling (n=7), dynamic modeling approaches (n=4) and meta-analysis (n=3). Four studies followed a qualitative case study approach. Additionally, the sample incorporates recent knowledge, as half of the studies in our final set have been published since 2017 (n=58).

4.2 Recurring Digital platform ecosystem constructs

We clustered **51 recurring DPE constructs** that were analysed in at least three studies, grouped by their layer and level of analysis (Table 3). For each level, constructs are ranked by the number of studies employing them, which is shown first in parantheses. The three following numbers indicate the subsets of studies operationalising the construct as a dependent, independent or moderator variable, subsequently also referred to as a construct's role. As studies may utilise constructs in a number of these roles, the subset sizes do not necessarily add up to the total study count. In the following, we introduce each construct and detail its predominant operationalisations with references to exemplary studies.

Regarding layers of analysis, almost all studies in our sample (n=92) utilise constructs within the micro layer, while over half of studies (n=57) examine constructs within the macro layer. In the **micro layer**, studies analysed constructs with individual complements (n=42), complementors (n=46), owners (n=28), platforms (n=27) or users (n=25) as their level of analysis. Two thirds of all studies with constructs at the **complement level** measured its *Performance* through sales (Rietveld et al., 2019), sales ranking (Yin et al., 2014) or usage and demand measures such as downloads (Wang et al., 2018), primarily operationalised as dependent variables. *Word of Mouth*, *Architecture* and *Updates* were operationalised with both independent and dependent variables, respectively measuring perceived quality through volume and/or valence of user review scores (Eckhardt et al., 2018), technical attributes, such as modularity or standardisation (Tiwana, 2015a, 2015b), and version evolution (Yin et al., 2014). The remaining constructs were operationalised as independent or moderator variables, including a complement's *Price*, *Age,* availability on multiple platforms (*Multi-Homing*), the *Information* available to users prior to purchase (e.g. descriptions), and its *Type*, describing the impact of its e.g. app categories and business models (Ghose and Han, 2014). Ghose and Han (2014) provide a comprehensive example of a complement-level study, analysing drivers on the *Performance* of smartphone applications.

Level of Analysis		Constructs
Micro Layer	Complement (42) [30/26/20]	*Performance* (28) [26/6/3], *Type* (17) [0/6/15], *Word of Mouth* (12) [3/9/3], *Price* (8) [0/8/2], *Architecture* (7) [4/5/3], *Updates* (6) [2/6/0], *Age* (6) [0/4/2], *Multi-Homing* (4) [0/4/1], *Information* (3) [0/3/0]
	Complementor (47) [31/32/19]	*Platform Engagement* (18) [13/6/2], *Performance* (13) [12/3/0], *Type* (11) [0/4/6], *Strategy* (10) [5/6/3], *Portfolio Size* (6) [1/4/1], *Portfolio Composition* (6) [1/4/1], *Experience* (6) [0/6/0], *Reputation* (5) [1/4/4], *Capabilities* (4) [2/2/2], *Generativity* (3) [3/0/0], *Perceptions* (3) [1/2/1], *Multi-Homing* (3) [1/2/1]
	Owner (28) [11/24/8]	*Governance Mechanisms* (16) [2/15/5], *Performance* (8) [8/0/0], *Market Entry* (7) [2/5/0], *Strategy* (5) [1/4/2]
	Platform (27) [4/21/6]	*Architecture* (9) [2/8/0], *Type* (8) [0/2/5], *Openness* (6) [1/5/1], *Word of Mouth* (6) [2/4/1], *Features* (4) [0/3/1]
	User (25) [23/16/10]	*Platform Usage* (14) [11/3/1], *Purchasing* (11) [11/2/0], *Type* (9) [0/5/4], *Perceptions* (8) [3/7/3], *Expectations* (7) [2/5/0], *Content Creation* (6) [6/4/1], *Satisfaction* (4) [4/4/1], *Search Effort* (4) [3/1/1]
Macro Layer	Ecosystem (51) [34/31/17]	*Complement Base Volume* (17) [10/12/2], *User Base Volume* (13) [6/10/1], *Performance* (12) [11/3/1], *Maturity* (8) [0/3/6], *Complement Base Variety* (7) [2/6/1], *Complementor Competition* (6) [2/4/2], *Complement Performance* (6) [5/1/1], *Complementor Base Volume* (5) [2/3/0], *Complementor Generativity* (4) [3/1/0], *Complement Base Multi-Homing* (3) [1/2/1], *Community Attention* (3) [2/3/0]
	Market (10) [2/5/3]	*Performance* (3) [0/1/2], *Competing DPE Performance* (3) [2/1/1]

Table 3. Recurring constructs by level of analysis. (Total study count). [Study counts for usage as dependent/independent/moderator variable].

The most prevalent constructs for the **complementor level** were *Platform Engagement* and *Performance*, which were both generally studied with dependent variables. *Platform Engagement* relates to a complementor's participation in a DPE by offering (Venkatraman and Lee, 2004; Wang and Miller, 2020) or not removing (Tiwana, 2015b; Zhu and Liu, 2018) products and services, as well as contributing code (Moqri et al., 2018). *Performance* was mostly operationalised through financial measures such as revenue or market share (Ceccagnoli et al., 2012; Li et al., 2019; Tanriverdi and Chi-Hyon, 2008). Solely operationalised with dependent variables, *Generativity* measured innovation efforts, e.g. through app updates (Boudreau, 2012; Foerderer et al., 2018). Commonly utilised independent variables related to a complementor's *Portfolio Size* (He et al., 2019), *Portfolio Composition* (Rietveld et al., 2019) or *Experience,* measured as number of prior releases (Yin et al., 2014) or active time in the ecosystem (Boudreau, 2012). *Strategy* encompassed competitive pricing (Zhu and Liu, 2018), marketing (Sun et al., 2020) or portfolio choices (Wen and Zhu, 2019) and was studied with both independent and dependent variables. Complementor *Reputation* (Sun et al., 2020) and *Type* were operationalised through independent or moderator variables. Thereby, *Type* was utilised across studies to explain heterogeneity within a group of complementors, e.g. by country of origin (Hong and Pavlou, 2017) or organisational size (Miric et al., 2019). The remaining constructs described participation behaviour on multiple platforms (*Multi-Homing,* Landsman and Stremersch 2011), *Perceptions* of platform attractiveness and governance (Benlian et al., 2015) and *Capabilities* such as intellectual property and marketing (Huang et al., 2013). Studies at the complementor level included Ceccagnoli et al.'s (2012) analysis of how an independent software vendor's participation in SAP's platform ecosystem (*Platform*

Engagement) together with its IP protection and marketing *Capabilities* influences *Performance* measures such as sales and IPO likelihood.

At the **owner level**, only *Performance* was primarily analysed as a dependent variable, comprising financial measures such as revenue, market share or firm survival (Chakravarty et al., 2014; Dushnitsky et al., 2020). *Governance Mechanisms* such as boundary resource provision (Karhu et al., 2018), input control (Thies et al., 2018) and complement endorsement (Rietveld et al., 2019) were mostly operationalised with independent variables. Similarly, other constructs explained the effects of *Market Entry* through first-party complement distribution (Foerderer et al. 2018; Zhu and Liu 2018) and marketing, collaboration or transaction *Strategy* (Dushnitsky et al., 2020; Gnyawali et al., 2010). An exemplary study at the owner level by Dushnitsky et al. (2020) analyses the effects of a platform firm's transaction *Strategy* and differentiation on its downside *Performance*, measured as firm dissolution.

The **platform level** contained mostly constructs studied as independent variables, concerning technical aspects (*Architecture*, *Type* and *Features*), access (*Openness*) or quality (*Word of Mouth*). *Architecture* was measured with generational platform transitions or development complexity (Cennamo et al., 2018; Kapoor and Agarwal, 2017; Ozalp et al., 2018), while *Features* referred to affordances such as machine translation (Brynjolfsson et al., 2019) or social network integration (N. Huang et al., 2017). *Type* was utilised mostly as a moderator to explain heterogeneity across platform specialisations, e.g. in meta-analyses (You et al., 2015). Lastly, *Openness* described technical interoperability with outside platforms, utilisation of open standards and the degree of integrating third-party complementors (Boudreau, 2010; Ondrus et al., 2015), while *Word of Mouth* referred to effects of integrated reviews (Babić Rosario et al., 2016; N. Huang et al., 2017). Most platform studies also included the owner level. An example of this is the study of Karhu et al. (2018), which explores how the provisioning of boundary resources (Owner *Governance Mechanisms*) influences a platform's *Architecture* and *Openness*.

At the **user level**, constructs operationalised as dependent variables focussed on *Platform Usage*, *Purchasing* or *Content Creation* behaviour. Thereby, *Platform Usage* was measured through platform adoption, visits or content consumption (Ahn et al., 2016; Albuquerque et al., 2012; Katona et al., 2011), whereas *Purchasing* was quantified through purchase rates or expenditures (N. Huang et al., 2017; Zhang et al., 2020). Similarly, *Content Creation* was determined through contribution likelihoods and volume (Ahn et al., 2016; Chen et al., 2018). A less utilised construct, *Search Effort* measured the consideration sets of buyers on their order journey (Dinerstein et al., 2018; Li and Netessine, 2020). *Perceptions*, *Expectations* and *Satisfaction* were analysed in varying roles, respectively referring to perceived ease of use, gains and risks (Krasnova et al., 2010; Xu et al., 2010), anticipations, intentions and goals (Albuquerque et al., 2012; Kankanhalli et al., 2015) and usage satisfaction or motivation (Chen et al., 2018; Q. Huang et al., 2017). Lastly, *Type* explained heterogeneity between users as independent or moderator variables, e.g. gender, age or personality (Katona et al., 2011). An exemplary study at the user level by Albuquerque et al. (2012) analyses *Expectations* and prior behaviour as drivers of future *Platform Usage*, *Purchasing* and *Content Creation*.

Within the **macro layer**, studies analysed constructs pertaining to the study's platform ecosystem and its encompassing market. At the **ecosystem level**, constructs described the networks of complementors and users interacting by providing or utilising complements on the platform. The only exception is posed by the ecosystem's *Maturity*, which is measured via a platform's age (Landsman and Stremersch, 2011) and employed as an independent or moderator variable. As with the micro layer, success measures, such as the ecosystem's *Performance*, its *Complement Performance* or *Complementor Generativity*, are mostly studied as dependent variables. Thereby, ecosystem *Performance* is measured through sales, market share, usage or transaction volume (Cennamo, 2018; Dushnitsky et al., 2020; Landsman and Stremersch, 2011). Similarly to their micro counterparts, the ecosystem's *Complement Performance* and *Complementor Generativity* were assessed with ecosystem-wide sales measures (Brynjolfsson et al., 2019) and measures of innovation efforts, such as app releases (Wen and Zhu, 2019). Further dominant constructs simply described the installed base of actors and artefacts on the platform (*Complement Base Volume*, *User Base Volume*, *Complementor Base Volume*), which were commonly studied with both dependent and independent variables to analyse dynamic same- and cross-side network effects (Boudreau and Jeppesen, 2015; Chu and Manchanda, 2016; Song et al., 2018; Thies et al., 2018; Zhu and Iansiti, 2012). The remaining constructs described the *Complement Base Variety* (Boudreau, 2012; Taeuscher and Rothe, 2020), as well as *Complementor Competition* (Cennamo and Santaló, 2013; Venkatraman and Lee, 2004) and *Complement Base Multi-Homing* (Landsman and Stremersch, 2011) at the ecosystem level. Lastly, some online community studies also utilised a *Community Attention* construct to measure effects of peer recognition (Chen et al., 2020; Q. Huang et al., 2017). As an exemplary study at the ecosystem level, Chu & Manchanda (2016) analyse cross and direct network effects on Taobao.com (*User Base Volume*, *Complementor Base Volume*).

Only ten studies considered the **market level**, with two constructs studied three times. *Market Performance* was analysed as an independent or moderator variable to describe the influences of industry growth and demand on an ecosystem's actors (Wang and Miller, 2020). *Competing Platform Performance* was studied in all three roles, analysing its dynamic interplay with a focal DPE's performance (Krijestorac et al., 2020). The study of Li & Agarwal (2017) incorporates the market level by analysing the effect of Facebook's integration of Instagram on the wider photo-sharing ecosystem.

In summary, we make **three observations**: **First**, there are archetypal constructs that were analysed for several levels of analysis, including *Performance*, *Word of Mouth*/*Reputation*, *Maturity*/*Experience*, *Architecture, Strategy, Multi-Homing* and *Type*. These are covered in a large part of our sample, with *Performance* constructs alone occurring across 60 out of 97 studies. **Second**, most constructs were predominantly analysed in a focus role, either with dependent (*Performance*, *Platform Engagement, Platform Usage, Purchasing*), independent (*Governance Mechanisms, Architecture, Price, Perceptions*) or moderator variables (*Type, Maturity/Experience*). Constructs studied in the field of network effects seem to pose an exception, as they were often analysed with dependent and independent variables to examine their interrelation at the ecosystem level (*Complementor Base Volume, Complement Base Volume and User Base Volume*). **Third**, despite this focus on certain roles, over two thirds of constructs (39) are analysed at least once with both dependent and independent variables, creating an opportunity to be studied as mediators of longer causal link chains spanning more than two constructs.

4.3 Causal links between levels of analysis

In the following, we present our analysis of causal links, starting with a **frequency matrix** detailing the number of studies analysing links within and between levels of analysis (Table 4). While moderated links are included, the moderator's level of analysis is not incorporated for simplification. As studies may analyse links between several levels, cells do not need to add up to their row or column totals.

Independent Variable Level / Dependent Variable Level		Micro					Macro		Total
		Complement	**Complementor**	**Owner**	**Platform**	**User**	**Ecosystem**	**Market**	
Micro	**Complement**	17	10	9	2	/	5	1	**30**
	Complementor	5	18	5	4	1	6	2	**31**
	Owner	2	2	6	4	/	3	/	**11**
	Platform	/	/	3	2	/	/	/	**4**
	User	2	2	3	2	15	8	1	**23**
Macro	**Ecosystem**	2	1	8	12	1	16	2	**34**
	Market	/	/	1	1	/	/	/	**2**
Total		**26**	**32**	**24**	**21**	**16**	**31**	**5**	**97**

Table 4. Number of studies analysing causal links between levels of analysis. '/' equals zero. Independent variable level of analysis in column, dependent variable level in row.

We make **three observations**: **First**, some levels of analysis exhibit a clear tendency to be studied more often with either independent or dependent variables. Both owner and platform are analysed mostly with independent (24 and 21 studies) compared to dependent variables (11 and 4 studies), meaning researchers predominately use their constructs to explain effects on other levels. On the other hand, the user is represented with dependent variables in 23 studies and independent variables in only 16 studies, indicating that researchers generally tend to explain user behaviour rather than inferring effects from it on other levels. **Second**, levels of analysis can be split into those utilised to explain intra-level and extra-level behaviour. For complement, complementor, user and ecosystem, over half of studies employing independent variables at their level use these to explain their own behaviour. In contrast, only one fourth of owner (6 out of 24) and one tenth of platform studies (2 out of 21) utilise their independent variables to explain intra-level behaviour, though they show causal links to all other levels. **Third,** only about half of our studies bridge the two layers of analysis, thus analyzing how individual DPE actors and artefacts shape their ecosystem or market, and vice versa. While we noted in the prior subsection that 57 and 92 studies employed constructs at the macro and micro layer respectively, an auxiliary analysis showed that 43 studies analysed links across the two layers, though this increases to 49 when including moderators. Bridging studies include the study of owner and platform constructs driving ecosystem behaviour (Wessel et al., 2017; Xue et al., 2019), and ecosystem constructs affecting constructs on the complement (Eckhardt, 2016), complementor (Boudreau, 2012), owner (Chakravarty et al., 2014) or user level (Ahn et al., 2016).

Finally, we visualised the causal links (edges) between individual constructs (nodes) by plotting them as a **nomological network** (Figure 2). To simplify interpretation, we only include direct empirical relationships found to be significant in at least two studies, ommitting moderated links. As a result, 49 causal links (out of 175), including 36 of our 51 identified constructs are shown here. While both layers of analysis are covered, the market level had no repeated causal links and is thus excluded.

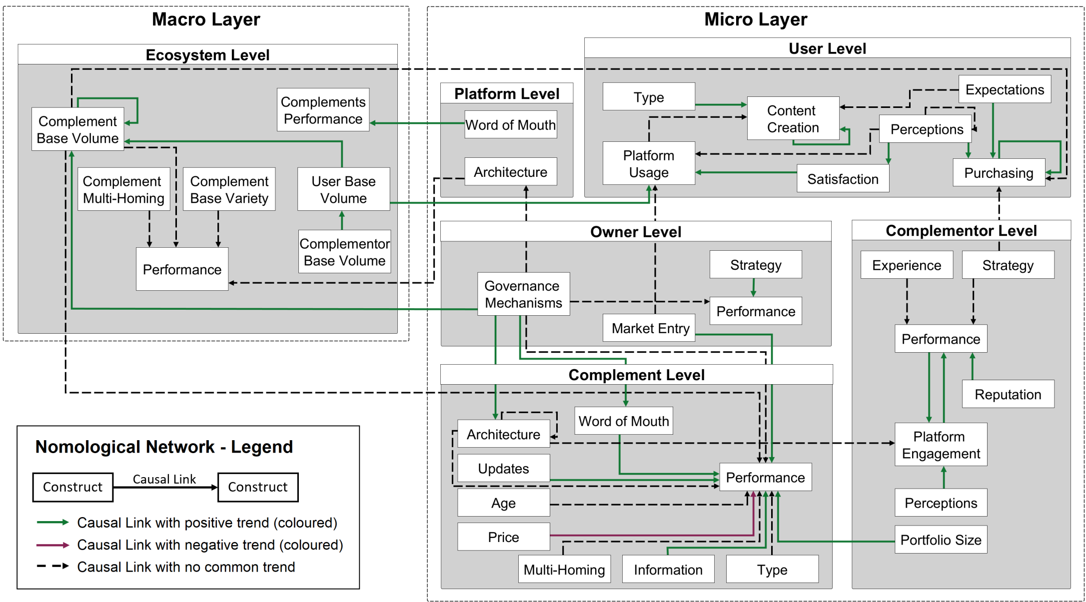

Figure 2. Nomological Network of causal links with significant effects in at least two studies.

The nomological network allows us to analyse the most frequently studied causal links and explore whether they had a common positive or negative trend (edge colour), for which we require at least 75% of underlying studies to evidence the trend. We find that causal links explaining constructs that ultimately drive economic DPE success (*Performance*, *Platform Engagement*, *Platform Usage*, *Purchasing* and *Content Creation)* are predominant as these make up 40 of the 49 causal links.

Even though all of our extracted significant causal links have been coded as either positive or negative, only 25 edges in the nomological network are shown with an aggregated positive or negative trend. These include e.g. the negative effects of *Price* and the positive effects of *Word of Mouth* and *Updates* on *Performance* at the complement level across a range of DPE categories, such as app stores (Ghose and Han, 2014; Tiwana, 2015a), video game consoles (Cennamo and Santaló, 2019) and social media and online communities (Lee et al., 2015; Lu et al., 2013; Zhu et al., 2020). As another example, we find repeated evidence of positive self-reinforcing effects for an ecosystem's *Complement Base Volume* (Ahn et al., 2016; Thies et al., 2018; Xue et al., 2019) or user's *Content Creation* (Ahn et al., 2016; Albuquerque et al., 2012; Chen et al., 2018), together with mutually reinforcing effects of a Complementor's *Performance* on its *Platform Engagement* and vice versa (e.g. Ceccagnoli et al., 2012; Wang and Miller, 2020). However, even for causal links with repeated evidence for a common trend, such as an ecosystem's *User Base Volume* positive effect on its *Complement Base Volume* (Boudreau and Jeppesen, 2015; Gretz et al., 2019; Zhu and Iansiti, 2012), there can be single cases for which these did not hold (Thies et al., 2018), making an inference of generalisability premature. Additionally, trends should be interpreted cautiously due to the high level of abstraction: Even though multiple studies showed that an owner's *Strategy* can positively influence its *Performance* (Chakravarty et al., 2014; Fang et al., 2015; Gnyawali et al., 2010), the underlying variables represent very different practices, from which one cannot infer that following a strategy is generally beneficient to performance.

The remaining 24 edges show no trend due to conflicting evidence. For example, while we found two studies with a positive effect of a complement's *Multi-Homing* on its *Performance* (Ghose and Han, 2014; Krijestorac et al., 2020), a third study found a negative effect (Pervin et al., 2019), leading us to infer no trend. As two studies (Ghose and Han, 2014; Pervin et al., 2019) were even conducted in the same DPEs (Apple iOS and Google Android), we cannot yet tell where this heterogeneity emerges from.

In closing, while the nomological network provides a condensed overview of recurring causal links and constructs, only 49 out of 175 distinct causal links (28%) and thus 337 out of 670 significant extracted causal links (50%) from our data are represented here. This means that there is a long tail of 126 distinct causal links between recurring constructs which were not replicated in our sample, representing a large body of knowledge that cannot be effectively summarised at the time.

5 Discussion

By presenting a synthesis of DPE constructs and causal links, we provide a current integrative overview of the field. We interpret and discuss our findings along three avenues for future research.

Connecting the isolated parts for an emergent multi-level perspective. Surveying empirical relationships across the field, we recognise that most studies analysed isolated parts of a DPE, such as complement(or) performance or user behaviour, often without considering these actors' environments. Yet, while most articles reduce the complex DPE phenomenon to small subsets of distinct constructs, our synthesised nomological network reveals manifold connections and dependencies between them (Figure 2). As platform ecosystems are inherently dynamic and multi-level systems, not incorporating multiple levels of analysis during research may lead to common fallacies that impair construct and internal validity (Burton-Jones and Gallivan, 2007). As a result, we call for future research to leverage these connected parts for an emergent multi-level perspective of DPE research: A promising direction could be to study the emergence of collective constructs in DPE, which result from an ongoing series of events and interactions of their individual entities (Morgeson and Hofmann, 1999). Recent research on 'DPE resilience' already emphasized the explanatory power of collective constructs to explain the success of DPE emerging from joint series of (inter-)actions by leveraging the platform-based nature and the ecosystem (Floetgen et al., 2021). Similarly, our nomological network provides a novel basket of opportunities to analyze not only emergent multi-level, but also multi-dimensional constructs: For example, DPE *Performance* might be more meaningful than just the sum or average of its actors' performances, as it was commonly studied in our sample (e.g., overall transaction volume). Thus, an emergent perspective of DPE *Performance* should represent more than mere financial measures, as success is not a property shared across actors (Wang, 2021). Similar to DeLone and McLean (1992) with their IS

Success model, future research could thus propose an interdependent and multi-dimensional view on the collective phenomenon of DPE *Performance*.

Looking ahead: Complex dynamics in DPEs. Our study shows that only few authors seem to look for longer causal link chains, with most studies trying to identify individual constructs that drive the economic performance of the ecosystem and its actors. While this reductionism is vital in achieving robust results, it tends to ignore the function of DPEs as a whole, where one effect can quickly become a new cause. A laudable example of a study 'looking ahead' is the analysis of Amazon's entry into the product spaces of its marketplace vendors by Zhu and Liu (2018), who find that Amazon is more likely to compete with sellers that offer successful products on the platform, which then negatively affects their future growth, thereby even closing a feedback loop. While only few comparable loops (e.g. Complementor *Performance* ←→ Complementor *Platform Engagement*) are currently evident in our nomological network (Figure 2) due to its high level of abstraction, one could extend it with further constructs and causal links outside our sample, possibly also by engaging industry experts, to uncover more avenues for emergent dynamics. As an example, possible additions include logically-inferable connections, such as a positive link between user *Purchasing* and ecosystem or complementor *Performance*, as well as the positive effects of developer-friendly *Architecture* on the ecosystem's *Complement Base Volume* (Ozalp et al., 2018) or changes in actor's behavior (e.g., complementor *Platform Engagement*) based on the ecosystem's *Performance* (Venkatraman and Lee, 2004). Broadening our horizon this way, a multitude of new and longer feedback loops emerge, of which we will consider one example: Owner *Governance Mechanisms* → Platform *Architecture* → Ecosystem *Complement Base Volume* → Ecosystem *Performance* → Owner *Governance Mechanisms*. In prose, platform owners may develop boundary resources to simplify their platform's architecture, which hopefully leads to a rise in complements developed for the platform, extending the DPE's value proposition and further increasing its transaction volume. The effectiveness of this approach will then affect the owner's future governance behavior and boundary resource development. In sum, we propose that the connected DPE constructs span new and longer feedback loops beyond established network effects, which may have profound implications for the prediction of future system behaviour (Benbya et al., 2020; Sterman, 2000) and our understanding of DPEs as a whole (Wang et al., 2021). Similarly to Clark et al. (2007) for management support systems or Fang et al. (2018) for overall IS research, we propose to analyse DPEs with a systems approach to consider their emergent dynamics and function as a whole, an appeal which is also in line with calls to further integrate a complexity perspective into platform ecosystems research (Phillips and Ritala, 2019).

Learning from heterogenity: Towards new insights from generalizing across DPE contexts. Prior reviews of the DPE field include diverse examples of DPEs, ranging from Microsoft's Xbox and SAP's cloud ERP ecosystem to Facebook and Wikipedia (Hein et al., 2019; McIntyre and Srinivasan, 2017; Schreieck et al., 2016). Similarly, our sample contains a multitude of profit and non-profit platforms with wildly different business models that fit the Hein et al. (2019) definition of a DPE. For instance, both Microsoft Xbox and Wikipedia are digital platforms that derive their value largely from their complements, yet in one case these are professionally-developed video games, while in the other they are crowd-sourced pieces of information. Interestingly, we still find the same themes analysed across DPE contexts, as we managed to attribute 606 of our 648 extracted variables to recurring constructs. However, as we fail to find repeated trends for many causal links, such as a complement's *Multi-Homing* on its *Performance* (Ghose and Han, 2014; Krijestorac et al., 2020; Pervin et al., 2019), this heterogeneity might unlock a novel approach of differentiation for DPEs: While a clearly positive or negative trend of a causal link could indicate a genrealisable "core causal link" valid across different DPE contexts, causal links with conflicting evidence might provide a promising starting point to differentiate DPEs based on their unique empirical relationships. This method to conceptualize their differences would go beyond established distinctions of digital platforms types based on value creation strategies, such as innovation and transaction (Cusumano et al., 2019), by inductively leveraging the empirical body of knowledge in DPE research. Moreover, we hope to inspire future research to analyse even further sources of heterogenity across DPEs (e.g., maturity stages, complementor types: in-house, 3rd party, etc., or even the combination of different sources) to gain novel and deeper understandings of DPEs and bridge their isolated insights.

6 Conclusion

Empirical research on DPEs is fragmented across different research streams, lacking a holistic overview. However, this body of academic literature constitutes the most comprehensive, rigorous, and reliable set of evidence on the field. Going with Steve Job's famous quote: "You can't connect the dots looking forward – you can only connect them looking backwards", we analyse 97 empirical studies in top IS and management journals. Thereby, we synthesised this body of academic literature into 51 recurring constructs with distinct causal links across seven micro and macro levels of analysis, showing existing foci and gaps and contributing towards bridging different research streams of DPE. As such, this paper shifts the focus from finding what autonomous actors in DPE interact (Riasanow et al., 2018; Riasanow et al., 2020) towards a deeper understanding of how the actors in DPE interrelate.

Naturally, our approach is not without limitations, leading us to critically discuss three aspects. First, despite our large sample of 97 empirical studies, our set of constructs and causal links cannot be considered exhaustive, as we limited our keyword search to a set of top journals without forward/backward search, excluding other refereed publications and top conferences. While a sole focus on top journals has been criticised in the past for reasons such as lack of comprehensiveness and publication bias, we believe it to be justifiable to ensure the inclusion of only the most rigorous empirical evidence and the explicitness and reproducibility of our approach. Still, future research could consider an even larger body of literature, also including further research areas such as software engineering. Second, while knowledge about the existence of positive or negative trends for significant causal links is valuable, it does not allow for detailed comparison. In particular when two causal links influence a focal construct in diverging directions, we cannot judge whether one outweighs the other without knowing their effect sizes. Thus, uncovering the strength of causal links across DPE contexts is another avenue for future work. Third, our review may suffer from issues of generalisability. On one hand, grouping variables into constructs is a partly-subjective task, which simplifies the results of studies to make them comparable, potentially losing granular insights in the process. We addressed this subjectivity by following grounded theory guidelines and discussing our clustering within the author team. On the other hand, generalisability of causal links to other DPE contexts was a regularly-cited limitation in our study sample. Thus, one should carefully evaluate whether a specific causal link is transferable to one's own research or business, which may require further analysis.

Our findings have profound implications for both DPE research and practice. From a theoretical perspective, we developed a holistic and connected overview of constructs and causal links in a quickly evolving and fragmented field (i.e. the 'What's' and 'How's' of theory, Whetten, 1989). Thus, we combine empirical knowledge across largely unconnected areas and showcase boundary constructs that can bridge theories. By formulating three aveues for the future of DPE research, we show how our perspective on the DPE research field can contribute to future theory development. From a practical perspective, we shed light on cause-effect relationships and effect chains in DPE. Prior research has shown that managers are often unable to correctly judge outcomes in complex socio-technical systems (Sterman, 1989, 2000). Demonstrating the connectedness of constructs within DPE, we enable managers to anticipate possible implications of their actions. This removes ambiguity about the effectiveness of interventions and improves decision-making, informing the future design and management of successful DPE.

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Introducing platform ecosystem resilience: leveraging mobility platforms and their ecosystems for the new normal during COVID-19

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Introducing platform ecosystem resilience: leveraging mobility platforms and their ecosystems for the new normal during COVID-19

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ABSTRACT
COVID-19 has created many constraint-related challenges for humans in general and organisations in particular. Specifically, businesses that require physical contact, such as mobility providers, have been severely impacted by the crisis. This paper reveals how mobility platforms and their ecosystem of actors have adapted faster than their non-platform competitors to become resilient. Whereas current research on resilience explicitly deals with the concept of organisational resilience, community resilience, or IT resilience, socio-technical characteristics of digital platforms have not been investigated. We build on a case survey approach, including heterogeneous qualitative evidence of 266 actions of 171 analysed mobility platforms. The results show five archetypes of how mobility platforms leverage their platform-based nature and the ecosystem to build resilience. Based on this, we develop the concept of platform ecosystem resilience as leveraging socio-technical factors of digital platforms and ecosystems frugally to design, deploy and use situation-specific responses to prepare for, endure and adapt by capturing new opportunities and engaging in transformative activities to cope with exogenous shocks and become resilient for future disruptions. Our results emphasise the importance of platform ecosystems for practitioners and policy planners to develop the "new normal" rather than resuming existing practices.

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1. Introduction

Never in modern times, and in such a short time frame, have the great majority of industries and societies faced a severe exogenous shock as COVID-19. The pandemic has brought unprecedented adverse effects to human healthcare systems, the economy, and social life. Driven by the need to dampen the exponential growth of the virus, governments have had to impose lockdowns and severe contact restrictions (UK Government, 2020), which have put enormous pressure on cities and communities, as both businesses and private institutions have had to adapt to these conditions.

In particular, these restrictions have severely impacted mobility platforms. By offering physically shared assets, digital matchmaking, and real-world interactions (Trenz et al., 2018), mobility platforms are exposed to constraint-related challenges in the physical world (Constantiou et al., 2016) and a dynamic and competitive digital environment. For example, real-world interactions and shared physical assets stand counter to social distancing requirements and the fear of infection (Hertzke et al., 2020). For this reason, mobility platforms have experienced adverse effects: spending on ride-hailing and bookings of electric scooters fell significantly (Leatherby & Gelles, 2020), and some operators had to pull out of certain cities (Bliss et al., 2020). Furthermore, the ever-growing number of private mobility platforms participating in the market (Lang et al., 2019) have had to compete for a reduced set of resources (such as customers) because of the pandemic. This effect has been accelerated as large areas of cities were made car-free to encourage walking and cycling (Taylor, 2020).

Despite the drawbacks of COVID-19, some mobility platforms have not only been resilient enough to survive the crisis but are thriving. For example, GoTo Global, GreenCar, and Meituan (formerly Mobike) have reported significant increases in users and trips (e.g., Laser, 2020) and already exceeded their set pre-lockdown business objectives of growth and profitability (Lunden, 2020). Mobility service platforms have capitalised on their platform-based nature to respond to the crisis. Some ride-hailing providers have opened up their digital platforms to local public authorities by offering a wide range of digital features. These include trip planning, real-time tracking, and navigation of vehicles to optimise the delivery of emergency logistics (e.g., ViaVan, 2020a) or to enable the creation and display of routing options, taking

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social distancing requirements for public transportation use cases into consideration (e.g., Spare, 2020).

Furthermore, mobility platforms have utilised their platform ecosystem to pivot out of the crisis-related limitations and become resilient: the peer-to-peer (P2P) ride-sharing provider "BlaBlaCar" has successfully introduced a new platform through which communities can support one another with grocery shopping during COVID-19. Not only did 20,000 people register within 72 hours, but the mobility platform subsequently experienced a significant increase in summer holiday bookings via its platform (McLaren, 2020). The new community platform, complemented by actors of the ecosystem, even led to positive cross-platform effects, which, in turn, gave rise to a level of bookings exceeding the pre-crisis level for certain travel destinations.

Research shows that the concept of resilience has proven useful in overcoming exogenous shocks such as COVID-19 (e.g., Rapaccini et al., 2020; Sakurai & Chughtai, 2020). However, research on resilience has not reached theoretical convergence; nor is there an understanding of how resilience can be built through the interplay of digital platforms and the ecosystem. Different research streams of resilience have developed isolated definitions, theories, and understandings in different contexts and on different levels (Linnenluecke, 2017). For example, research on the organisational scope of resilience (e.g., Urciuoli et al., 2014) falls short in accounting for the large set of opportunities that comes with platform ecosystems (Hein et al., 2020). On the contrary, the stream of community resilience (e.g., Hamann et al., 2020) does not account for the organisational level of resilience. Recently, there have been calls for papers to tackle the research gap in understanding resilience using information technology (Boh et al., 2020; Sakurai & Chughtai, 2020). Digital platform ecosystems represent a novel context showing that the socio-technical factors of the technical platform and its social ecosystem can be combined to develop resilience. Therefore, we explore the following research question:

1.1. *How can digital platforms and the ecosystem be leveraged to develop resilience during the COVID-19 pandemic?*

We follow the case survey method (Larsson, 1993) by applying the Eklund and Kapoor (2019) approach to analyse the announcements of mobility platforms regarding actions taken to cope with the pandemic. We reveal five archetypes of platform ecosystem resilience and derive the first conceptualisation of platform ecosystem resilience. The five archetypes represent patterns of how digital platforms can leverage the socio-technical factors of both the platform and the ecosystem to become resilient in the short and medium terms. We demonstrate that resilience is built frugally, socio-technically and contributes to a transformative "new normal" instead of "preserving the past," or leaping back to a pre-crisis state. The archetypes influence resilience on different levels, ranging from the platform owner's organisational resilience to the ecosystem resilience of complementors, to community resilience on a societal level.

2. Theoretical Background

The concept of resilience has been a prominent and emerging topic in various disciplines such as ecology, psychology, engineering, management, and information systems (Müller et al., 2013). Resilience originated at the individual level from social psychology, denoting positive engagement with internal failures, weaknesses, deviations, or impacts as they become apparent (Sitkin, 1992). Resilience has been adopted at different levels of analysis, such as the organisational, group, and community levels (Taani & Faik, 2019). As platforms orchestrate an autonomous ecosystem of actors through socio-technical means (McIntyre et al., 2020), the concepts of IT, organisational, and community resilience need to be considered. Moreover, we outline extant research on resilience in the context of a crisis as an exogenous shock, as the latter serves as a useful conceptualisation of the ongoing COVID-19 situation.

2.1. *IT resilience*

Research on IT resilience is manifested as a capability of a system itself. Examples are an information system's ability to anticipate risk and avoid potential losses (e.g., Hollnagel et al., 2006) and quickly recover from disturbances (e.g., Haimes et al., 2008). As part of organisational resilience, IT has been investigated from a backwards-oriented perspective by referring to resilience as the maintenance of system properties (Leveson et al., 2006), core practices and goals (Walker & Salt, 2012), a rebound of a system to its original state, or a continuation of its mission despite disruption (Müller et al., 2013).

Although the nature of COVID-19 heralds the need to develop resilience on a broader scale (e.g., society, organisations), only a few papers explore how information systems affect the resilience of a higher-level system. For example, the extent to which the use of ICT supported a set of ecological literature-derived resilience attributes applied to social communities has been investigated (Heeks & Ospina, 2019). This high level of abstraction, however, falls short in explaining organisational resilience building. This is aggravated by the lack of any empirical investigation that includes real-world examples of how IT can be used to build resilience. Our study goes beyond the traditional IS focus on how strong the "sword" (IS system) is, but to investigate how the "sword" (here: digital platform) can be used to build resilience. Moreover, despite two exceptions (Sakurai & Chughtai, 2020; Sakurai & Kokuryo, 2014), the literature on IT resilience does not account for exogenous shocks such as COVID-19.

2.2. Organisational resilience

On an organisational level, resilience has evolved from responses to external threats (Staw et al., 1981), to resilience as reliability (Weick, 1993), adaptable business models (Sutcliffe & Vogus, 2003), and design principles to reduce organisational vulnerabilities (Gittell et al., 2006). The focus has shifted towards an internal perspective of resilience, dealing with the reliability of processes and avoiding failures (Linnenluecke, 2017).

Later, the concept of adaptability and focus on external events was revisited. An organisation's ability to adapt to overcoming an immediate situation of adversity includes the development of flexible resources (Dierickx & Cool, 1989). Resilience can be achieved a priori by sensing and preparing an organisation for unknown threats or a posteriori by responding to identified threats. Building a priori resilience constitutes a continuous process of sensing for example, constant renewal (Wastell et al., 2007) or detection of drifting towards failure (Dekker, 2006). In turn, a posteriori resilience refers to a more recent stream of research that focuses on detecting a threat and activating an organisational response (Burnard & Bhamra, 2011).

When responding to external threats, firms can be backward- or forward-oriented. Backwards-oriented actions mean "bouncing back" to a previously existing "shape" (Sutcliffe & Vogus, 2003) and restoring normal operations of its essential structures and functions (Rice & Caniato, 2003). Forward-oriented actions, meanwhile, bring renewal beyond mere "adaptation" and rebound to the centre of resilience (Hamel & Välikangas, 2003). Forward-oriented actions refer to a proactive way of dynamically responding to situations. Examples are transforming (Walker & Salt, 2012), developing a new identity (Wastell et al., 2007), or capturing new opportunities (Hamel & Välikangas, 2003). This stands in contrast to returning to an original state that was unable to cope with the immediate shock in the first place (Sakurai & Chughtai, 2020). Thus, the forward-oriented, transformative role of resilience is thus greatly under-investigated.

2.3. Community resilience

Research on resilience also focuses on communities as social groups that prepare, respond, and recover from crises that challenge their social, political, or economic stability (Adger, 2000; Lee et al., 2013). Community resilience is "the ability of community members to take meaningful, deliberate, collective action to remedy the effect of a problem, including the ability to interpret the environment, intervene, and move on" (Pfefferbaum et al., 2007). The current literature shows the first indications that ecosystems, like communities, might also be important as a factor influencing resilience. For example, the interference of strategic social and environmental business practices, e.g., through interdependencies with diverse actors (DesJardine et al., 2019), as well as self-organising ecosystems and their impact for necessary social service provision (Belso-Martínez et al., 2020), has been investigated.

2.4. Resilience in times of exogenous shocks or crises

The nature of the involved threats can be a minor interruption or severe disruption resulting from exogenous events (Linnenluecke, 2017). We follow the latest research and conceptualise the COVID-19 pandemic as disruptive (Sakurai & Chughtai, 2020) for the following reasons. It has been challenging to prepare for the pandemic (Gephart et al., 2009), collectively experienced immediately due to sudden outbreak (Kaniasty & Norris, 1993), and this has had a global impact (Oh & Oetzel, 2011), with significant effects for both business and society (McEntire, 2015). As it was difficult to foresee, leading to radical socio-economic effects, this pandemic comes with a high level of complexity and uncertainty concerning the situation before, during, and after the initial outbreak.

The concept of resilience has already been investigated in the context of exogenous shocks, including recent resilience studies in COVID-19 (e.g., Sakurai & Chughtai, 2020). Here, the focus is on resilience at the organisational or wider system level, such as community members or society. For example, it has been investigated how organisational resilience is manifested through the severity of loss and time to recovery (DesJardine et al., 2019). Considering the impact of the concept on a wider level, local community members' resilience through venture creation (Williams & Shepherd, 2016) and emerging social response networks (Belso-Martínez et al., 2020) have been investigated. However, there has not been a joint investigation of the two concepts, which might be worth considering, especially in the platform ecosystem context.

As the pandemic triggers multilevel effects (Sakurai & Chughtai, 2020), not only the technical design features of the IT system but also their combination with organisational and social features of the ecosystem that contribute to resilience and a "new normal," are needed. Although some research has already acknowledged the socio-technical character of resilience by outlining the potential contribution of technical attributes to organisational benefits such as decentralised decision-making (Müller et al., 2013), it falls short of understanding ecosystem-related factors as an influence on resilience in times of crisis. Moreover, we follow Sakurai and Chughtai (2020) and conduct our research beyond the mere concept of a system's resilience by empirically investigating how digital platforms can contribute to resilience on a broader scale. We build on the first indications of literature that show ecosystems as influencing factors and the level of impact as a gap in information systems research.

3. Method

We followed a case survey (Larsson, 1993), inductively deriving the socio-technical characteristics of mobility platform ecosystems and their ability to respond to the outbreak of COVID-19. The case survey method facilitates learning from a large amount of heterogeneous qualitative evidence represented by case studies. Case surveys further enable aggregate reviews of individual cases (Yin & Heald, 1975) and allow for cross-case identification of patterns without compromising scientific rigour (Larsson, 1993). By inductively coding responses to the crisis and how mobility platforms could recover, we followed the spirit of current research to contextualise resilience in a novel way (e.g., Heeks & Ospina, 2019).

As our goal was to enquire how resilience is developed in the context of digital platform ecosystems, we followed the process suggested by Eklund and Kapoor (2019) and collected announcements showing how mobility platforms have coped with the pandemic. Announcements included social media channels, application updates, websites, news sources, and other types of practitioner-oriented outlets, as research articles addressing the pandemic are still sparse. Our data collection took place between February 2020 and the end of August 2020, covering the pandemic's first global outbreak. With our initial sample, we included a vast majority of mobility platforms and announcements. We included every provider related to shared mobility services that we could find based on the Crunchbase list of European and worldwide mobility-related firms, finishing with a total of 577 platforms. By iteratively running a manual search by scanning their websites, social media posts, and third-party information for relevant announcements, we found a total of approximately 1,500 announcements. Although in our study, in the context of digital platform resilience, the focus of our data collection has been more on the "respond" and "recover" phase after the first wave of COVID-19 (a posteriori), we did not want to exclude any long-term effects of the platforms' responses that could help them to continuously adapt and be "prepared" before (a priori) the second wave of this turbulent event. A detailed screening of the actions concerning the relevance of COVID-19-related response mechanisms yielded a final sample of 266 relevant individual actions by 171 mobility platforms (= cases). We included every announcement related to responding actions to the pandemic of the mobility platforms. We excluded duplicates and irrelevant announcements, for example, announcements relating to pre-crisis achievements such as an increase in rides in the earlier months. This shows that not every mobility platform has carried out actions to cope with the pandemic.

We took a systematic inductive approach to data analysis and iteratively compared our data with the emerging concepts (Corbin & Strauss, 2008; Locke, 2001; Miles et al., 2014). Two authors coded the cases following a three-step coding approach – open, axial, and selective coding––as proposed by Strauss and Corbin (1990).[1]

4. Findings

The case survey reveals the five platform ecosystem resilience archetypes of diversification (AT1), business model adaptation (AT2), serving the public good (AT3), creating a meta-platform (AT4), and optimising service operation (AT5). Each archetype utilises platform- and ecosystem-specific properties to cope with the structural changes introduced by COVID-19 (see Table 1).

4.1. AT1: platform ecosystem resilience through diversification

The first archetype covers 42 mobility platforms that diversify their service portfolios, building on mobility platforms' modular architecture and the variety of ecosystem actors. Government policies (e.g., closed borders or social distancing) have drastically reduced transport, production, and consumption. The modular architecture of mobility platforms has enabled non-platform firms to extend or re-configure existing platform services. Most mobility platforms have extended service offers from individual mobility to delivering essential (e.g., groceries, medicine) and non-essential supplies (e.g., items from local shops, prepared food from restaurants and cafés). The variety of ecosystem actors further enables mobility platforms to diversify. For example, local restaurants and cafés have switched from eat-in to take-away or delivery-only meals. However, many of these "non-essential" businesses lacked the technological (e.g., smartphone application) and operational (e.g., ready-to-scale delivery processes) capabilities, as well as

Table 1. Platform ecosystem resilience archetypes.

	Platform Ecosystem Resilience Through				
No. of actions	AT1: Diversification 42 (= 16%)	AT2: Business Model Adaptation 29 (= 11%)	AT3: Serving the Public Good 101 (= 38%)	AT4: Creating a Meta-Platform 2 (= 1%)	AT5: Optimising Service Operation 92 (= 35%)
Description: measures that contribute to	Direct or indirect service diversification, with the majority involving new complementors and a new type of user	Adaptation of the business model, including adjustments in terms of channels, revenue streams, or value propositions	Collaboration with public service authorities or other companies of the mobility service industry to serve persons in need	Collaborative development of a joint platform that integrates available mobility service providers	Adjustments towards a safer, more efficient and cost-effective service operation
COVID-19 nature	Drastically reduced transport, production, and consumption	Changed customer requirements and altered consumption patterns	Public-private initiatives surged to achieve a common goal (public good)	Demand for the development of support networks between different organisations has surged	Need to limit the provisioning effort for continued service delivery "as little as possible, and as much as necessary"
Usage of the platform	Modular architecture	Platform externalities, speed of platform development	Matchmaking mechanisms, private-sector platform capabilities	Information aggregation as platform broker	Operational innovation on the platform
Usage of the ecosystem	Diversity of actors and the innovation strength of the individual ecosystem actors	Internal and external information about the existing installed base (customers)	Technological modularity of the ecosystem, the public-sector ecosystem as a business opportunity	Multiple isolated successful service offerings of individual providers	Ecosystem as a resource

assets (e.g., vehicles and drivers), needed for this transition. Consequently, other firms cooperated with mobility platforms as a relatively easy and quick-to-implement "turnkey" solution. For example, the technology provider Autocab created the new service "Delivery Point," which enabled non-mobility firms to offer an individual delivery service with local taxis (Smith, 2020).

Mobility platforms use their modular architecture when adapting their existing service processes (e.g., individual mobility) to a new service type (e.g., delivering goods). The modular architecture contributes to resilience, as existing platform services can be reconfigured or extended without significant effort. For example, the autonomous driving start-up Pony.ai repurposed its autonomous vehicle fleet for goods delivery with a new complementor, the e-commerce site Yamibuy (Ludlow, 2020). Yamibuy automatically assigns orders for groceries to the mobility provider's vehicles, and the packages are then delivered directly to customers with almost no customer interaction.

Mobility platforms of this archetype gain resilience using the ecosystem by amplifying their innovative potential through the diversity of actors and the innovation strength of the ecosystem. Users can rapidly shift from merely being consumers of the mobility service to offering complementary services. Besides, the ecosystem actors can offer their unique resources and capabilities, such as cooking skills (with restaurants as new complementors), in combination with mobility services, to overcome physical contact restrictions. Thus, both the platform and the complementor gain resilience. Besides, complementors can innovate and co-create value with the platform. Helbiz, for example, partnered with Italy's largest health products supplier, eFarma.com, to offer same-day delivery of COVID-19 safety kits (Spriano, 2020). Hence, platforms are not limited to their value creation but can utilise situation-dependent complementors to diversify their service offerings.

4.2. *AT2: platform ecosystem resilience through business model adaptation*

A total of 29 mobility platforms of this archetype have adapted their business models by exploiting platform externalities and customer information from the ecosystem. Mobility platforms harness the scale and implementation speed of digital technologies to quickly implement short-term adaptations to their business models (focal mobility service). These can be withdrawn whenever circumstances call for normality. With COVID-19, these business model adaptations are triggered mainly by changing customer requirements and altered consumption patterns. For example, office closures led to different commuting behaviours, creating a changed demand towards longer rental periods of various mobility-sharing services. Mobility platforms of this archetype adapt their business model to incentivise users to use the service despite the changed

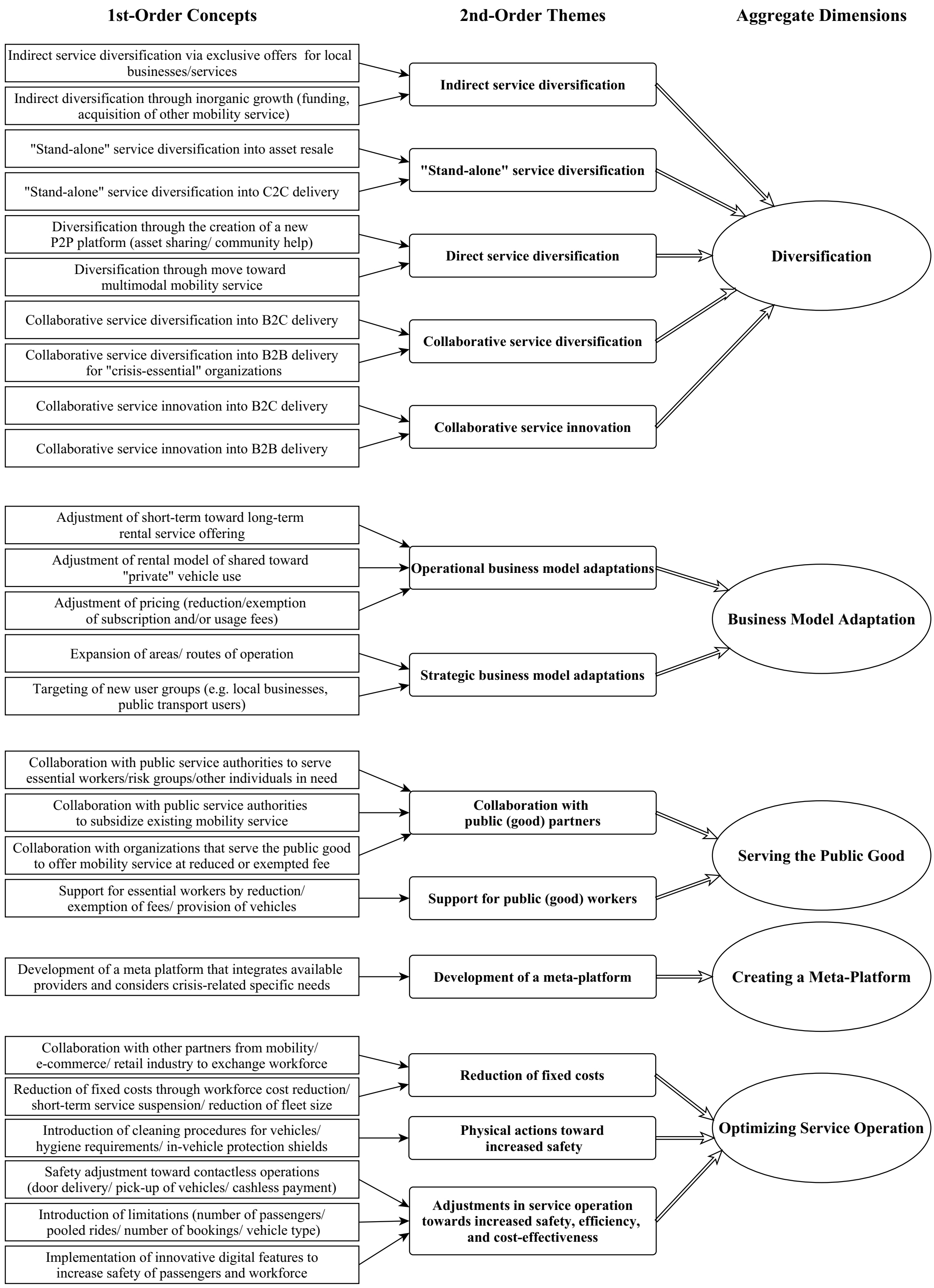

Figure 1. Overview of final Data Structure.

conditions. The resulting increase in service bookings can counteract the changed customer behaviour and contribute to resilience. For example, several providers, such as Yulu, Bounce, or SPIN, have started to offer long-term rental plans (e.g., weekly or monthly rates) in addition to their short-term rental models (per-minute or per-hour pricing; Bounce, 2020; Spin, 2020; Yulu, 2020a). Thus, the scale of platform adjustment helps mobility service platforms to easily adjust their business models to all customers in a scaled manner and at short notice as well as to undertake actions with a potential long-term impact on their existing services.

By adapting the business model, this archetype capitalises on platform externalities and speed of platform development to contribute to platform ecosystem resilience. For example, a large majority of providers quickly applied for short-term reductions or exemptions from subscription or usage fees within their mobile applications in the very first stage of the pandemic, between March and April 2020. For example, Whim App and GoVolt introduced short-term price reductions during the “first wave” of COVID-19 (GoVolt, 2020; Whim, 2020). By implementing exclusive pricing for certain groups, mobility platforms are also targeting new types of user: CityScoot offered discounted minute packages to employers (Cityscoot, 2020), which could then be transferred to employees. Building on platform externalities, the newly created services can scale, having reached a critical mass, and they have the potential to grow significantly.

Alongside the internal information from the ecosystem stored on the platform (e.g., aggregated customer-service-usage behaviour), mobility platforms can use additional external information from the ecosystem of actors. For example, knowledge about changed commuting needs (e.g., from customers calling the mobility platform; Frank, 2020) enables operators of mobility platforms to sense opportunities early and adapt existing services accordingly. Hence, mobility platforms could target additional short-term revenue streams as the crisis surfaces previously unseen demands. For example, Blade has introduced a limited amount of “Commuter Passes” for exclusive helicopter services from the Hamptons to New York for the first time (Davis, 2020). With increased office closures and work-from-home arrangements, the demand changed from weekend trips to houses in the Hamptons, to users living in the Hamptons and commuting to the city on an occasional basis. The passes sold out in less than 24 hours. Consequently, the stimulus of the ecosystem on the mobility platform contributes to platform ecosystem resilience by endorsing business model adaptation.

4.3. AT3: platform ecosystem resilience by serving the public good

This archetype covers 101 mobility platforms that build on platform matchmaking mechanisms and the technological modularity of the ecosystem, as well as the longevity and stability of the public sector. Mobility platforms collaborate with public service authorities (i.e., city governments, public transportation), humanitarian or public health-care organisations, local NGOs, or other companies of the mobility service industry to create joint initiatives. The COVID-19 pandemic affects both public and industrial corporations. Consequently, the new situation cuts across different policy areas and allows for the previously unseen public-private initiatives to jointly achieve public goals. Axon Vibe and its newly created “Essential Connector App,” for example, combine public and private transportation to help New York’s essential workers to move during nightly subway closures (Hawkins, 2020). The combination of the entrepreneurial spirit of private platforms and the longevity and stability of the public mission facilitates the creation of new services in the short term and alliances that might last beyond the pandemic.

Mobility platforms orchestrate a variety of autonomous actors. The matchmaking mechanisms of mobility platforms can build new alliances between formerly unconnected and unrelated suppliers and users. For example, the ride-hailing provider Gett identified DKMS, the German stem-cell non-profit company, as a potential partner at an early stage and offered a seamless service so that donors can book their free on-demand ride as soon as they arrive in the designated city to ensure a seamless journey to the hospital (DKMS, 2020). The example also illustrates that the modular design of mobility platforms allows actors to access, deploy, and co-innovate based on resources provided by the mobility platform. These resources can then be integrated by public authorities, who often lack the technological capabilities to serve a common good to a crisis-necessary extent, such as functioning health-care or critical infrastructure systems. Simultaneously, these allow partners to implement new innovative features, such as safe last-mile connections, automated dispatching, user personalisation, and passenger capacity planning respecting social distancing requirements. For example, several technology providers have opened their platforms up to existing public transportation systems and health-care organisations to let authorities to establish additional flexible on-demand services, as in the case of Spare and ViaVan

(ViaVan, 2020a; Vik Hansen, 2020). Apart from creating additional opportunities for the platform, this might lead to intensive joint service innovation projects in the future.

Next to platform-specific factors, the ecosystem's technological modularity adds to the ease of integration of services and features. For example, Routable AI adapted its digital technology from vehicle dispatching to efficiently allocate beds for homeless people suffering from COVID-19 in Boston Health Care hospitals (Van der Zee, 2020). It also connected its in-house optimisation tools with the hospital-owned ambulance-dispatching platform to directly transport patients to their assigned beds. Complete access to actors' ecosystem as potential complementors for (public) organisations offers several opportunities for collaboration. Many mobility providers directly support essential workers, risk groups, or persons in need. BIXI offered a free 30-day subscription to all employees of Montreal's public health and social service institutions (BIXI, 2020). These examples illustrate how mobility service providers offer alternative transportation modes to essential and safe options for getting from A to B. In all, we found that private mobility platform providers benefit significantly from public-sector ecosystems, which provide mobility platforms with business opportunities and thus, survival assistance to continue running their businesses during COVID-19.

4.4. AT4: platform ecosystem resilience by creating a meta-platform

This archetype includes two mobility platforms that build on information aggregation as a platform broker to develop a meta platform. These meta platforms aggregate available mobility service providers, public transport, and other services into a one-stop-shop with a standardised front-end for mobility options allowing for inter-modal routing algorithms with social distancing as a prioritised parameter. Interestingly, this centralised action has been initiated not by focal mobility platform ecosystem leaders but by Tier-1 technology providers. As COVID-19 has negatively influenced the mobility ecosystem, mobility providers have faced significant restrictions and existential threats. This has unleashed a social "all-in-the-same-boat" situation, in which helping one another can potentially compensate for adverse events. Consequently, demand for the development of support networks between different organisations has surged. It has become essential for a central actor to step up efforts to provide a means for organising collective action. In this way, the ecosystem profits the meta-mobility platform owner, with other providers being dependent on them as a broker. Examples include the "COvid-19 REsilielt Mobility as a Service" (CORE MaaS) platform of the providers Iomob Technology Services and Factual (Shepard, 2020, March 27), as well as the newly created WeAllMove platform by a newly formed alliance, including different mobility providers, insurance companies, and the World Economic Forum (WeAllMove, 2020).

Information aggregation as a platform broker acts as an enabler of this archetype in three ways: first, individual providers mobilise to participate in the collective movement, as new complements can be provided as easily as possible through open APIs and SDKs. Second, the information flow into the meta platform is managed in a coordinated way. Third, it facilitates disseminating the information to mobility service users in a standardised and transparent manner. As a result, resources (such as the standardised booking front-end) can be easily shared within the mobility ecosystem, reduce costs, and enable individual providers to work towards common goals with mutual benefit. This contributes to platform ecosystem resilience, as the platform owner can pivot from a somewhat passive role in value creation (e.g., by providing intelligent routing systems to other platforms) to an active role in creating new solutions.

Mobility platforms of this archetype used the ecosystem to aggregate multiple isolated providers and services to develop a shared identification. This might reduce the unpredictable behaviour of individual actors and facilitate adequate coping responses compared to competitors. In total, the archetype possesses platform ecosystem resilience by leveraging the vast ecosystem collective.

4.5. AT5: platform ecosystem resilience by optimising service operation

The last archetype involves 92 mobility platforms where a safety or resource usage adjustment to the operations of the mobility services was needed. Examples include the in-app set-up of no-parking zones in areas with a high risk of infection (e.g., Hellobike, 2020), the implementation of "last-sanitised" timestamps (e.g., Yulu, 2020b), and specific reward programmes to encourage individuals to stay at home (e.g., Hytch Rewards; Stone, 2020). This could be achieved by utilising the operational innovation of the mobility platforms and exploiting the ecosystem as a resource. As COVID-19 hit, mobility platforms were confronted with drawbacks such as reduced service bookings and infrastructure restrictions. These drawbacks revealed the need to adjust the way of mobility service provision to sustainably continue service delivery. In doing so, mobility platforms of this archetype allow for an "as-much-as-possible" innovative selling proposition with "as-little-as-necessary" input, thereby contributing to resilience.

The creation of new value is achieved by focusing on new or established platform transaction processes (i.e., contactless) afforded by operational innovation on the platform: Yulu established door delivery and pick-up of vehicles (Yulu, 2020a), and Careem enforces digital payments instead of cash (Careem, 2020). Additionally, platforms introduced new innovative operational features. For example, the technology provider Trafi and SkedGo implemented pandemic-adapted routing algorithms. These help users comply with social distancing requirements by disclosing crowding levels and alternative travel options (SkedGo, 2020; Trafi, 2020). Moreover, mobility platforms can also be used as a central lever to instantly optimise the physical service operations of their complementors. This includes, for example, hygiene requirements that call for daily temperature checks for chauffeurs (e.g., Blacklane, 2020), and increased vehicle cleaning (e.g., Eloop, 2020), which must be confirmed by the drivers. Furthermore, significant limitations regarding the service itself have been implemented. Lyft, for example, disabled pooled rides and offered only single-passenger rides (Hawkins, 2020). All new value propositions add to resilience, as mobility platforms gain a competitive advantage compared to other transport alternatives.

Mobility platforms took advantage of the ecosystem "as a resource" by repelling or adding modules (e.g., platform workers as complementors). For example, Bird cut 30% of its workforce (Dickey, 2020a), Zity completely suspended its service for ten weeks (Elizondo, 2020), and BiciMAD halved the fleet size of the bicycles in Madrid (China.org.cn, 2020). However, the workforce can be exchanged within the mobility ecosystem, as the platform structure of most of the providers allows for collaborative, on-demand workforce lending: while Uber partnered with CloudTrucks to open up more income options for drivers to start transporting freight loads (Dickey, 2020b), Lyft referred drivers to jobs at Amazon (Statt, 2020). Exploiting the ecosystem as a resource allowed mobility platforms to absorb possible further deteriorations such as mass unemployment in the mobility industry.

5. Discussion

The COVID-19 pandemic has had severe negative consequences for many industries and public systems. While one option has been to fall into a state of "shock-induced numbness," the pandemic has also revealed that some mobility platforms are well-equipped to cope with the crisis. As an example, we show how mobility platforms have built on platform and ecosystem-related characteristics to build resilience. Surprisingly, those characteristics have strengthened not only their organisational resilience but also the community resilience of their ecosystem. Based on this platform- and ecosystem-induced resilience, we have identified five archetypes, and we conclude with a definition of platform ecosystem resilience.

5.1. Impact of platform ecosystems on organisational resilience

We discovered several aspects of how platform ecosystems influence organisational resilience. First, all five archetypes leverage the digital platform to strengthen their organisational resilience. For example, mobility platforms from the first archetype diversified their service portfolios and value propositions with transitions to food delivery, P2P community help, and asset re-sale. Those platforms helped local businesses to mitigate the consequences of contact restrictions by offering new ways of interacting with clients. As a result, both the platform and ecosystem actors were able to transition from dried-up revenue streams to new sources. The flexibility and diversification provided by platforms not only increased the organisational resilience of the platform owner (Heeks & Ospina, 2019) but also the resilience of ecosystem actors (Shepherd & Williams, 2014).

Second, the adaptability of a system's outcome, such as the business model change (system as an interplay of platform and ecosystem factors), can achieve organisational resilience. This adds to the organisational resilience literature on information systems, which highlights the mere adaptability of the system (e.g., the platform) itself, such as a range of controls to manage perturbations (Barn & Barn, 2015).

Third, brokers and matchmakers have proven useful in minimising COVID-related challenges for the mobility ecosystem (AT4). These meta-platforms helped to organise collective crisis-intervention actions by facilitating interactions with ecosystem actors (Bimber et al., 2005). Although brokerage has recently been studied in the context of the COVID-19 response (Belso-Martínez et al., 2020), it lacks a theoretical anchoring in the organisational resilience literature. This study illustrates that meta-platforms (AT4) are essential actors and indispensable partners in the post-crisis response to match crisis-related complementors into one centralised pool, which effectively fosters organisational resilience.

Fourth, we identified perceived pro-social behaviour as a potential context-related complement to organisational resilience. For example, developing services targeted at serving the public good and addressing the crisis-related urgent needs of society (e.g., by providing safe options for commuting for health-care personnel) might be perceived as pro-social (AT3). These actions inform the sharing mobility platform's image and thereby open access to new customer groups. Like to the literature on post-disaster ventures (Shepherd & Williams, 2014), these pro-social actions appear to serve a higher purpose. This positively influences the identity of individual providers from the viewpoint of customers and potential future partners (Lilius, 2012). Pro-social perceived behaviour might also benefit actions that could otherwise easily be seen as critical and thus damage the image of respective mobility platforms. For example, in AT5, using the ecosystem as a resource to flexibly shift the workforce presents a more ethical alternative to merely laying off employees, which permits for cost-saving without sacrificing the social reputation from a mobility service user perspective.

5.2. Impact of platform ecosystems on community resilience

First, the archetypes AT1, AT3, AT4, and AT5 reveal how mobility platforms can create community resilience. The resilience literature highlights that building trust and interdependence (Goldstein, 2012), and sharing knowledge and goals between actors, is crucial to building community resilience (Shepherd & Williams, 2014). However, we found cascading effects and highly intertwined actions where partners in the ecosystem indirectly support or subsidise one mobility platform's actions. Thus, the interdependence between the focal platform owner and ecosystem actors can lead to community resilience. For example, after the announcement by the car-sharing provider ZITY that it would offer a free service to health-care and Red Cross workers in Paris, two of its leading suppliers, Continental (for vehicle retrofitting parts) and Ridecell (for routing technology), reduced their pricing for the car-sharing provider (Ridecell, 2020). This contributes to community resilience, as not only can ZITY reduce the operational costs inherent in running its service, but this might also be a first move towards shared solidarity for a common interest, in this case, the post-crisis survival of mobility services. Another example is ViaVan: together with a local government authority, it launched an intelligent delivery platform for goods. This platform ensures reliable routing and delivery of emergency food and supplies to more than 1,000 residents in London's Borough of Sutton. Volunteers receive all the relevant parcel information, including routing options through a mobile app. Customers no longer need to line up to receive this information, and drivers can complete more delivery trips. Residents in need also profit from ViaVan's technology, as the app notifies them in time, allows contactless delivery, and provides the ability to contact drivers (ViaVan, 2020b). In this way, ViaVan's action has positively influenced not only its institutional partner, Sutton Council but also providers of emergency food and supply, as well as individuals, both volunteers and persons in need. This underlines the idea that the impact of measures by shared mobility providers is multilevel and can positively contribute to the entire affected community's resilience.

Second, platforms influence resilience not only within the mobility ecosystem but also at an inter-industry level. Inter-industry collaboration can be seen in archetypes AT1 and AT3, as the newly created joint services also imply impacts (e.g., increased revenue) on platforms of other industries (e.g., e-commerce, delivery service, digital payment provider), non-platform businesses (e.g., local shops, restaurants), or higher-order public institutions and services (e.g., health care, government organisations). Intra-industry co-opetition between mobility ecosystem actors supports working together on pandemic-specific issues of common concern and creates value while competing elsewhere. This adds to the community resilience of the mobility platforms, as fixed costs can be significantly reduced (AT5). The centrally coordinated action to bring together different providers and services can reduce the unforeseen behaviour of single actors and facilitate the planning of adequate coping responses compared to competitors (AT4). Hence, intra-industry collaboration (as in AT4 and AT5) might provide a first step towards developing a joint ecosystem roadmap to cope with the pandemic. In the long term, it can also enhance thus-far-unrealised potential, such as for AT4, the vision of a centralised multi-modal mobility system with an open technology stack to enable seamless cross-provider transactions. Therefore, similar to Moldovan et al. (2018), we argue that increasing the exchangeability and flexibility of ties within the broader ecosystem involving different entities for joint action and shared practices contributes to resilience at the community level.

Our findings are in line with the present literature on disasters. For example, unexpected crises might require collaboration within the ample scope of organisations and result in new inter-organisational arrangements to meet socio-economic needs (Wachtendorf et al., 2006). Similarly, resource sharing is vital for collaboration (Jiang & Ritchie, 2017), and response networks in the aftermath of unexpected disasters can also include distant actors who cover similar or complementary function domains (Lai & Hsu, 2019), which indicates that the notion of inter-industry collaboration becomes even more important in a crisis context. Interestingly, our findings also indicate that the importance of locality (Glückler & Hammer, 2011) and geographical proximity in building these new relations and collaborative services seem to play a major role. Although one could argue that platforms do not exhibit the need to select local and nearby partners for joint crisis response, as their modular architecture and matchmaking capabilities allow the integration of geographically dispersed actors, we observed a tendency towards cooperation with local partners (e.g., local restaurants, shops). Therefore, we argue that, in a pandemic context, mobility platforms might be more prone to interacting with partners who find themselves in similar surrounding conditions (e.g., regional specificity of the COVID-19 related restrictions). However, in contrast to the existing literature, we cannot necessarily confirm that there is a natural tendency for mobility platforms within emerging support networks in times of crisis to select organisationally or cognitively proximate partners based on similar tasks or a shared organisational vision (Comfort & Haase, 2006; Hossain & Kuti, 2010). Our findings, on the contrary, show most new partnerships between mobility platforms and non-mobility-related actors, as in AT1 and AT3, companies that do not necessarily share a similar organisational structure.

Third, multiple public-private collaborations (AT3) serve the public good and provide a new perspective for community resilience. The existing literature on community resilience already indicates the potential impact of public-private partnerships (e.g., Chen et al., 2013). However, we found that the mobility platform partnerships add to the community resilience of both the mobility platform ecosystem (private sector) and the public-sector ecosystem. The newly formed networks facilitate joint emergency response, necessary resource sharing (Belso-Martínez et al., 2020), and the development of a mutual understanding. Especially in terms of a potential future crisis (a second or third wave), this might make it more likely to interact collaboratively with the crisis-proven partner.

5.3. Developing the concept of platform ecosystem resilience

Having outlined how digital platforms contribute to organisational and community resilience, we see the following patterns.

First, almost all archetypes (AT1, AT3, AT4, and AT5) leverage both the platform and its ecosystem, and each can contribute to both organisational and community resilience. However, the current research on resilience separately analyses resilience at the individual, organisational, and community level (Taani & Faik, 2019). We propose that digital platforms link the platform owner's organisational resilience with the community resilience of the platform ecosystem. The inherent embeddedness of digital platforms in ecosystems and the pandemic crisis's contextual nature might explain the observed joint appearance. Thus, any resilience contribution might go beyond the organisational boundaries.

Second, all archetypes show a forward-orientation in altering their ecosystem with both short-term and long-term impacts. These impacts change the critical characteristics of platforms' business into a "new normal." For example, many platforms are addressing new user groups (DR1, DR3), shifting value propositions (DR1, DR3, DR4, DR5), changing value streams (DR1, DR2, DR3), or collaborating with new partners from the same industry (DR4) and other industries (DR1, DR3). In particular, developing a meta-platform (DR4) makes it clear that an unrealised vision, namely, a centralised multi-modal mobility system, is becoming a reality. Contrary to the origins of resilience, namely, leaping back to an old state (Sutcliffe & Vogus, 2003), resilience in the context of digital platform ecosystems means moving forward with new, innovative ecosystem behaviour.

Third, in addition to digital technologies, the platforms also took several non-digital actions. Following the past literature on resilience (Rapaccini et al., 2020), we can confirm that non-digital factors are important. However, our findings underline the dual role of resilience in platform contexts, an interplay between both the digital and non-digital side of actions. For example, Blade, an exclusive air-taxi provider, built on its platform's operational flexibility and refitted its SUVs (previously used to transport customers from the helicopter landing pad to the airport) for ground transportation to set up a new car-sharing service (DR1). This underlines the socio-technical character of resilience in the digital platform ecosystem context and stands in contrast to the existing literature on information systems which mostly neglects the social perspective of a system to support the resilience of groups.

Fourth, most of these archetypes contribute to the resilience of digital platform ecosystems in a "frugal" way. Crises force organisations to face limited access to resources in the first place and before any response action is taken. For example, mobility platforms within AT1, AT3, and AT4 required low input effort to create additional revenue in the short and long terms. Building on existing capabilities, they created a new type of service or value proposition. Also, AT2 and AT5 build on the low-effort adaptation of the existing mobility service to incentivise the demand and increase revenue from existing customers. Many actions can be developed and deployed with minimal and pre-existing resources to meet the need for timely and efficient responses to the crisis. Frugality is about creating affordable, sustainable, and straightforward services when resources are scarce (Watson et al., 2013; Zeschky et al., 2011). We see frugality as an additional concept to understand resilience in the context of digital platform ecosystems in crises. The literature mentions the efficient exploitation of resources in the context of resilience and post-disaster functioning (Hobfoll, 2002). Two examples are venture creation and the pursuit of opportunities without relying on currently controlled resources (Stevenson & Jarillo, 1990). However, the importance of mobilising existing resources (Hobfoll, 2002) and achieving resource gains (Hobfoll, 2011) in such a way that losses are replaced or substituted (Ironson et al., 1997) with minimum input effort is still under-investigated. We add to the literature on resilience regarding the mobilisation of resources (e.g., Sakurai & Kokuryo, 2014) by proposing that frugality is even more critical in crises.

5.4. The concept of platform ecosystem resilience

Our findings have shown the socio-technical character of resilience in the digital platform context as a process of "how to" achieve resilience: it is not only built on socio-technical factors but also contributes to a broader socio-technical outcome system. Both digital and non-digital factors contributed to the resilience of both platforms and their ecosystem as socio-technical entities. As existing definitions neither cover the degree of detail nor the scope of resilience needed to account for the findings of our study and the context of platform ecosystems in times of exogenous shocks, a new definition of the concept of platform ecosystem resilience became necessary.[2] Integrating platform and ecosystem as influencing factors (*what* is used to build resilience), accounting for its a priori, frugal, transformative and forward-oriented nature (*how* resilience is being built) as well as for the long-term impact of the actions (extent of resilience *impact*) resulting in the final definition of platform ecosystem resilience as

> "*leveraging socio-technical factors of digital platforms and ecosystems frugally to design, deploy and use situation-specific responses to prepare for, endure and adapt by capturing new opportunities and engaging in transformative activities to cope with exogenous shocks and become resilient for future disruptions.*"

This definition goes beyond the latest definition of "digital resilience" in IS (Boh et al., 2020) by highlighting how and to which impact platform ecosystems as socio-technical entities contribute to resilience on a wider level in the specific context of an exogenous shock.

5.5. Limitations

This research has several limitations, starting with the nature of case surveys. As the case survey comprises 171 cases of mobility providers and 266 relevant individual actions, we cannot explore each case in-depth. Second, the novelty of the unprecedented pandemic restricts the data sources, as it is still unfolding. New or until so far not officially announced cases might appear that need to be considered during the crisis. Furthermore, long-term outcomes such as post-crisis sales growth and mobility platform survival rates can only be revealed in a longitudinal study after the crisis. We have tried to mitigate this issue through data collection over seven months; however, only the first wave of COVID-19 has been covered. Third, to analyse the resilience-building of crisis-affected firms in-depth, we selected mobility platforms as a sample. Therefore, it is necessary for generalisability to extend the study to other platform contexts to verify the archetypes of platform ecosystem resilience. Last, and because of our study's qualitative nature, we acknowledge the somewhat interpretative stance of our theoretical construction. Although we triangulated our collected data with different sources and iterative author team discussions, we cannot exclude the notion that our findings are subject to subjective interpretation (e.g., Walsham, 1995).

5.6. Theoretical implications

Our main contribution is the new concept of platform ecosystem resilience: resilience as frugally built by the socio-technical characteristics of both the platform and its ecosystem in a forward-oriented manner. This context-specific resilience concept contributes to two main literature streams. First, we contribute to resilience research with five archetypes that show *how* mobility platforms can leverage both the digital platforms and their ecosystems to build resilience. Specifically, we reveal that a combined and multilevel view of organisational and community resilience is needed in the context of platform ecosystems. For example, we show that the archetypes interact and positively influence different levels of analysis. Beyond the boundaries of a single organisation, resilience is also being built at an intra- and inter-ecosystem level. This contrasts with prior research on resilience, mostly focusing on organisational (e.g., Lee et al., 2013; Vogus & Sutcliffe, 2007) and community resilience (e.g., Heeks & Ospina, 2019; Taani & Faik, 2019) in an isolated manner. Therefore, with our new concept of platform ecosystem resilience, we are the first in IS research to acknowledge platform ecosystems as an influencing factor and the affected level of the resilience impact in times of pandemics. Furthermore, it indicates that the actions taken might lead to a long-term change in the pre-crisis status quo towards a "new normal" ecosystem behaviour, including new inter-and intra-industry partnerships. This contradicts the current understanding of resilience as a "preserve-the-past" state.

Second, our findings underline the importance of distinguishing investigations on resilience in platform ecosystems vs. non-platform ecosystems as the first indicate reinforcing effects. All archetypes show that the nature of platform ecosystems can reinforce the potential for resilience building: Platform owners as central actors can efficiently facilitate access to not connected actors of former non-platform ecosystems as they design, facilitate and alter modular architecture (e.g., AT1) and governance (e.g., AT4), this way strengthening coordination and collaboration. Coincident, platform complementors gain resilience by capitalising on joining multiple platform ecosystems with access to a variety of complementors. In return, resilient complementors reinforce platform ecosystem resilience again.

5.7. Managerial implications

In practice, our insights provide managers a three-part understanding of how to leverage digital platform ecosystems to specifically cope with the COVID-19 pandemic, prepare for other exogenous shocks but also to develop platform ecosystem resilience generally.

First, managers can use the presented archetypes to prioritise actions, conduct fit-gap analyses, and derive roadmaps to develop platform ecosystem resilience. Using COVID-19 as an exemplary exogenous shock, we provide a structured overview of the solution space, which might be essential for identifying, selecting and planning relevant coping actions to prepare for similar crises. This is because the identified structural changes (e.g., changed customer demands and altered consumption patterns) are introduced by (but not limited to) COVID-19 which is why platform owners can also consider the archetypes for platform ecosystem development facing similar adversities. However, we should point out that digital platforms do not need to implement all platform ecosystem resilience archetypes equally. Instead, they are asked to critically reflect and decide which are required to cope with a specific structural change.

Second, revealing different pathways of building platform ecosystem resilience might incentivise platforms to proactively turn a crisis into an opportunity. A forward-looking ecosystem behaviour might help managers use crises to further develop their ecosystem rather than leaping back to the pre-crisis status. For example, platform owners looking beyond their organisational boundaries and facilitating novel joint service innovations might generally derive stimuli for unprecedented progress of their platform ecosystem. This might generate post-pandemic advantages beyond the COVID-19 pandemic in comparison to competitors simply resuming existing operations.

Third, managers of non-platform businesses should consider and carefully evaluate either joining or building a platform ecosystems structure in times of exogenous shocks as this might benefit both their organisational and ecosystem resilience in general.

Last, policymakers should consider how they can undertake initiatives to foster the efficient structures of platform ecosystems. Specifically, long-term investments or the easing of regulations for platform ecosystems serving the public good beyond COVID-19 can support their positive societal impact on a broad scale accompanied by sustainable support of their platform ecosystem resilience.

5.8. Future research

The initial concept of platform ecosystem resilience provides various avenues for future research. From a platform perspective, researchers should take a process perspective and conduct longitudinal investigations on how exactly platform ecosystem resilience unfolds. A time dimension helps to investigate the chain of effects from the manifested impact of the pandemic to a platform and its full recovery. An investigation into how the archetypes unfold over time, including questioning whether any specific chronological sequence or maturity level of resilience effects could be observed, might also be promising. Second, as we only included actions in the first wave of this pandemic, it remains unclear if the observed platforms are still conducting actions to counteract the effects of COVID-19 or whether they have already passed this state and are now in the "new normal." Finally, a closer look at how platforms are mobilising and switching their resources to target the crisis-related bottlenecks (e.g., dealing with the increased demand for food delivery, Uber drivers now delivering food instead of carrying passengers) could be promising, as our study takes a wider perspective on what is being done to cope with the situation.

From a platform ecosystem perspective, further studies could first examine the effects from a platform complementor standpoint, as our study mostly took the viewpoint of platform owners. For example, looking at how customers or platform workers (resilience at the individual level) cope with the pandemic and their effects on platform ecosystem resilience would improve our understanding of platform resilience. Second, as we did not shed light on different types of ecosystem, it would be interesting to investigate how the structure and type of an ecosystem (e.g., its homogeneity, complexity, innovation ecosystems, technology ecosystems) influence resilience. Third, although we found inter-ecosystem effects (e.g., impact on public service organisations), future research could contribute by investigating how ecosystem compatibility (Riasanow et al., 2020) contributes to platform ecosystem resilience. For example, which similarities and differences (e.g., needed capabilities, resources) between two ecosystems positively influence, or even hinder, successful coping? Fourth, as our findings show positive reinforcing resilience effects that come with the nature of platform ecosystems, future research could take a closer look at potential negative effects. For example, the high level of ecosystem control centred on a platform owner could imply that complementors are hindered in their scope for resilience-coping actions or that the platform owner could have capabilities to market services that compete with complementors. Instead of positively contributing, this would mean that the platform nature could also reduce the overall ecosystem's potential to build resilience.

6. Conclusion

More than ever before, the current crisis has revealed the importance of individual actions for the collective strength to successfully survive the crisis. What is more, digital platforms and their ecosystems present a vast basket of opportunities to contribute to organisational and collective resilience. Our study addresses the research question on how digital platforms and their ecosystems may be leveraged to develop resilience. To do so, we followed the case survey approach to identify relevant coping actions to develop resilience by building on digital platforms and their ecosystems. This is manifested through our five archetypes and their key context-specific factors. As the archetypes interact and imply consequences for various actors, we also contribute by showing that socio-technical factors can positively influence the resilience of single platforms and the entire ecosystem. Moreover, our findings indicate a "new normal", transformative, and frugal notion of resilience, a state where changed practices define the new reality instead of pre-crisis established positions of being, which can be reinstated once the situation returns to normality. In this way, the archetypes operationalise and extend existing knowledge on organisational and community resilience by deriving a first understanding of platform ecosystem resilience. In sum, our findings help practitioners by providing a structured overview of potential short-term coping actions for crisis times, with many having the long-term impact of generating post-COVID-19 advantages.

Notes

1. Appendix A shows details on the coding process which resulted in the final data structure for each of the five archetypes as illustrated in Figure 1.
2. See Appendix B for more details on the definition development process.

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Appendix A – Coding Scheme

Starting with open coding, we carefully read and re-read the cases and focused on keywords such as "launch of a new service," "partnership with," "free opening of," reflecting which actions have been taken by mobility platforms to cope with the crisis. While maintaining openness about what the data would reveal to us without categorising the information into pre-set categories (Suddaby, 2006), we labelled any evidence of related actions that we considered relevant and clustered similar actions taken into 26 first-order categories (Strauss & Corbin, 1990). After re-coding them multiple times to allow for a recursive process (Lincoln & Guba, 1985), the initial first-order codes covered a variety of topics, such as "indirect service diversification via exclusive offers for local businesses/services" and "adjustment of short-term vs. long-term rental offering." In this way, our first-order constructs already included an initial interpretation of the raw data and provided insights for the development of second-order themes as a next step.

Second, in the context of axial coding, we arranged the data into tables in which the rows represented the individual actions and the columns showed the similarities discovered among them. This allowed us to systematically explore potential patterns and boundary conditions of the first-order codes (Strauss & Corbin, 1998) and to reduce them to a manageable number of themes. For example, we distinguished between cases that did not respond to the crisis with new partnerships and those that collaborated with new partners. As we wanted to achieve generalisable findings (Eisenhardt, 1989; Eisenhardt & Graebner, 2007), we developed generic, second-order themes found in multiple data sources and across multiple mobility platforms. We ascended the ladder of abstraction by following Osigweh (1989): we reduced the properties of a first-order concept while extending its breath by determining the concepts by negation, that is, by understanding what they are not. For example, "collaboration with public (good) partners" was meant to summarise actions in collaborative public service authorities and non-profit organisations; hence, collaborations with partners of the private sector were not included. As the first step, this was an iterative process until all the announcements had been accounted for and no new codes were produced, leading to the identification of the final 13 second-order themes.

Third, we related second-order codes into aggregate dimensions with selective coding, which then formed our archetypes. We did this by again iterating and re-coding the data based on constant comparison with the emerging higher-order concepts (Glaser & Strauss, 1967). For example, "collaboration with public (good) partners" and "support for public (good) workers" merged into "serving the public good." Following this process, we derived five overarching archetypes of measures that rely on both the platform and the ecosystem to build resilience. Consistent with Gioia et al. (2013), and as a means of demonstrating the rigour of our research (Pratt, 2008; Tracy, 2010), Figure 1 (main document) illustrates the final data structure for each of the five archetypes.

Lastly, we verified the trustworthiness of our analysis by triangulating data across multiple data sources. In particular, the coding process involved detailed discussions with all authors after every coding step, challenging one another's assessments until a consensus in the team had been achieved. We, therefore, ensured that we avoided interpreting the data differently. Moreover, we maintained a chain of evidence for data collection across various sources. For example, we ensured that we checked cross-references of sources and followed up on initial announcements.

Table A-1. Illustrative quotes of the announcements related to the second-order themes

Aggregate Dimensions	Second-Order Themes	Supportive Announcements
Diversification	Indirect service diversification	"How can we get you rolling? Would you like to deliver to your customers yourself?! […] With our limited monthly packages, we offer businesses the opportunity to rent our red scooters for an entire month at greatly reduced prices. […] Together, we roll better - but at a distance! To report about you and to draw our customers' attention to your shop, you can also benefit from our newsletter & social media reach! […]" *(Emmy, shared micro-mobility provider, Germany)* "Lime – perhaps best known for its bright green scooters scattered across Brussels – will officially be taking over the assets of Uber Jump in Europe, the company confirmed to the press on Tuesday. […] This decision comes amid rising interest in alternative mobility in Brussels in particular. Bolstered by the coronavirus health crisis, many users are avoiding public transport in general, while the Brussels region continues to invest in cycling in the city". With the increased resources, Lime intends to offer 'safe, sustainable and community-based transportation options to riders and cities as an essential part of reopening the world after the pandemic,' the release adds. […]" *(Lime, Shared micro-mobility provider, Belgium)*
	"Stand-alone" service diversification	"Thrilled to be launching Voi Resell - our B2B e-scooter re-sale platform where we're offering organizations of all sizes the chance of owning their own e-scooters - a fun, practical and low-carbon way to move around while giving a scooter a second life 🌱🌱 […]" *(Voi, Shared micro-mobility provider, Sweden)* "Uber is launching a pair of new services called Uber Connect and Uber Direct as the ongoing COVID-19 pandemic minimizes demand for its traditional ride-hailing business. They are focused on moving items rather than people. Uber Direct will offer deliveries from shops like pharmacies and pet stores, while Uber Connect is a same-day courier service to let Uber users send items to one another. […] Uber says all deliveries will be contact-free to help prevent the spread of the virus. […]" *(Uber, Ridehailing provider, Global)*
	Direct service diversification	"🚀 Introducing #BlaBlaHelp, the BlaBlaCar community app to support each other with grocery shopping during #COVID19. […] How it works: -> Want to help? Mark your availability on the app. -> Need help buying basic necessities? Search for volunteers in your area & get in touch. […]" *(BlaBlaCar, P2P Carsharing provider, Europe)* "[…] Vulog, the leading shared mobility technology provider, announced a new partnership with electric bike manufacturer and operator Zoov, expanding upon its expertise in shared mobility and multimodal travel. […] The partnership enables Vulog clients to execute a seamless transition into the multimodal space, allowing users to combine the shared electric bike with other forms of transport (car, metro, etc.) within a single trip to arrive safely, efficiently, and sustainably, at their final destination. Zoov's electric bikes will be integrated with Vulog's AiMA (Artificial Intelligence Mobility Applied) platform so that they are 'sharing ready,' allowing operators to go multimodal faster than ever before. Vulog customers stand to benefit from Zoov electric bikes, which come with a compact parking station that allows up to 15 bikes to park in a single car parking spot. […]" *(Vulog, Shared mobility technology provider, France)*

Aggregate Dimensions	Second-Order Themes	Supportive Announcements
	Collaborative service diversification	"I'm very proud to announce that thanks to our new partnership with eFarma.com - I tuoi Farmacisti online, Italy's biggest online supplier of #health products, Helbiz will now offer same-day delivery of #COVID19 Safety Kits. For every Kit purchased in the Helbiz app, you will donate 3 surgical masks to Humanitas Research Hospital. The COVID-19 Safety Kits, composed of a KN95 safety mask & a 80ml hand sanitizer gel, are now available for delivery in Milan, Turin, Rome and Verona. #helbiz #helbizfamily #micromobility […]" *(Helbiz, Shared micro-mobility provider, Italy)* "Lyft today announced the launch of Essential Deliveries, a program aimed at servicing the needs of health care and government organizations and non-profits during the ongoing COVID-19 pandemic. Launching today, the service will use drivers to deliver a variety of essential products, from groceries and meals to cleaning and medical supplies. The ride-hailing service notes the program will be opt-in and derivers will be informed about the nature of the deliveries, which are entirely contact-free. […]" *(Lyft, Ridehailing provider, US)*
	Collaborative service innovation	"With autonomous-vehicle companies parked by Covid-19, Pony.ai has teamed up with Los Angeles-based e-commerce site Yamibuy to deliver packages and groceries in the city of Irvine. Yamibuy specializes in Asian foods and home goods. The partnership is meant to help meet the surge in delivery demand, as consumers across the U.S. and around the world have been forced to stay at home. Pony.ai, a Fremont, California-based startup, will deploy its fleet of 10 modified Hyundai Kona battery-electric cars with a safety driver in every one. The contactless and autonomous deliveries will go directly to customers' doorsteps, with Yamibuy automatically assigning orders from its platform to Pony.ai vehicles in Irvine. Packages then will be collected from a local distribution center, driven to a customer's address and left on the doorstep by the safety driver—or a customer can choose to collect a package from the trunk of the car. […]" *(Pony.ai, Autonomous-driving startup, US)* "[…] B2B customers are welcome to book a CAR2Deliver on a daily, weekly or monthly basis, as well as to get connected to hundreds of potential couriers should they need some to hire. […]" *(GoTo Global, Carsharing provider, Israel)*
Business model adaptation	Operational business model adaptations	"[…] While we have suspended our primary services across the country to curb the spread of COVID-19, we want to make commuting as safe as possible for the unsung heroes who don't have the option of staying at home during this lockdown – the ones who are delivering essential items to homes, working in sectors considered essential services or taking care of loved ones in hospitals. Hence, we're introducing an exclusive service called Yulu Privé, which lets you use a dedicated Yulu Miracle 24*7 at just Rs. 89/ Day. Each Miracle comes with a personal charger, is thoroughly sanitized and then delivered to your doorstep to make it as convenient for you as possible. […]" *(Yulu, Shared micro-mobility provider, India)* "[…] As a result of evolving needs during the coronavirus, Zipcar announces it is expanding Dedicated Zipcar, an option that provides members the exclusive use of a vehicle Monday through Friday for approved uses of transportation. Dedicated Zipcar provides exclusive access to a dedicated vehicle Monday through Friday with parking, gas, insurance, and regular maintenance included in the monthly cost. […]" *(Zipcar, Carsharing provider, US)*

Aggregate Dimensions	Second-Order Themes	Supportive Announcements
		"[…] We still have to stick to the recommendations we have been accustomed to during the quarantine - to be separated from other people. The solution is easy - individual transport on scooters. That's why want to help you and have made BeRider available to everyone for free under the #SKODAAUTOhelps initiative. […] You will be able to use BeRider free of charge until the end of April, i.e., midnight on 30 April. The maximum length of one ride is 60 minutes. Then you will be charged at standard rates. You can make an unlimited number of free trips per day. […]" *(BeRider, Shared micro-mobility provider, Europe)*
	Strategic business model adaptations	"Blade is an app-based aviation company that allows users to book private or shared helicopters to nearby airports, including the Hamptons and Nantucket. 'Last summer when we flew, we used to say that we would fly you from New York to Nantucket, to the Jersey coast, to the Hamptons, to Westchester, to the airports,' Blade CEO Rob Wiesenthal previously told Slotnick. 'But now, from a marketing and product perspective, we're flying to New York from other places.' On a recent phone call with Business Insider, McLaren said that as offices open back up, people are planning to commute from their second homes to their jobs in NYC. To fill the commuting need, Blade is launching a new September commuter pass. […]" *(Blade, Private aviation service, US)* " "New at #Cityscoot! ⚡ As a company, you can now offer a new #mobility solution to all your employees. ➡ You buy CityScoot minutes at a reduced price ➡️ You distribute them freely to your employees. The perfect opportunity to facilitate your teams' trips, individually, cleanly and quickly 💡 [...]" *(CityScoot, Shared micro-mobility provider, France)*
Serving the public good	Collaboration with public (good) partners	"Spare and Denton County Transit Agency (DCTA) respond to the COVID-19 health emergency by expanding microtransit service zones. In response to the COVID-19 pandemic, DCTA is expanding its on-demand transit to replace fixed-route bus services. These additional microtransit services powered by the Spare Platform, an on-demand transportation system, allow DCTA to manage the number of riders on a vehicle, trace where riders have traveled, on which vehicles, and with whom they have come in contact while still providing crucial transit services in the community during these unprecedented times. […]" *(Spare, Shared mobility technology provider, USA)* "PBOT has partnered with @ridespin to reduce the cost of e-scooter rentals in order to encourage Portlanders to take advantage of this option for essential travel. Through the end of this month, Spin e-scooter rides will be 50% off. #StayHomeSaveLives" #WeGotThisPDX #COVID19" *(Spin, Shared micro-mobility provider, USA)* "minicabit, Britain's largest cab comparison service, has joined forces with a leading livery charity (The Fishmongers' Company's Charitable Trust) to offer free cab rides across the country for NHS workers supporting the Coronavirus response. The free cab service is available to NHS staff around the UK, travelling to and from hospitals in the smallest towns and the largest cities, and will make a real difference for workers coming off long or late shifts. The initiative will also enable frontline healthcare workers to avoid travelling on public transport, thus reducing the risk of infection. […] *(Minicabit, Shared mobility technology provider, United Kingdom)*

Aggregate Dimensions	Second-Order Themes	Supportive Announcements
	Support for public (good) workers	"Free e-scooter passes are now available for public health workers. In support of efforts to combat the spread of coronavirus (COVID-19), Neuron is offering a free monthly pass to the indispensable public health workers in Adelaide and Brisbane. […]" *(Neuron, Shared micro-mobility provider, Australia)*
Creating a meta-platform	Development of a meta-platform	"[…] The CORE MaaS (COvid-19 REsilient Mobility as a Service) project developed by Iomob and submitted in partnership with Factual as part of the Enhanced EIC Accelerator Pilot (SME Instrument Phase 2) urgent call for projects proposes to develop an open SDK-based middleware platform that integrates available mobility service providers (MSPs), public transport, taxis, and other mobility services across multiple cities and regions within Continental Europe. The platform will provide intermodal routing algorithms to allow users to select available mobility options within a selected geography that optimize social distancing, as a prioritized parameter. […]" *(Iomob Technology Services, Shared mobility technology provider, Global)*
Optimising service operation	Adjustments in service operation towards increased safety, efficiency and cost-effectiveness	"[…] In order to protect you and our captains, we ask you to be mindful of your own personal hygiene and ensure you avoid physical contact with our captains. Using the notes feature in our app to communicate specific requests to the captain is a great way to maintain social distance. Messages could be "please leave my order at the door" or "ring my doorbell and leave my order in the lobby." Another practical way of doing this is by using the cashless payment options as much as possible through the Careem wallet or your credit card. […]" *(Careem, Ridehailing provider, Middle East)* "Uber and Lyft are suspending their respective carpooling services in response to the novel coronavirus pandemic. Uber is suspending Uber Pool in the US and Canada, following an expansion of its paid sick leave policy for drivers. Lyft, meanwhile, is suspending Lyft its carpooling service Shared Rides in 'all markets.' […]" *(Uber, Lyft, Ridehailing providers, Global)* "Mobility as a Service (MaaS) tech-enabler SkedGo is launching a new feature that enables passengers to assess crowding levels before they travel, supporting transport journey planning during the COVID-19 pandemic and beyond. The feature allows passengers to choose quieter routes and carriages, or switch to alternative forms of transport to maintain social distancing, such as cycling or e-scooters. The occupancy feature has been trialed using open-source data from Transport for New South Wales in Sydney, Australia, and can be rolled out worldwide, depending on data availability. App developers and local transport authorities will also be able share government COVID-19 health alerts through SkedGo's TripGo API (Application Programming Interface) or SDK (Software Development Kit) tools. […]" *(SkedGo, Shared mobility technology provider, Australia)*
	Reduction of fixed costs	"Uber has partnered with trucking startup CloudTrucks to make it easier for its ride-hail drivers to get jobs as truckers during the pandemic. […] During this time, Uber drivers with valid commercial driver licenses can join CloudTrucks to start transporting freight loads. If they don't have access to a truck, CloudTrucks' partnership with Ryder enables them to lease a tractor and/or trailer. CloudTrucks says it will cover the deposit fee. 'Truck drivers are the backbone of our economy, and communities are depending on them now more than ever," Uber Freight Head of Business Development and Strategy & Planning Laurent Hautefeuille said in a statement. "Our objective at Uber Freight is to support all truck drivers whether they are industry veterans or just starting out, and we hope this partnership with CloudTrucks and COOP by Ryder will open up more opportunities for

Aggregate Dimensions	Second-Order Themes	Supportive Announcements
		those already on the Uber platform.' […]" *(Uber, Ridehailing provider, USA)* "Today, Bird laid off about 30% of its employees amid the uncertainty caused by the coronavirus, TechCrunch has learned. This came out to 406 people laid off out of 1,387 employees prior to the layoffs, Bird confirmed. 'The unprecedented COVID-19 crisis has forced our leadership team and the board of directors to make many extremely difficult and painful decisions relating to some of your teammates," Bird CEO Travis VanderZanden wrote to staffers in a memo, obtained by TechCrunch, today. 'As you know, we've had to pause many markets around the world and drastically cut spending. Due to the financial and operational impact of the ongoing COVID-19 crisis, we are saying goodbye to about 30% of our team. […]" *(Bird, Shared mobility technology provider, Global)*
	Physical actions towards increased safety	"Technology company Autocab is working with Driver Bubble, a supplier of screens for the interior of private hire taxis, to ensure drivers and passengers are protected during the coronavirus pandemic. Plastic and PVC screens supplied by Driver Bubble shield drivers and passengers, reducing the risk of virus transmission. They are quick and easy for private hire firms to install and clean – and are compatible with almost any make of vehicle. By forming this partnership, the two companies are aiming to keep costs down for private hire firms and help get drivers back to work safely. An exclusive price on the screens can be accessed through 'Autocab Connect' – an online marketplace which offers taxi operators a range of third-party services, including insurance and marketing, intended to help support and grow their businesses. […] "*(Autocab, Shared mobility technology provider, Europe)*

Appendix B – Platform Ecosystem Resilience Definition Process

We developed the concept of platform ecosystem resilience in a two-stage process. First, we started with the concept of digital resilience (Boh et al., 2020), and iteratively exchanged specific elements of their definition to match our findings (Table B-1). Second, we complemented the resulting preliminary definition by notions that our results show to be important but until then have not been included (Table B-2). This then resulted in the final definition of platform ecosystem resilience.

Table B-1. Stage 2 of Concept Definition Process: Adjusting the Definition of 'Digital Resilience' (Boh et al., 2020)

Iteration	Type of changes made	Definition used	Element to be adjusted	Rationale for findings-related adjustment	Adjustment for concept of 'Platform Ecosystem Resilience'	Literature used for adjustment
1	Adjustment of existing definition	**Boh et al. (2020, p.1):** "[…] designing, deploying, and using information systems to quickly recover from or adjust to major disruptions from such shocks"	What is used to build resilience	Platform and ecosystem as socio-technical information system used to build resilience via actions	"leveraging socio-technical factors of digital platforms and ecosystems […] to design, deploy and use situation-specific responses […]"	None, own conclusion based on findings
2	Adjustment of existing definition	**Boh et al. (2020, p.1):** "[…] to quickly recover from or adjust to major disruptions from such shocks"	How resilience is manifested	Focus here is not only on a posteriori but also on a priori resilience as long-term impact of actions could also influence resilience for upcoming exogeneous shocks	"leveraging socio-technical factors of digital platforms and ecosystems […] to design, deploy and use situation-specific responses to prepare for, endure and adapt […]"	To account for the a priori, a posteriori, and flexibility character of resilience: Organisational resilience as "the ability to anticipate, **prepare for**, respond and **adapt** to events […]" (British Standards Institute, 2014) To add the stability notion of resilience: Organisational resilience as "both the ability and capability of organizations within systems to anticipate, **endure** and adapt to environmental changes "(Tuazon et al., 2019)
3	Adjustment of existing definition	**Boh et al. (2020, p.1):** "[…] major disruptions from such shocks"	Type of disruption as resilience context	Pandemic as exogeneous shock	"leveraging socio-technical factors of digital platforms and ecosystems […] to design, deploy and use situation-specific responses to prepare for, endure and adapt […] to cope with exogeneous shocks […]"	None, contextualisation of study
*Highlighting in red indicates adjustments, and therefore differences compared to the used definition ** Highlighting in green indicates adopted elements of the used definition						

Table B-2. Stage 2 of Concept Definition Process: Complementing derived Concept of "Platform Ecosystem Resilience"

Iteration	Type of changes made	Definition used	Element to be added	Rationale for findings-related addition	Addition to concept of 'Platform Ecosystem Resilience'	Literature used for addition
1	Addition to newly derived definition	**Platform Ecosystem Resilience:** "leveraging socio-technical factors of digital platforms and ecosystems […] to design, deploy and use situation-specific responses to prepare for, endure and adapt […] to cope with exogeneous shocks […]"	How resilience is being built	Frugality as important notion to build resilience under resource scarcity	"leveraging socio-technical factors of digital platforms and ecosystems frugally to design, deploy and use situation-specific responses to prepare for, endure and adapt […] to cope with exogeneous shocks […]"	None, own conclusion based on findings
2	Addition to newly derived definition	**Platform Ecosystem Resilience:** "leveraging socio-technical factors of digital platforms and ecosystems frugally to design, deploy and use situation-specific responses to prepare for, endure and adapt […] to cope with exogeneous shocks […]"	How resilience is being built	Transformative, and forward-oriented notion of resilience that goes beyond simple adaptation and rebound to an original state	"leveraging socio-technical factors of digital platforms and ecosystems frugally to design, deploy and use situation-specific responses to prepare for, endure and adapt by capturing new opportunities and engaging in transformative activities to cope with exogeneous shocks […]"	None, own conclusion based on findings
3	Addition to newly derived definition	**Platform Ecosystem Resilience:** "leveraging socio-technical factors of digital platforms and ecosystems frugally to design, deploy and use situation-specific responses to prepare for, endure and adapt by capturing new opportunities and engaging in transformative activities to cope with exogeneous shocks […]"	Extent of resilience impact	Long-term impact of actions with the potential to contribute to resilience for future disruptions of similar magnitudes	"leveraging socio-technical factors of digital platforms and ecosystems frugally to design, deploy and use situation-specific responses to prepare for, endure and adapt by capturing new opportunities and engaging in transformative activities to cope with exogeneous shocks and become resilient for future disruptions"	None, own conclusion based on findings
Resulting final definition of "**Platform Ecosystem Resilience**": *"leveraging socio-technical factors of digital platforms and ecosystems frugally to design, deploy and use situation-specific responses to prepare for, endure and adapt by capturing new opportunities and engaging in transformative activities to cope with exogeneous shocks and become resilient for future disruptions"*						
*Highlighting in red indicates additions to the preliminary version of the self-derived concept						

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Platform Ecosystem Structures: Leveraging Platform-based Technology and the Finance Ecosystem for the New Normal

Completed Research Paper

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Abstract

The fierce competition in the finance sector in general, which was reinforced by uncertainty that the COVID-19 pandemic brought along, turned into a race for capturing new opportunities and engaging in transformative activities. In particular, structures of financial platforms and their ecosystems thus far provided competitive advantages compared with non-platform businesses. This paper reveals six archetypes of how finance firms achieve platform ecosystem structures by using platform-based technology and the ecosystem. We follow a case survey approach and analyze a qualitative data set of 152 actions of 61 financial platforms. We further demonstrate that platform ecosystem structures reinforce themselves, enable a sense of cohesiveness, and contribute to a "new normal" instead of a "preserving-the-past" reality. Our overview of the solution space might support practitioners in identifying, selecting, and planning relevant coping actions of digital platforms to prepare for future challenges, stay competitive, and provide innovation.

Keywords: Platform ecosystem, structure, finance, actor–network theory

Introduction

For some time in the past, the persistent low revenue growth and deteriorating macro-outlooks put much pressure on the finance sector (Unicredit 2019). The growing number of new players such as bigtechs, fintechs, payment provider, and neobanks entering the ecosystem are competing for a share of the financial services market-pie (Riasanow et al. 2018), thus creating a dynamic and competitive digital environment (Cusumano et al. 2019). Moreover, the COVID-19 pandemic brought unprecedented negative effects on human healthcare systems, social life, and the economy (Haleem et al. 2020). However, what started with a gloomy outlook, followed by a pandemic standstill, might now turn into a race of capturing new opportunities and engaging in transformative activities for the finance sector.

In particular, financial platforms' collective stability to the pandemic has been notable thus far. For example, Robinhood, a zero-commission-fee trading platform, provided automated, stable, and efficient operations by just executing code (CNBC 2020); however, it faced a surge in activity and a massive rise in first-time stock traders (Barber et al. 2020). On the one hand, the platform-based technology of financial platforms enabled both the accommodation of the increased demand and the scaling up of their service offerings while adapting to the "new normal". By providing a meta-platform for subscription management service, Lloyds Bank (2020), was able to respond to customers' desires for more control and flexibility in managing their money during a crisis. On the other hand, financial platforms obtained an understanding to leverage their ecosystem. For example, Tink, an open banking platform, strengthened its product offerings and market position through the integration of Instantor, a leading provider of credit decision solutions. By extracting data from the ecosystem, for example, consumer bank transactions, Tink (2020) can now verify income and identify risk behaviors to allow for improved assessments of credit risk. In sum, the combination of different characteristics of digital platforms and the ecosystem might generate overreaching collective "platform ecosystem structure," which supports higher stability, more agility, and more resilience than non-platform ecosystem structures (Floetgen et al. 2021b). Therefore, these platform ecosystem structures are worth being actively achieved.

Research showed that the concept of actor–network theory (ANT) is useful in providing a foundational understanding of structure. ANT structure is described as networks between human and non-human actors acting together, just like the network generated by financial platforms and their ecosystem. However, holding structure in place demands continuous effort, and "there is always the possibility that things escape from the hold" (Steen et al. 2006, p. 305). The structure is thus an achievement rather than a natural state (Latour 1996; Law 1992). Extant research on ANT has not reached theoretical convergence nor an understanding of *how structures can be achieved* and *what are structures made of*. Structures of financial platforms and related ecosystems represent a novel context indicating that socio-technical factors of the technical platform and ecosystem can be combined to achieve platform ecosystem structures (Böttcher et al. 2021). Therefore, we explore the following research question: *How can finance firms achieve platform ecosystem structures with their platform-based technology and ecosystem?*

We follow the case survey method (Larsson 1993) by applying the approach of Floetgen et al. (2021b) to analyze the announcements of financial platforms regarding their actions taken to cope with the current challenges of the industry and changing environmental conditions. We contribute to the literature by presenting six archetypes representing patterns of how digital platforms can leverage the socio-technical factors of both the platform and the ecosystem to build platform ecosystem structures. The archetypical patterns also contribute to the descriptive knowledge of platform ecosystems, which is important because they are highly reliant on digital technologies and infrastructure.

Theoretical Background

Digital platforms are technological entities that enable value creation by orchestrating an autonomous ecosystem through socio-technical means (Boudreau and Hagiu 2009). Such an ecosystem consists of platform owners, stakeholders, complementors, and digital-platform-specific applications (Tiwana 2014). Digital platforms and their ecosystems are by nature interconnected, and simultaneously, participants compete and cooperate as complementary providers (de Reuver et al. 2018). These connections form a network that spans even wider when considering the whole ecosystem, thus leading to increased complexity (Floetgen et al. 2020; Tilson et al. 2010). Consequently, concepts of heterogeneous entities, mutual dependence, and dynamic development need to be considered (Floetgen et al. 2021a). Research showed that ANT, a form of constructivism originating in social science and technology research, can be an appropriate theoretical foundation in this context to build upon.

The original thought of ANT is about the unity of the actors and the network to describe the very nature of societies. The network is not understood in the technical sense; that is, it is a set of paths connecting nodes and giving strategic character to some nodes, for example, a subway or computer network. Neither of the networks is limited to social networks spanning relations between individual human actors like in social theories. This approach extends the notion of the actor to non-human entities such as technology objects. Thus, ANT considers a heterogeneous network of sharing action by many actants (Callon 2001). The ANT structure is understood to have emerged from confrontations between actors (Steen et al. 2006) and is described as "relatively durable alliances between human and non-human actors acting together" (Law 1992, p. 385). According to ANT, holding the structure in place necessitates continuous effort (Steen et al. 2006), and thus, the structure is not a natural state but rather an accomplishment (Latour 1996; Law 1992). To describe the emerging structure, network theory uses graph-theoretic measures to assess the modeled network, including network degree centrality (focal actor's number of links normalized by network size), closeness centrality (distance between focal actor and other network nodes), and betweenness centrality (number of shortest paths between a pair of nodes containing the focal actor) (Basole, 2009; McIntyre et al., 2020; Nischak and Hanelt, 2020). This approach gains importance with increased data availability, where data-driven analysis can be used to generate insights (de Reuver et al. 2018).

ANT helps explain the form of structures and their influence (Latour 1996); however, how these structures can be achieved and what structures are made of remain unclear. For example, Basole (2009) analyzed interfirm relations based on ANT and visualization to explore the structure of the mobile ecosystem and its actors' network positions and relationship patterns. Gaining further insights into how firms operate within the network requires knowledge on how firms contribute to achieving these explored structures. In addition, ANT claims to overcome the highly controversial separation of micro- and macro-level in social science (Callon and Latour 1981). However, this context requires a multi-level perspective because platform actions can affect different scales (Hein et al. 2020).

Furthermore, ANT allows looking at developments without a priori order relations or categorizations, as the connectivity of elements solely counts, which is a subject of transformation itself. ANT is described as a background/foreground reversal because it starts with unconnected localities and ends up being commensurably connected without considering social or natural universal laws ex ante (Latour 1996). Although the inductive approach toward its beginning in parts allows learning from the data, the conclusion to the "whole" is missing. On the one hand, actors are shaped by their ecosystem (Mantovani and Ruiz-Aliseda 2016); on the other hand, ecosystems are not exogenous but dynamically influenced by their participants. Therefore, consideration of dependency and consequently of the "whole" is of fundamental importance (Floetgen et al. 2021a). The alignment of autonomous yet interdependent actions is challenging, and effects are tainted with uncertainty (Yoo et al. 2010). Moreover, the nature of dependencies in ecosystems is not dyadic as relationships between two actants are themselves dependent on other interactions within the ecosystem (Adner 2017). However, ANT neglects this multilateral property of ecosystems because structures are emerging through direct relationships, and thus, external influences on relationships are not taken into account. In addition, although the broad concept of actors in ANT explicitly considers technology (Latour 1996) and is thus well suited to look at socio-technical systems such as platform ecosystems, the theory falls short in explaining how technology can be leveraged to achieve the network structure.

New associations are built most visibly and actively in environments of uncertainty and generativity (Steen et al. 2006); thus, ANT is suited to analyze financial ecosystem structures. As financial platforms trigger multi-level effects, not only the technical design features of financial platforms but also their combination with organizational and social features of the ecosystem that contribute to the overall ecosystem and a "new normal" are needed. We assume that the notion of network structure proposed by ANT provides a good foundation; however, capturing an overreaching collective "platform ecosystem structure" is not sufficient. Therefore, we add to ANT by examining the interplay of platform-based technology and the ecosystem to understand how platform ecosystem structures can be achieved. Our study builds on the socio-technical conception of ANT, as well as its understanding of structural development through dynamic engagement of actants, which will be the key to understanding the function of platform ecosystem structures in the finance sector. Moreover, fostering the consideration of the "whole" advances the understanding of ecosystems and their structural developments.

Method

We used the case survey strategy (Larsson 1993) to build upon a powerful method of learning from a comprehensive quantity of heterogeneous qualitative evidence in the form of case studies. This approach enabled us to aggregate individual case reviews (Yin and Heald 1975) and allowed for cross-case identification of patterns without compromising scientific rigor (Larsson, 1993).

Table 1. Data Structure

First-order concepts	#	Second-order themes	Aggregate dimensions
Enabling/advancing B2B payment	5	Enabling/advancing B2B payments	*Exchange-oriented service expansion*
Enabling/advancing B2B payment with new platform launch	1		
Enabling/advancing P2P payment	4	Enabling/advancing P2P payments	
Enabling/advancing A2A (account to account) payments	1		
Enabling/advancing contactless commercial payment (B2C)	6	Enabling/advancing commercial payments	
Enabling/advancing online commercial payment (B2C)	4		
Advancing digital currencies with crypto payment system	6	Advancing digital currencies	
Launch of a digital currency testing platform	1		
Launch of a new crypto bank	1		
Advancing digital currencies with stacking rewards	4		
Bigtech launching new payment system	5	Bigtech launching new payment system	
Enabling/advancing mobile payments with partner	5	Enabling/advancing mobile payments with partner	
Launch of a new blockchain platform to advance global trade	3		
Bank cooperating with technology vendor to advance digital payment	3		
Advancing open banking	3	Enabling/advancing open banking	
Advancing open banking by using M&A	4		
Launch of a new open banking platform	1		
Cooperating with open banking technology provider	8		
Expanding digital banking services organically	6	Expanding digital banking services	*Banking core service extension/improvement*
Fintech cooperating with bank to advance crowdlending service	2		
Fintech cooperating with bank to advance funding service	1		
Launch of a new marketplace platform	2		
Bank cooperating with platform company to expand digital banking service	6		
Expanding digital services by the means of M&A	2	Expanding digital services by the means of M&A	
Enabling/advancing expense management services	9	Enabling/advancing expense management services	
Launch of a new money management platform with partner	1		
Advancing asset management by robot advisory	1	Advancing investment services	
Bank advancing investment service with partner	5		
Bank cooperating with technology vendor to advance investment risk management	1		
Digital wealth manager expanding products with partner	1		
Enabling/advancing broker services	4		
Advancing financial inclusion with partner	2	Advancing financial inclusion with partner	*Taking social responsibility*
Advancing social impact and sustainability	5	Advancing social impact, transparency and sustainability	
Establishing a foundation to end hidden fees in international finance	1		
Donating due to COVID-19	3	Donating/waiving fees due to COVID-19	
Waiving interests for overdraft to support retailers in the crisis	1		
Waiving fees for donations through the platform	2		
Launch of a payment relief information hub for people impacted by COVID-19	1	Launch of the information hub	
Launch of a giving platform to support fundraising activities	1	Launching/advancing a giving platform	
Expanding a giving platform with round up donation feature	1		
Launch of a disbursement platform to distribute financial support with partner	1		
Advancing crowdfunding by the means of M&A	1	Promoting innovation	*Innovation promotion*
Launch of a startup accelerator with partner	1		
Supporting fintech growth acceleration	1		
Platform company expanding technology offer to advance banks' digital banking service	1	Providing technology for financial services institutions	
Platform company providing technology for financial service companies	2		
Enabling e-commerce for small businesses	2	Digital economy acceleration	*E-commerce acceleration*
Bank cooperating with fintech to enable invoice insurance	3		
Enabling/advancing e-gift-card with partner	2		
Advancing reward schemes	5	Enabling/advancing bonus schemes	
Enabling/advancing cashback system	2		
Advancing fraud detection and cyber security	6	Cyber security advancement	*Cyber security advancement*
Cooperation with technology provider to advance digital identity services	2		

For data collection, we followed Floetgen et al. (2021b) and gathered company announcements, because our goal was to investigate how financial platforms are exploiting their platform and the ecosystem to achieve ecosystem structures. Announcements included social media channels, application updates, websites, news sources, and other types of practitioner-oriented outlets, as traditional research articles may not include up-to-the-minute actions due to their publication delay. Our data collection includes the most recent actions performed by financial platforms between September 2019 and the end of December 2020. To derive a widespread sample of financial platforms and announcements, we took advantage of the Crunchbase (2020) database, a leading destination for company insights from early-stage startups to the Fortune 1000. To broaden the scope of our sample even further, we also researched and included direct and indirect competitors of the extracted financial platforms and the ten largest established banks in the world, resulting in a total sample of over 500 platforms. Next, we iteratively and manually searched for company announcements by scanning their websites, social media posts, and third-party information for the relevant announcement, resulting in approximately 700 announcements. A detailed screening of the actions concerning the relevance of finance platform-related mechanisms yielded a final sample of 152 relevant individual actions (= cases) by 61 financial platforms. Exclusion criteria for announcements include repeated cases in different sources or lack of relation to digital platforms.

For data analysis, two authors coded the cases by following a three-step coding approach – open, axial, and selective coding – as proposed by Strauss and Corbin (1990). We did not use an initial coding scheme to avoid a priori judgments. Starting with open coding, we carefully read the announcements and highlighted any findings that we considered relevant. Aspects of interest include (but not limited to) changes in the platform actioned by different actor categories (e.g., bank, fintech, credit card company, bigtech, and neobank), cooperation through partnerships or M&A activities, new platform launches, extensions of existing platforms (e.g., implementation of new services/features), or advancement of services (e.g., new technology). Second, as part of the axial coding, we identified the overarching categories and their relations. For example, we identified the "Enabling/advancing mobile payments with partner" category from "Enabling/advancing mobile payments with partner," "Launch of a new blockchain platform to advance global trade," and "Bank cooperating with a technology vendor to advance digital payment." Third, using selective coding, we identified the most important categories that then formed our six archetypes leveraging platform ecosystem structures. In particular, axial and selective coding involved detailed discussions with all authors until a consensus had been achieved. The final data structure and the number of actions are illustrated in Table 1. Additionally, we analyzed the impact of each archetype on its ecosystem, including other industries and regarding short- and long-term effects to reveal implications for the "new normal."

Findings

The case survey reveals the following six archetypes of how platforms can use digital technology to drive platform ecosystem structures: exchange-oriented service expansion (AT1), banking core service extension/improvement (AT2), taking social responsibility (AT3), innovation promotion (AT4), e-commerce acceleration (AT5), and cyber security advancement (AT6). Each of the six archetypes uses platform- and ecosystem-specific properties to achieve ecosystem structures of finance (Table 2.).

AT1: Platform ecosystem structures through exchange-oriented service expansion

The first archetype comprises 65 financial platform actions of advancing exchange-oriented service offerings by exploiting modular architecture and interconnectivity and data from the ecosystem. These services include B2B and P2P transactions, commercial payments, contactless payment options, and secure customer-consented financial data exchanges enabled by open banking. Financial platforms use open application programming interfaces (APIs) to implement banking-as-a-service concepts, thus enabling the exchange of data between a bank and authorized third parties. As an example, the fintech Nordigen launched a free open banking API platform to support innovation and competition in the financial industry toward quicker and more user-friendly payments. This archetype might be accelerated by changed customer behavior and an increase in e-commerce, resulting in the need for contactless payment solutions, especially during the COVID-19 pandemic. This reduction in barriers accelerates the processing of data within the banking sector and causes product and service innovation to drive platform ecosystem structures.

Next, financial platforms achieve platform ecosystem structures by using their modular architecture and standardized interface when extending their exchange-oriented services. For example, Facebook builds the WhatsApp real-time money transfer service based on the unified payment interface (Facebook 2020) to be able to use the same card information across all Facebook family's apps in the future (Facebook 2019). Meanwhile, Railsbank (2020b), a banking-as-a-service platform, transforms building and managing financial applications by allowing financial service providers to promote their products into the platform and be available within a user interface layer on top of Railsbank's operating system for customers to build apps. Thus, financial platforms contribute to seizing the opportunity for distributed innovation in the financial ecosystem. In addition, financial platforms use blockchain technology to advance digital currencies and global trade. CaixaBank (2020) launched the blockchain platform "we.trade" to execute and finance its customers' foreign trade transfers.

Financial platforms of this archetype capitalize on the ecosystem by using available (account) data and interconnectivity between financial institutions. Bigtech companies like Google enter the finance industry by launching new payment systems. They were able to easily connect with credit card companies or banks that enable payment processing. As an example, the bigtech Apple partners with Goldman Sachs as an issuing bank to launch the Apple Card, which can be used immediately with Apple Pay (Apple 2019). Moreover, banks, for example, the Citi Group (2020), seek collaborations with network partners like Google Pay because Google exhibits more data, merchant relationships, and technology resources and capabilities. Furthermore, fintechs and credit card companies are partnering to advance exchange-oriented services. For example, the fintech Coinbase (2020b) launched a VISA debit card that allows cryptocurrencies to be used for payments online and in-store and for ATM cash withdrawals.

AT2: Platform ecosystem structures through banking core service extension or improvement

A total of 41 financial platform actions of this archetype point toward expanding or improving either digital banking services, expense management, or investment services, building on data homogenization and partnerships within the ecosystem. Financial platforms extend their service range to attract more especially digital-savvy customers, react to the increasing customer requirement for more transparency, and require greater computing scale to enhance the client experience. For example, BlackRock (2020a) decided to host their risk management platform Aladdin on the Azure cloud platform.

Platforms of this archetype contribute to platform ecosystem structures by establishing data homogenization. An example represents the data analytics fintech Plaid (2020), which expanded its liability product with credit card details including terms and payment due dates to allow for better expense management solutions. Another supporting characteristic of platforms is real-time data processing. For example, the Bank of America (2020) implemented real-time cross-border payment tracking to meet the customer's need for transparency. Financial platforms also use the modularity of the platform and its ease of use for clients to integrate new services and improve digital banking experience. For example, the cryptocurrency exchange platform Bitfinex (2020) added a new advanced trading feature to complement the existing offer in a user-friendly way.

Financial platforms of this archetype capitalize on the ecosystem through partnerships to achieve ecosystem structures. More than half of the actions are conducted by fintechs, which deliver innovative banking solutions either by cooperating with other fintechs or banks as infrastructure partners. For example, the fintech Gig Wage (2020) that aims to provide an end-to-end solution for the gig economy partners with a bank holding company to improve its financial tools. Meanwhile, banks are seeking technology providers to advance their services. For example, Deutsche Bank (2020a) cooperated with the communication technology platform Symphony to enable new secure and compliant communication channels with clients. The mutual exchange of technology and data produces digital banking innovation like the launch of new platforms (e.g., the marketplace platform Lending Club (2020)) or the implementation of new services (e.g., tax-filling service from Credit Karma (2020)). The actions of this archetype show the ambition of financial platforms to offer a holistic and comprehensive financial solution.

Table 2. Archetypes of Platform Ecosystem Structure Building

	AT1: Exchange oriented service expansion	**AT2: Banking core service extension/ improvement**	**AT3: Taking social responsibility**	**AT4: Innovation promotion**	**AT5: E-commerce acceleration**	**AT6: Cyber security advancement**
No. of actions	65 (= 43%)	41 (= 27%)	18 (= 12%)	6 (= 4%)	14 (= 9%)	8 (= 5%)
Description: Actions that contribute to…	Money transactions and financial data exchange	Innovative digital banking solutions	Financial inclusion, sustainability and Covid-19 relief efforts	Technological innovation and start-up acceleration	Growth through e-commerce and digital SME enablement	Fraud detection and digital identity verification
Inducement:	Increased need of user-friendly digital payments solutions	Service range expansion to attract more digital-savvy customers	Changed requirements towards more focus on ESG criteria	Unstoppable digitalization of the finance sector	Accelerated shift of commercial business in the digital world	Increased security need and technology advancement
Usage of platform:						
Modularity	X	X		X	X	X
Development speed			X	X	X	
Multisidedness			X	X	X	
Data homogenization	X	X				X
Editability & re-programmability			X			X
Layered architecture	X					X
Distributed innovation	X			X		
Ease of use/Inter-connectivity	X	X	X		X	
Real-time data processing	X	X			X	
Usage of the ecosystem:						
New actors as business opportunities	X		X	X	X	X
Downstream technology provider	X	X		X	X	X
Collaboration of two fintechs	X	X			X	X
Cooperation with bank as infrastructure partner	X	X	X		X	
Cooperation with credit card company	X	X	X		X	
Using the network and ecosystem reach	X		X		X	
Growth medium for launch of new platform	X	X	X	X		

AT3: Platform ecosystem structures by taking social responsibility

This archetype includes 18 financial platform actions that serve the public as financial platforms and are taking social responsibility and promote sustainability. Deutsche Bank (2020b), for example, initiated sustainable investment solutions to reduce the environmental footprint. These actions also include helping to overcome the COVID-19 pandemic by waiving fees and interests, promoting donations, launching financial-giving platforms, and providing help to ensure society liquidity. Drivers for these developments might be the aim of financial platforms to reach a broader customer basis with actions toward financial inclusion and changed investment requirements toward more climate risk assessment. This is not surprising as the COVID-19 pandemic might have accelerated changed customer requirements such as the importance of behaving ethically to consumers' purchasing decisions.

Multisidedness is one of the platform properties used for ecosystem structures associated with this archetype. As an example, PayPal (2020), a fintech, introduced a new giving platform to connect fundraisers and customers who can offer their support. Moreover, financial platforms use fast platform development speed to quickly react to the COVID-19 pandemic. For example, the banking-as-a-service platform Railsbank (2020a) contributed to rapidly build a unique disbursement platform called LightingAid with support from fintech complementors and VISA. This case shows the ability of the platform to provide an easy-to-spread and frugal solution, as it enables government departments and community groups to distribute financial support with little effort directly to those in need. Furthermore, platform editability and re-programmability allow to change the pricing model for specific transactions; for example, TransferWise (2020) exchanges donations through the platform to three selected organizations working on the COVID-19 vaccine via the mid-market rate and waives fees entirely

Financial platforms use the ecosystem by capitalizing on the existing network and available reach. Vodacom Financial Services, for example, developed a new easy-to-use payment app together with the technology provider Alipay (2020). As of June 30, 2019, Alipay serves more than 1.2 billion users worldwide. This technology partnership with Alipay enables Vodacom to be at par with its leading global digital counterparts quicker and more efficiently. Interestingly, financial platforms profit from the reach of non-financial platforms. Examples include the data analytics platform entering the financial market in offering advanced climate risk assessment data. Through the cooperation with and the reach of the leading data providers, such as Sustainalytics and Refinitiv, BlackRock (2020b) was able to expand their access to environmental, social, and corporate governance data for the introduction of their novel risk management platform Aladdin Climate.

AT4: Platform ecosystem structures through innovation promotion

The fourth archetype covers six financial platform actions that are designed to drive innovation in the financial industry by advancing technology, promoting startup acceleration, and experiencing exchange. The open access to the ecosystem for fintechs and technology providers enables financial platforms of this archetype to focus on increasing the customer range and value proposition extension. Thus, actions serve not only to participate in the ecosystem but also to shape the future of the financial ecosystem.

Financial platforms use their development speed to shorten the time-to-market ratio of innovations and modularity to allow for flexible platform extensions. For example, Stripe (2020), a technology vendor, launched Stripe Treasury to give platform users powerful APIs to embed financial services with a few lines of code, and thereby, Stripe promotes innovation and development in the finance industry. Multisidedness of the platform is used to enable broad information, experience, and idea exchange. Furthermore, the platform's advantage is the distribution of innovation processes; for example, the fintech Coinbase (2020a) promotes continuous innovation improvement through the launch of Rosetta as an open-source specification to simplify the blockchain deployment.

Financial platforms take advantage of the ecosystem as it provides open access for fintechs and their innovative solutions and dynamic spirit. We found that the endeavor of incumbent banks to win fintechs around supports their growing influence. For example, Barclays (2020) launched a startup accelerator designed to support early-stage tech businesses. In half of the cases, technology vendors serve as sub-providers to accelerate financial platforms in the ecosystem and thereby create inter-dependences among them. For example, the ClearEdge solution of FIS (2020b) offers community banks a pre-integrated, comprehensive bundle of technologies for operating modern banking and providing superior customer experience.

AT5: Platform ecosystem structures through e-commerce acceleration

The fifth archetype covers 14 financial platform actions advancing e-commerce in lowering the barrier to entry especially for small businesses and providing capabilities to master digital purchases. To give an example, financial platforms enable and advance bonus schemes like cashback systems or reward schemes and claim discounts to make e-commerce more attractive. These actions might be induced as commercial business increasingly shifts to the digital world. However, we argue that this is further reinforced by the COVID-19 pandemic, as more than 60% of the cases are influenced by the pandemic.

Financial platforms take advantage of their real-time data processing such as discounts Erste Group (2019), a bank that collaborates with the startup Dateio to integrate a new discount system into its banking platform George, which processes card transaction data to immediately identify applicable discounts. Furthermore, by integrating new services on their existing platform that accelerate e-commerce, financial platforms deploy platform modularity. For instance, Revolut (2020), a neobank, extended its platform with a reward tab to see all offered brands and easily claim discounts or cashback. Retailers are offering the rewards, and end customers are bringing the new platform feature to life; hence, the case of Revolut also shows the positive reinforcing effects of financial platforms in enabling bonus schemes. Moreover, the ease of use, which is an important factor, is provided by the financial platforms to the e-commerce sector. One example is the service provided by the neobank Shine that easily ensures single invoices on the platform and thereby lessen the risk of late and unpaid invoices (Hokodo 2020).

Financial platforms of this archetype use the ecosystem through business opportunities from other industries and the ecosystem's technological modularity. The retailers are attracted by these financial platforms to advertise with bonus schemes throughout the banking platform, as in the case of Revolut. Furthermore, financial platforms capitalize on the ecosystem by encouraging customers to support small businesses or by using the e-commerce industry to incorporate and promote new solutions. For example, the credit card company American Express (2020) launched a new e-gift card that is available for purchase on their platform and on many retailers' websites like Walmart.com. Interestingly, half of the actions are driven by credit card companies showing their ambition to empower other digital platforms in the financial ecosystem and take advantage of online payments and build a digital presence.

AT6: Platform ecosystem structures through cyber security advancement

The last archetype covers eight financial platform actions aiming to advance cyber security, either by providing technology to improve fraud detection or by solutions for digital identity verification and e-KYC risk assessment. For example, Mastercard, a credit card company, launched a suite of tools powered by artificial intelligence (AI) that allows banks to assess cyber risk across their ecosystem and prevent potential breaches. Additionally, acquiring banks can help merchants understand their own cyber risk and resell the technology (Mastercard 2020b). These actions might be driven by the growing demand for digital banking solutions, which is accompanied by an increased need for security, especially for sensitive bank data. We found that 80% of the actors of this archetype are fintechs with innovative solutions that aim to build more trust in digital banking and e-commerce. In addition, further developments in AI research enable broader application as 63% of the actions use AI.

Financial platforms use modularity and layered architecture to implement platform extensions that improve cyber security; for example, Ingenico (2020), a payment solution company, provides for its e-commerce clients an anti-fraud e-payment solution that can be integrated into the client's payment system. Homogenization of data from various sources allows advanced risk assessment as it ensures consistency of data and validity of results. Moreover, platform editability and re-programmability allow to quickly improve the data due to insights from real-time learning. The two fintechs Yoti (2020) and Synectics Solutions, for example, use this by offering a joint real-time digital identity and e-KYC risk assessment solution based on multiple sources.

Financial platforms capitalize on the ecosystem by outsourcing and using the ecosystem's cyber security capabilities as a resource. As an example, the fintech FIS (2020a) partnered with Forter, a fraud prevention platform, to combat fraud in the high-growth cryptocurrency industry by offering a chargeback identification solution for cryptocurrency brokers and exchanges. On the one hand, predominant fintechs provide technology for digital identity verification and thus serve as sub-providers for banks. On the other hand, credit card companies provide cyber security solutions for small businesses. For example, RiskRecon, a Mastercard (2020a) company, provides a free cyber security tool as many small businesses need to quickly move their activities online due to the pandemic, and they face a lack of knowledge on cyber threats.

Discussion

The finance industry is no longer confined to incumbent financial institutions like licensed banks because an increasing number of companies are entering the industry to participate in the ecosystem. Although reasons exist to presume that the financial market is fiercely contested, we surprisingly observed that platform ecosystem structures still provide space for various business opportunities. We found that financial platforms can contribute and participate in this competitive digital environment through their platform-based technology and the ecosystem. Based on the concept of platform ecosystem structures, we identified six platform development archetypes that can advance the structural understanding of ecosystems. We can draw the following five major findings.

First, across all archetypes, the role of the platform-based technology is essential for the platform ecosystem structure as platform properties enable its creation in several ways. One leading edge of financial platforms is the flexibility through platform modularity (ATs 1, 2, and 4–6), which consequently allows for service adaptions and implementation of innovative features. Next, platforms further produce new value propositions (ATs 1, 2, and 5) and the possibility of signaling actions (AT 3). Another way is the contribution of platforms to quick coping actions, such as platform development (ATs 4 and 5) and the implementation of short-term measures (AT 3). Moreover, financial platforms enable new collaborations (ATs 1–3, 5, and 6) and distributed product development supported by layered modular architecture (ATs 1, 4, and 6). Furthermore, financial platforms' capabilities of interconnectivity through standardized interfaces and real-time data processing (ATs 1, 2, and 5) shows how digital technologies enable building platform ecosystem structures.

Second, our findings lead toward a detailed three-part understanding of how the established platform ecosystem structures can be extended: (1) An (new) actor can split a connection of a pair of other actors and thereby gain betweenness centrality. For example, Facebook Pay positioned in-between credit card companies and end customers because the customer interface is now operating through virtual card provision. (2) Platform ecosystem structures enable extensions on the intra-ecosystem level, such as banks cooperating with fintechs to launch a new platform. (3) Interestingly, we also observed platform structure extensions on the inter-ecosystem level, thus opening up completely new business opportunities. Especially, AT 5 shows the efforts of platforms to span the structure beyond the finance industry and to earn a stake in the e-commerce sector. This consideration expands ANT, which so far does not distinguish the different types of expansion by new actors.

Third, we observe that platform ecosystem structures are reinforcing themselves as actions on the platform level to support the ecosystem and vice versa; Financial platform owners as central actors, for example, actively facilitate access to unconnected actors or non-platform ecosystems to create a new service, thus supporting coordination and collaboration. As a consequence thereof, joining actors, for example, gain access to new customer groups. In return, platform ecosystem structures are reinforced. We argue that actions (such as partnering with fintechs) that tend to actively support reinforcing effects should be pursued much more strongly. Although ANT aspires to overcome the separation of a micro- and a macro-level, our findings support the importance of a multi-level perspective on the structure of financial platform ecosystems. As our archetypes shed light on how ecosystems as a whole and their parts interact, we contribute to an underexplored yet important issue of the broader interplay between platform and ecosystem dynamics to avoid cross-level fallacies (Floetgen et al. 2021a).

Fourth, we observe a special "spirit" of mutual help and strengthening or sense of cohesiveness within the platform ecosystem structures that exceed known network effects of ANT. Big players such as Mastercard offer a cyber security solution for small businesses (AT6), whereas small actors help the big ones in return (AT 4). Hitherto, the research on network effects revolved around size, network's structure, and conduct. Although network conduct compromises factors such as opportunistic behavior, reputation signaling, or perceptions of trust (McIntyre et al. 2020), we argue that "spirit" in a sense of a prevailing and typical quality or attitude of financial ecosystem structures might be worthy of consideration.

Last, due to the platform actions, all the platform ecosystem structures spawn changed practices with short- and long-term impacts on the ecosystem as a whole. These impacts change key characteristics of the finance industry into a "new normal," by, for example, involving new user groups throughout all archetypes. New customers are, for example, rural user groups because of financial inclusion activities or new digital payers because of actions pointing toward making online payments as attractive as cash. Furthermore, value propositions are shifting toward more customer-centricity (AT 1, 2, and 5) by providing multi-banking solutions, for example. Additionally, value streams are changing as reflected through banks being infrastructure partners or cooperation with fintechs. Moreover, actors are collaborating on a long vision with new partners either within the ecosystem or with partners from other industries (e.g., e-commerce). However, we also observe short-term ecosystem impact especially regarding COVID-19 measures (AT 3), as they might be in place only for a limited time.

Limitations and Implications

The results of this study exhibit some limitations. Although we cannot provide a complete representation of the industry, our dataset of 152 cases and 61 financial platforms considers a substantial quantity of evidence. However, we did not perform an in-depth analysis of every single case. Further, as we consider the impact of the pandemic and top current cases, data sources are limited because platforms publish the latest actions with delay. Although we attempt to capture long-term impacts with our data collection period of 15 months, an elaborated longitudinal study was not conducted. Finally, as the qualitative nature of our study leaves room for interpretation, we performed data triangulation with different sources and iterative team discussions.

Our findings contribute to the literature in three ways. First, to the best of our knowledge, we provide a first understanding of ecosystem structure in the context of platforms. Our study is in contrast to prior literature focusing on non-platform or single-level perspective (Latour 1996). We reveal six ways in which firms can leverage the socio-technical interplay of platform-based technology and the ecosystem to achieve platform ecosystem structures. The archetypes can easily be extended and reconceptualized by thus far unidentified mechanisms of platform ecosystem structure, thereby laying the ground for developing further artifacts such as platform ecosystem structure maturity models. Furthermore, we show that the actions interact and positively influence different levels of analysis. Our study develops an understanding of platform ecosystem structure at the firm level and the intra- and inter-ecosystem level. Second, our work broadens the descriptive knowledge of ANT on structure. Additionally, this study shows that structures can be extended in different ways and may reinforce themselves. Third, our study reveals that the actions taken might lead to a long-term change of the status quo toward a "new normal" reality of finance industry practices. Moreover, it supports the foundational understanding of the structure as an "achievement." In practice, our results provide managers with an understanding of how to build digital platform ecosystem structures to specifically cope with industrial challenges and prepare to leverage platform-based technology and the ecosystem generally. Our archetypes showcase a structured overview of the solution space of financial platforms, which might be essential for identifying, selecting, and planning relevant coping actions to prepare for future challenges, stay competitive, and provide innovation. Further, highlighting different possibilities of building platform ecosystem structure might incentivize managers of non-platform businesses to consider and carefully evaluate either joining or building platform ecosystem structures as it might benefit their organization.

Conclusion

The socio-technical interplay of platform technology and the ecosystem in the finance sector demonstrated that platform ecosystem structure provides competitive advantages concerning non-platform structures. Moreover, we show that platform ecosystem structures can be developed and reinforced not only within the scope of single digital platforms and their direct partners but also in the entire ecosystem as a whole, namely, through the interaction of archetypes. In this way, our work underlines the advantages of looking beyond organizational boundaries to foster a new era of positive change and previously unseen collaboration in the financial sector at the intra- and inter-ecosystem-level through platform ecosystem structures. Exploring the relationship between the desire of financial platforms to reimagine the business for the long-term and the need to remain disciplined and profitable in the short- term, we also demonstrate that platform ecosystem structures contribute to a "new normal" instead of a "preserving-the-past" reality.

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Implications of Emerging Financial Regulatory Reporting Frameworks for Digital Platforms Boundary Resources

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Abstract

Regulators and banks have identified the necessity of a more holistic and harmonized approach for financial regulatory reporting than the current approach of "just" adopting new regulations to decrease the reporting burden on banking industry. Thus, new platform-based reporting frameworks for supervisory and statistical reporting of banks are being discussed to foster more efficient processing and reporting of data in Europe. Toward this goal, we use the e3-value method to model the ecosystem of emerging financial regulatory reporting frameworks based on publicly available laws, legal documents, guidelines published, consultations and industry surveys by supervisory authorities. Extending Ghazawneh & Henfridsson (2013) conceptualizations of boundary resources, the paper reveals that the boundary resources for financial regulatory reporting platforms will have to be co-created with the emerging regulatory reporting framework itself as foundation for the boundary resources and the regulated entity (i.e. banks) as they require the control about their sensitive data.

Keywords

Digital platforms, boundary resources, financial reporting, regulation.

Introduction

The banking industry has been historically regulated by government authorities and central banks at the national level (Quaglia 2008). The timely implementation of new regulatory reporting requirements, different competent authorities for banking supervision at the national and supranational level, and lack of precise specifications resulted in partly redundant and non-harmonized data collection schemes, including the lack of overall data and reporting standards, have increased the reporting burden on banks (European Central Bank 2018a; Kardorf 2018; Kienecker et al. 2018; Kumar 2018) as well as for regulators (Piechocki 2016). Until recently, the reporting requirements for European banks used a template-driven approach to submit the processed data to the national or supranational competent authorities. The implementation of such a template-driven approach is partially based on different data repositories, i.e. accounting, risk, and regulatory data, facilitates the implementation of data silos, dedicated processing steps for different reports as well as manual processes such as corrects and reconciliation between different repositories (Bier et al. 2018; Broersen and Koppen 2017; European Commission and Financial Stability Financial Services and Capital Markets Union 2019; Kienecker et al. 2018; Kumar 2018). Aggravating to this, regulatory bodies in Europe have indicated that the reporting of granular data will be intensified in the future to fulfill their duties in the future (Bier et al. 2018; Cœuré and European Central Bank 2017).

Recently, new platform-based reporting frameworks for supervisory and statistical reporting of banks are being discussed by regulators and the banking industry to foster more efficient processing and reporting of data in Europe. In particular, the following frameworks which exist or are in development, the Integrated Reporting Framework (IReF) (European Central Bank 2018a; European Central Bank 2019b), Banks'

Integrated Reporting Dictionary (BIRD) (European Central Bank 2019f) and the already existing Data Point Model (DPM) of the European Banking Authority (European Banking Authority 2019). These frameworks drive a paradigm shift in banking supervision from an template-driven reporting to a standardized, comprehensive reporting framework that would enable a platform-based ecosystem for the processing of supervisory and statistical reporting data for banks in Europe (Bier et al. 2018).

With this development, platform owners get the opportunity to enter the banking supervision market to implement platform-based solutions for the emerging financial regulatory reporting frameworks (Hagiu 2014; Yoo et al. 2010). Boundary resources that define the interface between the platform owner and third-party developers are traditionally governed by the platform owner (Karhu et al. 2018; Prügl and Schreier 2006). As financial reporting ecosystems are highly regulated, platform owners are forced to co-create their boundary resources with additional influences. Recognizing this interdependence, researchers did not analyze the implications for boundary resources in highly regulated industries (de Reuver et al. 2017). Another complicating factor is that boundary resource relevant laws, legal documents, guidelines and reporting frameworks in Europe are fragmented in different documents and documented by different institutions. Therefore, literature does not provide how these emerging financial reporting frameworks can be holistically integrated into the current state of the financial regulatory reporting ecosystem. Toward this goal, and to trigger further research, this paper answers the following research questions: *How does the ecosystem of emerging financial regulatory reporting frameworks in Europe look like and which implications for the boundary resources evolve?*

Digital Platforms Boundary Recourses

In the past decades, software platform ecosystems such as Google's Android, Apple's iPhone operating system (iOS) and Salesforce' Customer Relationship Management platform have emerged as successful software models in the B2C and B2B markets replacing the traditional development of proprietary software product lines. Tiwana et al. (2010) describe software platforms as "the extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interface through which they operate". However, third party developers play a significant role in the success of ecosystems surrounding software platforms by sourcing innovations and co-creating value through the development of non-proprietary applications on the platform (Bosch 2009; Boudreau 2012). Therefore, the platform owners must provide the resources to enable third parties to develop applications (Prügl and Schreier 2006). These resources are referred to as boundary resources, which are software tools and/or regulations that define the interface between the platform owners and third-party developers (Ghazawneh & Henfridsson (2013). Typical examples for boundary resources are for instance application programming interfaces (APIs), software development kits (SDKs), app stores, software libraries, licenses and guidelines (Bianco et al. 2014; Eaton et al. 2015; Ghazawneh and Henfridsson 2013; Karhu et al. 2018; Skog et al. 2018). Further research shows, that the boundary resources can be subdivided into technical and social boundary resources (Ghazawneh 2012). The technical boundary resources are further classified into application and development boundary resources (Bianco et al. 2014). Notably, boundary resources are not static and can undergo changes due to the interaction between the platform owners and platform users (Eaton et al. 2015), or changes in the platform itself to include new value-creating processes (Skog et al. 2018). Existing studies focus either on the platform owner balancing the platform control with boundary resources (de Reuver et al. 2017; Hein et al. 2020) or distributed actors that collectively tune boundary resources (Eaton et al. 2015; Islind et al. 2016). Thus, research is missing a detailed holistic analysis of forced co-creation of boundary resources by authorities; it is largely focused on platform and third-party developer interoperability (Riasanow et al. 2019; Riasanow et al. 2020).

Research Approach

This work uses a qualitative research approach based on publicly available legal documents, guidelines published, consultations and industry surveys by supervisory authorities, and other publicly available articles and studies providing insights on the current financial regulatory reporting ecosystem and emerging financial reporting frameworks. For this work, we define the term 'regulatory reporting' as the supervisory and statistical reports that have to be compiled and submitted by banks to the competent authorities on a regular basis, e.g. monthly, quarterly or annually (European Central Bank 2019f; European Commission and Financial Stability Financial Services and Capital Markets Union 2019), excluding financial transaction specific reporting obligations (European Union 2012a; European Union 2015). We investigate the reporting obligations for significant banks based in Germany as a surrogate case for the European banking sector. We conduct a four-step research approach and develop the ecosystem of emerging financial regulatory reporting frameworks to get an inter-organizational overview. We first identify the entities in the ecosystem and the values streams between them. Second, we present the ecosystem based on previously identified entities and value streams. Third, we propose an extension of the boundary resource model by Ghazawneh & Henfridsson (2013) using qualitative content analysis. Next, we validate the ecosystem as well as our proposed model with five semi-structured expert interviews.

For the first step, we used laws, regulations, directive, guidelines, and circulars of regulatory authorities at the European and national levels as well as consultations and industry surveys to derive the entities in the ecosystem. In general, the publicly available documents empower and define the competences of the relevant authorities, and determine reporting obligations of banks such as frequency, format and who to report to. Although the central bank of Germany (Deutsche Bundesbank) officially informs the reporting banks in Germany about new or changed reporting requirements with a circular or with an official notification, the publicly available legal documents are the only source of information regarding specifics on the content, form, and reporting frequency of the regulatory reports and dependencies. This led us to capture the main established and emerging entities and value streams, which are representative of the ecosystem of emerging financial regulatory reporting frameworks covering statistical and supervisory reporting for banks in Germany. We extracted all documents listed in Table 1 on November 20, 2019 from EUR-lex and comparable sources.

Document Source	**Analyzed Reference**
General guidelines from the Federal Financial Supervisory Authority and Basel Committee on Banking Supervision	Basel Committee on Banking Supervision (2013); Federal Financial Supervisory Authority (BaFin) (2017a); Federal Financial Supervisory Authority (BaFin) (2017b)
Statistical Reporting System Germany	Act on the Central Bank of Germany (BBankG); Central Bank of Germany (2019b)
European Statistical Reporting	European Central Bank (2016); European Union (2012b); European Union (2016)
Banking Supervision Germany	German Banking Act (KWG); Large Exposures and Million Loan Regulation (Großkredit- und Millionenkreditverordnung – GroMiKV); Solvency Regulation (Solvabilitätsverordnung - SolvV)
European Banking Supervision	European Banking Authority (2018b); European Central Bank (2018b); European Parliament and the Council (2013a); European Parliament and the Council (2013b); European Parliament and the Council (2014); European Parliament and the Council (2019); European Union (2013); European Union (2014)
Current Reporting Frameworks in Europe and Germany	Central Bank of Germany (2019a); European Banking Authority (2018a); European Banking Authority (2019); European Commission and Financial Stability Financial Services and Capital Markets Union (2019)
Emerging Reporting Frameworks	European Central Bank (2015); European Central Bank (2017); European Central Bank (2018a); European Central Bank (2019a); European Central Bank (2019b); European Central Bank (2019c); European Central Bank (2019d); European Central Bank (2019e); European Central Bank (2019f); European Parliament and the Council (2019)
Regulatory Reporting Software	Hrynko et al. (2018)

Table 1. Dataset for the ecosystem development

To collect the relevant legislative acts, we researched the legal basis of the competent authorities involved in regulatory reporting on European and German levels which led to a sample of 20 main legislative acts that determine the competences of these authorities. In the next step, we identified the relevant legislative acts regarding regulatory reporting drafted by these authorities defining the reporting requirements to banks. Overall, we derived a set of 34 documents (Table 1). We first conducted a structured content analysis, including an inductive category development based on Mayring (2010)) and Miles and Huberman (1994)). With this method, we identified a set of 15 ecosystem entities as well as the value streams between them. We established inter-coder reliability to ensure consistent coding. Two experienced raters independently coded the 34 documents. Before both the raters started coding the documents, they coded a test document to become familiar with the coding scheme and then compared their coding for calibration. All authors confirmed the final coding of each document and discussed the coding discrepancies until we reached a consensus; this helped eliminate individual disparities (Bullock and Tubbs 1990). For example, we coded European Banking Authority as "EBA" based on the legal basis that the "EBA shall develop draft implementing technical standards to specify the uniform formats, frequencies, dates of reporting, definitions and the IT solutions to be applied in the Union for the [supervisory] reporting" (Article 99(5) – Regulation 575/2013). We used the same approach for identifying the value streams but combined the document information with secondary publicly available information from public consultancy cases, reports, press articles, or annual reports. For example, we coded the value streams between "Bundesbank" and "Bank" as the definition of reporting requirements and submission of statistical reports according to section 7(1) of the German Banking Act. After both the raters completed the coding, we used Krippendorff's (2004) Alpha to determine inter-coder reliability. The results indicated an Alpha of 0.89, reflecting acceptable inter-coder reliability (Krippendorff 2004).

In the second step, we used the e^3-value method to visualize the ecosystem of the emerging financial regulatory reporting frameworks based on the identified entities and the value streams between the entities. The e^3-value method is a business modeling methodology to elicit, analyze, and evaluate interrelations from an ecosystem perspective. It is used to evaluate the economic sustainability of the ecosystem by modeling the exchange of things of economic value between entities (Gordijn and Akkermans 2003; Riasanow et al. 2018).

In the third step, drawing on qualitative content analysis following Mayring (2010) and Miles and Huberman (1994), we extended the boundary resource model by Ghazawneh & Henfridsson (2013). We derived the added influence on platform boundary resources by comparing the analyzed theory with the modeled financial platform-based regulatory reporting ecosystem due to emerging regulatory frameworks.

In the fourth step, we conducted five interviews with experts from the financial industry to validate the ecosystem. We used a semi-structured technique (Myers and Newman 2007) to interview two executives from leading strategic as well as technology banking consultancies (I1, I2), a head of department for regulatory reporting of a significant bank (I3), a project lead for large-scale projects in banking and IT also at a significant bank (I4), and an expert on data harmonization for regulatory reporting (I5). The interviewees either work in a leading strategic position or information technology-related function (Goldberg et al. 2016) and have privileged access to information and knowledge on the subject (Bogner et al. 2009). This allowed us to draw from extensive knowledge and different insights from various companies. We conducted the interviews in February 2020. The interviews were recorded and transcribed afterwards and took about 60 minutes on average. To validate the ecosystem and our proposed boundary resource, we discussed the entities, value streams of the proposed ecosystem, and our proposed boundary resource model with experts.

Moving to a platform-based ecosystem for regulatory reporting

Due to emerging financial reporting frameworks, the way banks do regulatory reporting is transforming. This is particularly due to potential new market entrants like digital platforms. To model the ecosystem of the financial industry, we follow the approach of Gordijn and Akkermans (2003). This paper focuses on banks and banking groups in Germany. The identified entities, a representative bank (with its IT department and business units), the standardized reporting framework (with its working groups and the reporting framework), other European National Competent Authorities (NCA), the European Banking Authority (EBA), the European Central Bank (ECB), the German Central Bank (Bundesbank) and the Federal Financial Supervisory Authority (BaFin). The composite actor cloud computing service represents the service as perceived by banks and regulatory authorities. Therefore, the composite actor is comprised of the roles Infrastructure Provider, Platform Provider, Application Provider and Market Platform. Roles within this composite actor may offer objects jointly with other roles, but they may also offer objects on their own (Böhm et al. 2010), as shown in Figure 1.

Due to the emergence of harmonized and comprehensive reporting framework covering statistical and supervisory reporting requirements including IT-ready specifications, a significant impact on the ecosystem for regulatory reporting by shifting the value-creating processes to different entities can be observed. As Figure 1 shows, the BIRD working and expert groups comprise representatives from the ECB, EBA, NCAs and the banking industry that consolidate the relevant legislative acts and develop the underlying data model and transformation rules in an IT-ready format. Similarly, for the IReF, the European System of Central Banks (i.e. the ECB and the European NCBs) develops the reporting framework in collaboration by consolidating the statistical reporting requirements, potentially including additional national reporting requirements. Hence, the traditional key-value activity is performed within banks and platform owners to consolidate all legislative acts to derive the respective regulatory reporting requirements, and to specify the IT-ready requirements for reporting solutions shifts to the reporting framework specification. The different competent authorities lay down their legislative acts including the reporting requirements, which will be incorporated in the standardized reporting framework by the work of expert groups. The result is a publicly available, comprehensive reporting framework including IT-ready specifications. In return, the competent authorities receive a coherent set of reporting data from the banking industry to ensure the stability of financial markets.

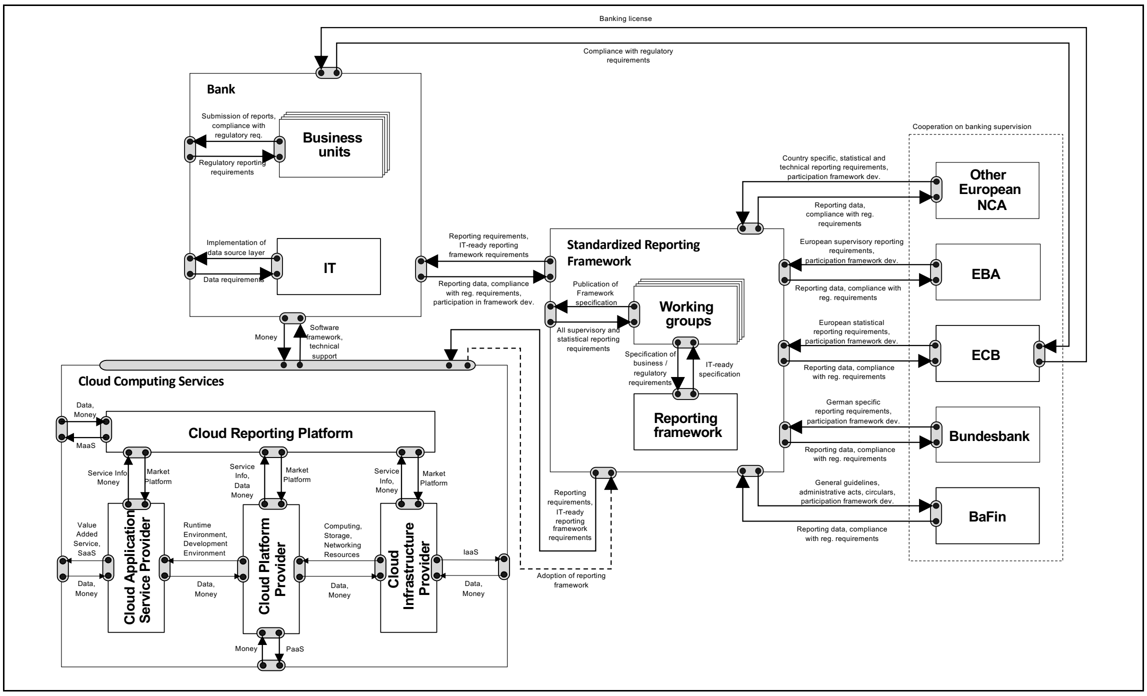

Figure 1. Ecosystem in Europe with the introduction of a standardized platform reporting framework

The specifications of the reporting framework are a public good for all interested entities. For banks, after the initial adoption, the reporting framework will reduce the burden for the implementation of new or changed reporting requirements, thus the cost of compliance. Furthermore, the standardization of the data interface between the banks' internal IT system and the reporting framework reduces the complexity to switch to another reporting solution significantly. Hence, the currently existing lock-in effect for traditional regulatory reporting solutions will be diminished by this standardization.

Platform owners can also easily adopt the new reporting logic into their software framework as the specifications are clearly defined. Hence, any future changes to the reporting requirements require less effort for the development of the reporting software, which will help software firms reduce cost. However, for software firms, the coverage of regulatory reporting requirements and the functional scope are the key value propositions. They invest and have invested significant effort and knowledge into the development of a software internal data model and transformation rules to cover as many regulatory reporting requirements from different authorities to create a unique selling point for their product. The publicly available comprehensive reporting framework will replace this intellectual property. Therefore, the value created by the regulatory reporting platform is reduced to the provision of a platform-as-a-service with additional features e.g., GUI, data analysis, workflow, and documentation tools. This is the reason why a new, standardized reporting framework poses a fundamental risk to the current business model for the software firms providing regulatory reporting software as the key value will be commoditized by public good and shifted to a platform-based solution.

The data processing steps to compile the regulatory reports can be centralized within a reporting platform as these processes are standardized with the application of a comprehensive framework. BIRD, for example, provides a harmonized data model that specifies data to be extracted from the banks' internal IT systems as well as standardized data transformation rules, which are required to produce regulatory reports (European Central Bank 2019f). A reporting platform using the reporting framework will provide a standardized data interface, i.e. the BIRD Input Layer, followed by standardized data processing steps specified through the reporting framework. Hence, this input layer represents the ideal interface from the banks' internal IT systems and architecture to a regulatory reporting platform. Additionally, the standardized data interface will reduce the complexity for banks to switch between reporting platforms, thus enforcing a stronger competition among third party software providers. An opportunity to increase the variety of functionalities and foster innovation for software platform is the creation of a software and services ecosystem by opening the software platform to third party developers and users. The successful creation of a software ecosystem around a software platform supports the software leadership of the platform (Bosch 2009; Boudreau 2012). The methodology to foster and control the cooperation with third party developers are the boundary resources. The key value proposition of regulatory reporting data is the high quality, granular and harmonized data across the different domains of risk, accounting and master data. However, this set of unique data is currently often only used to comply with regulatory reporting obligations, instead of leveraging the data for internal purposes and management decisions. Hence, any additional functionality or application developed by third parties will most likely be related to the processing and usage of the reporting data.

Discussion

With a financial regulatory platform, additional applications offering services beyond the core reporting functionality can be integrated into the reporting platform through the platform's boundary resources. The platform owner, banks using the reporting platform, or other third-party firms, e.g., RegTech and FinTech firms are potential developers of additional applications. Boundary resources enable the efficient development of third party applications for software platforms. Ghazawneh & Henfridsson (2013) proposed a boundary resources model describing the interaction between the platform owner and third-party developers. The platform owner designs the boundary resources in order to secure the platform's integrity and source variety and innovation to the platform. Third-party developers use the boundary resources to develop applications.

As our analysis for the ecosystem of emerging financial regulatory reporting frameworks based on a standardised reporting framework shows (Figure 1), the boundary resources for financial regulatory reporting platforms will have to be co-created. We propose to extend the boundary resources model of Ghazawneh & Henfridsson (2013) by two additional dimensions, the regulated entity (i.e., the banks) and their reporting data, and the regulatory authorities providing the reporting framework (Figure 2). The interviews confirmed that the platform users, i.e. the banks, would definitely require that the platform boundary resources reflect their needs. Hence, banks will significantly influence the design of the boundary resources of the regulatory reporting platform. The interviewees stated specifically the importance of 'control by the banks for their sensitive reporting data' (I1 + I2) combined with 'data security and privacy' (I4) and that the platform needs to provide a 'high degree of transparency [for third party applications] and data governance' (I3). Beyond the obvious foundation by the regulator for the design of boundary resources, one interviewee mentioned the idea that the regulatory reporting 'platform could receive some kind of certificate from the regulator' (I5). Thus, the regulatory authorities might also influence the design of the boundary resources (Figure 2).

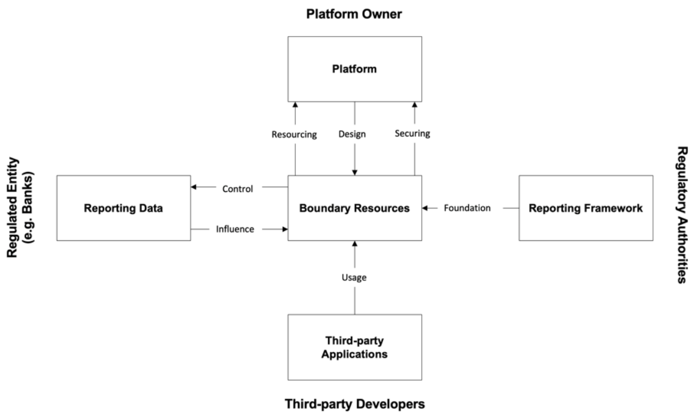

Figure 2. Boundary Resources Model for a Financial Regulatory Reporting Platform extended from Ghazawneh & Henfridsson (2013)

With an open regulatory reporting platform, the platform owner can extend its business model by sharing revenues with the third-party developers, which can extend the platform by additional components. Furthermore, banks can use the platform to develop applications for their own needs. These applications could be also shared or licensed among other platform users, i.e., other banks. Additionally, besides technical boundary resources such as APIs and SDKs, the platform owner can create social boundary resources like developer and user forums for the platform, including the interaction of third-party developers with end users. Overall, a regulatory reporting platform with an ecosystem of additional applications and services offered by third parties creates exciting opportunities for new innovation and co-creation patterns within the specific RegTech and FinTech industries (Schreieck and Wiesche 2017).

Limitations and Future Research

Our study is subject to limitations. First, the model is limited by the information provided by the analyzed documents and our coding of the entities. However, we established inter-coder reliability among two independent coders with an Alpha of 0.89. Second, we conducted five semi-structured interviews with experts from the financial industry to validate the proposed ecosystem and our extended boundary resource model. Third, drawing on the overall ecosystem, our analysis relies on the European financial regulatory reporting ecosystem and the current state of emerging financial regulatory reporting frameworks DPM, BIRD, IReF. Nevertheless, all coded documents indicate that these or similar platform-based approaches will provide new overarching frameworks.

First, it interests us to examine if the influence of emerging financial regulatory frameworks and banks on reporting platforms' boundary resources is observable in further countries, such as the American financial regulatory reporting ecosystem. Second, the co-creation of boundary resources should be analyzed in further contexts and across industries. Current anticompetitive practices of digital platforms build upon the control of platform owners to illegal use their boundary resources to give their services unfair advantages (e.g. Google used its Mobile Application Development agreement to strengthen dominance of its search engine) (Edelman and Geradin 2016). Co-creating boundary resources with regulatory institutions might help prevent the clear threat of anticompetitive behavior.

Conclusion

This paper presents the ecosystem of emerging financial regulatory reporting frameworks based on 15 entities and value streams, which were identified by a structured content analysis of the data of 34 official documents. New financial regulatory reporting frameworks enable a paradigm shift to a platform-based financial regulatory reporting ecosystem, which has implications for the boundary resources of the emerging platform-based financial regulatory reporting solutions and thus affects the whole ecosystem. We extended boundary resources model for a financial regulatory reporting platform from Ghazawneh & Henfridsson (2013) with the regulatory reporting framework itself as an external factor acting as foundation for the boundary resources and banks as they require the control about their sensitive data. Our modelled ecosystem can help banks as basis for innovative holistic reporting solutions. We encourage all actors in the financial regulatory reporting ecosystem to actively engage with the discussed emerging regulatory reporting frameworks for a holistic and harmonized solution of financial regulatory reporting.

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B2B App Store Governance in Software Platform Ecosystems: Dimensions and Types

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Abstract

The ever-increasing customer demand for use case-specific B2B software puts platform owners into a challenging situation where integrating a B2B app store into their digital platform becomes a necessity to manage the dynamics of software platform ecosystems. However, platform owners face uncertainty and experiment, while platform ecosystem research provides limited guidance for specific B2B app store governance. Closing this gap, we use multiple case studies and develop three taxonomies for architecture, control mechanisms, and demand generation to provide an overview of the solution space for B2B app store governance. We further derive three robust B2B app store governance types: platform play, transaction channel, and community platform. This paper enriches the B2C-driven and core-offering related research on digital platform governance with tangible B2B app store governance dimensions and types. We envision to guide practitioners in identifying and selecting governance characteristics to remain competitive and provide innovation for their B2B app stores.

1. Introduction

In the past decade, an ever-growing number of large business-to-business (B2B) software platforms such as Amazon Web Services or Microsoft Azure continued to proliferate proprietary online application marketplaces (e.g., B2B app stores) as “digital storefronts” on top of their digital platforms offering core products and services. Whereas Apple may have been responsible for acquainting “app store” as a portion of the general public and common vernacular, the godfather of the B2B app store is Salesforce’s AppExchange which was launched back in 2005 [1]. The concept of a B2B app store is to provide additional value to the platform owner’s customers and enable third-party developers (e.g., independent software vendors) to distribute own-build software extensions; thereby complementing the in-house built application portfolio [2].

As platform owners increasingly realize that supplementary applications are critical to successfully manage the dynamics of software platform ecosystems [3], the reasons to launch a B2B app store become obvious: For example, B2B software platforms are often developed as a standard software solution that provides natural extension opportunities for integrating specific customer use cases. B2B app stores allow software platforms to provide their users with the expertise from their own and particularly their partners’ best practices from domain specific implementations [4], which could shorten the typically long and resource-intensive B2B software sales cycles [5]. Moreover, software platforms utilizing B2B app stores might generate higher competitive differentiation through more solutions and higher adoption of their software platform, reducing churn [6].

However, continual governance adjustments of putative mature and also recently launched B2B app stores indicate that platform owners face uncertainty and are forced to experiment [7]. For example, the Execution Management platform vendor Celonis, who recently launched its EMS Store, is continually determining and optimizing the governance characteristics of its B2B app store based on recent user adoption and interactions with complementors [4].

Existing research on platform ecosystem governance, e.g., network effect governance [8], traditional pricing [9], platform openness [10], or boundary resources [11] provides a fundamental understanding that can be conveyed toward specific B2B app store governance. While these studies have been vital in advancing a holistic understanding about the governance of platform ecosystems [12], these frameworks are either too narrowed (e.g., related to the core offering of the digital platform [8]), too specific (e.g., focusing on B2C markets [13] or only focus on few governance dimensions [10]), incomplete (e.g., not considering recent originated characteristics [14]), or too general (e.g., not deriving overreaching and robust

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governance types [15]) to classify the rapidly developing and changing nuances required to explain the complex mechanisms of B2B app store governance. In sum, the existing literature yields only sparse and tangible conceptual guidance concerning our research question: *What are the B2B app store governance dimensions and types in software platform ecosystems?*

To evaluate, organize, and understand this complex domain, taxonomies might be appropriate [e.g., 14]. Taxonomies constitute a "form of classification," i.e., a "conceptually or empirically derived grouping" that enables researchers and practitioners to structure a complex domain [16]. Taxonomies further assist in deriving robust overreaching types, as they may reveal unique building blocks of B2B app store governance [15, 17].

Building on taxonomy development, we connect the knowledge from existing research and empirical data, i.e., ten interviews and 2180 pages of secondary data, such as partner documents. We derive recurring governance dimensions and tangible characteristics through constant comparison and visualize them in three taxonomies, i.e., architecture, control mechanisms, and demand generation. Aggregating the repeated analyzed combinations of characteristics, we identify three robust governance types for B2B app stores. Thus, we combine and structure the fragmented knowledge across platform ecosystem governance toward specific B2B app store governance and provide decision support when designing a B2B app store. Finally, we discuss our findings considering the lessons learned from our interview partners through designing app stores, as well as our theoretical contribution to the research field.

2. Theoretical Background

A substantial body of IS research has examined digital platforms and their ecosystem from multiple perspectives [12, 18]. From a technical perspective, digital platforms are defined as an extensible codebase on which third-party developers can develop complementary products and services through the use of interfaces [19]. In our research, we follow the socio-technical definition of platform ecosystems to empirically study the mechanisms for orchestrating a B2B app store where "a platform owner […] implements governance mechanisms to facilitate value-creating mechanisms on a digital platform between the platform owner and an ecosystem of autonomous complementors and consumers" [20]. Following the three dimensions "providing autonomy", "ensuring integration", and "creating incentives" of platform ecosystem governance by Tiwana [19], previous research provides a decent understanding of relevant governance mechanisms to orchestrate a digital platform ecosystem [15]. For example, a concept relevant to platform ecosystem governance is providing boundary resources through APIs, SDKs, and other development interfaces that enable and facilitate complementors to co-develop solutions on the platform [21]. The concept of openness describes a relevant platform ecosystem governance mechanism to limit the use, development, and commercialization of solutions shared on the platform [10]. The concept of pricing and revenue sharing in platform ecosystem governance addresses monetization streams in the ecosystems and how they influence network effects [9].

By integrating app stores into the concept of digital platforms [13] we use the term "product platform" to refer to the core offering of the digital platform (e.g., Microsoft Azure) and the term "app store" (e.g., Azure Marketplace) to designate the digital interface between the platform owner and the stakeholders in the platform ecosystem (Figure 1) [2]. Platform owners implement app stores to create a venue for the simplified exchange

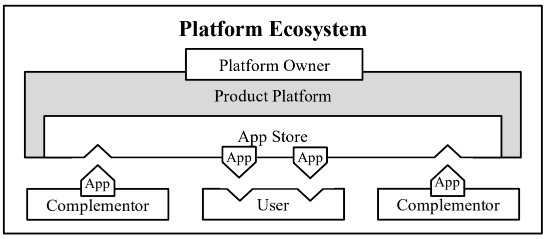

Figure 1: Platform Ecosystem Architecture with App Store

of solutions between third-party developers and end users [22]. Given the inherently high fragmentation of complementors and users, app store ecosystems provide a healthy environment for ecosystem participants and lead to a high number of platform-specific applications [23]. App stores offer both complementors and end users a novel environment to develop and procure software that differs from previously used channels [22]. However, the experience can influence the perceived trust in the platform owner–complementor relationship [24]. To date, few studies on platform governance have integrated concepts of novel expectations and trust through the implementation of app stores. As a basic functionality, payment and commissions are enabled through app stores [25]. Previous implementations of app stores have shown innovative forms of monetization for both complementors and users, e.g., development fees, upfront commitment to a certain level of usage, or paid ancillary services [26]. Still, the current literature on platform governance focuses on traditional pricing strategies, such as revenue sharing and subsidizing complementors; thus, specific, relevant metrics are not considered [27]. The implementation of app stores offers complementors and users new opportunities for co-creating value [28]. Consequently, to encourage complementors to align with the platform's strategic and operational objectives, input control becomes an essential concept in platform governance [29]. Furthermore, newly created partner programs for different types of complementors facilitate participation in the app store ecosystem; however, such programs require an effective mechanism for the validation and allocation of partners [30]. Yet, research on platform ecosystems in terms of novel characteristics, such as B2B app store experience, pricing, and partner programs remains sparse.

Building on the concepts associated with platform ecosystems, an extensive body of IS research on mobile app stores has emerged that attempts to understand the underlying concepts that drive the success of B2C app stores [31]. Existing implementations, such as the Apple App Store and Google Play Store, have become commonly used empirical cases to investigate value co-creation within a large ecosystem of users and complementors [32]. In such B2C-based app stores, research found that the degree of control over developer autonomy correlates with the quality and productiveness of the overall ecosystem [33]. Another study on B2C app stores highlights the importance of the quality assurance mechanisms exercised by the platform owner for submitted applications, as users are not willing to search and pay for apps of unknown quality [2].

However, B2B differ from B2C markets. As B2B app store users often have IT and business-related backgrounds, the buying process is different because whole departments rather than a single person are responsible for buying products or services in companies. Thus, pricing methods need to be flexible and cannot simply be based on approaches used with B2C app stores. Another distinguishing feature of B2B app stores compared to B2C stores is the increased expectation of users concerning the quality of the apps, as prices are significantly higher and the applications are often used in production software systems, where reliable operation is critical to the entire system. Furthermore, a B2B app store attracts commercially motivated complementors, e.g., independent software vendors, original equipment manufacturers, or consultants with whom further go-to-market motions are planned on top of the solution and access to the sales base is given. In contrast, B2C app stores have both private and commercial users and offer predominantly standardized demand generation packages, which are not sustainable in the B2B domain. It is thus unclear, under which conditions a digital platform with an app store can be successful in B2B ecosystems.

As the number and importance of B2B app stores increases, a detailed overview of the specific governance concepts for B2B app stores is required. Although the current literature on platform governance provides a profound understanding of mechanisms to orchestrate a platform ecosystem, relevant concepts that specifically address the novel features and tangible characteristics of B2B app stores have not been considered. Existing research provides frameworks to classify high-level governance concepts [17]; however, granular analyses that could guide practical app store implementations are lacking. Even the more specific studies on B2C app stores do not consider numerous characteristics that are relevant to B2B app stores and therefore cannot be used to infer governance principles from the B2C to the B2B domain. A general overview of governance concepts for B2B app stores that combines relevant theory on platform governance with practical insights from successful app store implementations is required.

3. Methodology

This work follows a three-phase research approach. First, we created the empirical basis of this study with multiple case study research based on Yin [38] and coded the cases based on Corbin et al. [34]. This rich case study data provides the basis for the second phase: the development of a detailed taxonomy and types. We apply the method proposed by Nickerson et al. [16] to systematically build and evaluate a taxonomy for B2B app store governance. This method facilitates combining theoretical concepts about platform ecosystem governance with empirical findings from the multiple B2B app store case study. The third phase follows the approach of Punj et al. [35] to cluster and derive robust B2B app store governance types.

3.1. Multiple Case Study

First, following the method proposed by Yin [36], we performed a multiple case analysis with ten cases, as shown in Table 1. Each case in the database represents a B2B app store implementation in the enterprise software domain. The criteria used to choose the cases were selected to provide sufficient information on app store governance from cases that have a large number of active users and complementors [37]. Second, following the guidelines provided by Gläser et al. [38], we conducted ten semi-structured interviews with the case vendors and triangulated the data with 2180 pages of partner-related documents that were retrievable through the vendors' websites [36]. The selected interviewees are either working in a leading strategic position or had ownership stakes in the app store, who have privileged

Table 1: Interviews and documents from the case study

#	Case	Vendor	Market	Interviewee Role	Duration	Sec. Documents Pages	Exemplary Reference
In1	Appian AppMarket	Appian	BPM	App Store Owner	51:40 h	60	[39]
In2	AWS Marketplace	AWS	Cloud	ISV Manager	58:47 h	285	[26]
In3	Azure Marketplace	Microsoft	Cloud	Cloud Architect	55:46 h	831	[40]
In4	Blue Prism Digital Exchange	Blue Prism	RPA	App Store Owner	99:38 h	8	[41]
In5	Celonis EMS Store	Celonis	EMS	ISV Manager	47:32 h	34	[42]
In6	Pega Marketplace	Pega	BPM	ISV Manager	76:08 h	6	[43]
In7	Salesforce AppExchange	Salesforce	CRM	ISV Manager	92:34 h	90	[30]
In8	SAP Store	SAP	ERP	Digital Sales	60:47 h	27	[44]
In9	ServiceNow Store	ServiceNow	ERP/CRM	Solution Engineer	53:02 h	22	[45]
In10	Splunkbase	Splunk	Analytics	Product Manager	76:37 h	817	[46]

access to information and knowledge on the respective B2B app store (Table 1). Third, following the method proposed by Corbin et al. [34], we applied an iterative coding approach to the interview results with open, axial, and selective coding to identify governance characteristics in the interview quotes and identify relationships between the characteristics.

3.2. Taxonomy Development

Following the approach adopted by Nickerson et al. [16], we performed three iterations with alternating inductive and deductive cycles to develop and evaluate the taxonomy on B2B app store governance. In addition, we specified objective and subjective ending conditions to terminate the iterative process [16]. Before starting, we adopted the governance dimensions of Tiwana [19] with insights from our first research phase (3.1) to structure B2B app store governance toward the three sub-taxonomies of *architecture*, *control mechanisms,* and *demand generation* to better guide the selection of governance dimensions. For each sub-taxonomy, the following three iterations were performed:

The first iteration follows the conceptual-to-empirical approach and builds an initial taxonomy for B2B app store governance connecting general B2B app store literature. Considering the rigor of the defined characteristics, we analyzed the literature for existing governance dimensions and characteristics and synthesized relevant concepts into an initial taxonomy. For example, the governance concept of "External Relationship Management" was considered to attribute for the management of complementors in the digital platform ecosystem [14]. Due to the limited number of publications on B2B app store literature, we expanded our initial search to include research on platform ecosystem governance, where app stores are not part of the platform. The more generalist nature of the governance concepts for platform ecosystems allows some concepts to be re-applied and referenced to platform ecosystems with app stores. The second iteration follows an empirical-to-conceptual approach and further develops the initial taxonomy with empirical aspects from the multiple case studies. For example, the initial concept of "External Relationship Management" evolved into the dimensions "Supervision Roles" and "Supervision Engagements" of the *control mechanisms* taxonomy. We classified nine app stores from our sample with the taxonomy, added further characteristics that were derived from the coded results, grouped the characteristics into dimensions, and revised the taxonomy [16]. Ultimately, we performed this process until all cases were included. In the third iteration, we applied an empirical-to-conceptual approach to evaluate the resulting taxonomy by exposing it to a tenth case that was not used in the previous inductive step. The case was fully representable by the dimension and characteristics defined in the taxonomy.

3.3. Qualitative Cluster Analysis

In the third phase, we applied the resulting B2B app store governance taxonomy to the ten cases by following a within-case analysis approach [36]. As part of this, we conducted a qualitative cluster analysis in a cross-case setting and applied constant comparisons to the resulting types. Ultimately, we were able to identify three robust B2B app store governance types that share common governance expressions within their case group. The derivation of robust types is based on the relative occurrence of governance characteristics within the group of a type. For example, the *Platform Play* governance type is characterized by the consistent occurrence of the characteristic "High Verification" for the "QA Rigor Level" dimension. Each type has different centers along the dimensions and characteristics in the taxonomy [36]. To ensure clarity and singularity among the types, we pruned the taxonomy on dimensions where there was no singular identifiable expression.

4. Results

4.1. B2B App Store Governance Taxonomy

The resulting taxonomy on B2B app store governance is divided into three sub-taxonomies that relate to *architecture*, *control mechanisms* and *demand generation* (Tables 2, 3 and 4). Dimensions marked with an asterisk (*) are mutually exclusive and can only be defined through a single characteristic, and dimensions without an asterisk are not mutually exclusive and can be defined by a combination of multiple characteristics.

The first sub-taxonomy on *architecture* covers the infrastructure and solution-related governance components and resources that form the fundamental and operational basis of each app store (Table 2). The concept *Solution* describes the types of solutions that are distributed through the app store and how they relate to the product platform. The concept *Infrastructure* relates to the governance of app store infrastructure, i.e., the different portals and components that characterize the usability of the app store. The *Technical* concept addresses all dimensions related to the technical functionality of an app store and the solution types offered. The *Resources* concept describes the tools provided to complementors to facilitate the development of solutions and enable complementors to use the platform elements.

The second sub-taxonomy on app store governance comprises aspects related to *control mechanisms,* which establish operating principles and exert fundamental directives on all participants in the ecosystem (Table 3). The concept of *Openness* defines which groups have access to the app store and can participate in the ecosystem to create or receive value. The concept of *Complementor Selection* defines which type of complementors participate in the app store ecosystem and how they are selected. By defining the concept of *Complementor Management*, the supervision through assigned roles is specified. The concept of *Input Control* is implemented in app store governance to validate and ensure a certain level of quality of the content offered through the store. The concept of *Monitoring* provides feedback about the complementors solutions. The concept of *Complementor Monetization* defines the mechanisms that app store owners implement to monetize complementors. The concept of *End user Monetization* describes the monetary mechanisms used to price the use of the app store and the available solutions.

The third sub-taxonomy, i.e., *demand generation,* describes the governance principle employed to incentivize complementors and end users to participate, contribute, and consume content through the app store (Table 4): The concept of *Marketing* defines the components used to incentivize partners and end users to engage on the app store. The concept of *Sales* describes the method used to sell content through adjunct channels. The concept of *Feature* describes further incentives for partners and how end users are targeted to consume through the app store.

Table 2: Architecture Taxonomy (1=AWS Marketplace, 2=Salesforce AppExchange, 3=Appian AppMarket)

Concept	Dimension	Characteristics					
Solution	Solution Type	SaaS [2]	Application [1, 2, 3]	Use Case [1, 2, 3]	Service [2]		
Solution	Application Types	Platform App [1, 2]	Modules [1, 3]	Connectors [2, 3]	Templates [2, 3]	Dashboard [1, 3]	
Solution	Integration Type	Platform Native [1, 3]	Native + Integration [1, 3]	Integration [1, 3]	Hosting [2]		
Solution	Application Packaging*	Add-On [1, 2, 3]	Standalone [3]				
Solution	Application Customization*	Full [3]	Modular [1, 2]	Not Allowed			
Infrastructure	Portal Types	App Store Portal [1, 2]	Partner Portal [1, 2, 3]	Developer Portal [1, 2, 3]	User Portal [2]		
Infrastructure	Developer Portal Location*	On App Store [3]	On Home Page [1, 2]				
Infrastructure	App Store Location	Dedicated Website [1, 2]	Developer Portal [3]	Product Platform			
Infrastructure	Application Filters	Type [1, 2, 3]	Free/Paid [1, 2, 3]	Author [2, 3]	Badges [2, 3]	Industry [2, 3]	Business [2]
Infrastructure	Submission Account*	Complementor Account [1, 2]	User Account	No Account Required [3]			
Infrastructure	Submission Location	App Store Portal [2]	Partner Portal [1, 2]	Website [3]			
Infrastructure	Lead Destination	Partner Portal [1, 2, 3]	CRM [1, 2]	HTTPS Endpoint [2]	Mail		
Technical	Software Coding Effort*	Code [1, 2, 3]	Low-Code [2, 3]	No-Code [1]			
Technical	Application Fulfillment	App Store [1, 3]	Complementor Landing Page [2]				
Technical	Application Deployment	Cloud Environment [1, 2, 3]	On-Prem Environment				
Technical	Application Installation*	Automatic [1, 2]	Manually [3]				
Resources	Development Environment*	Offline IDE [1, 2]	Online IDE [1]	None [3]			
Resources	Development Tools	API [1, 2, 3]	Libraries [1, 2, 3]	SDK [1, 2, 3]	Data Models [2]	Components [1, 2, 3]	Semantic Layer [2]
Resources	Developer Enablement	Documentation [1, 2, 3]	Tutorials [1, 2]	Guidelines [1, 2, 3]	Sample Code [1, 2]	Use Cases [1, 2]	Community [1, 2, 3]

Table 3: Control Mechanisms Taxonomy (1=AWS Marketplace, 2=Salesforce AppExchange, 3=Appian AppMarket)

Concept	Dimension	Characteristics					
Openness	App Store Accessibility*	Public [1, 2, 3]	Customers [3]	Individual [3]			
	Developer Portal Users*	Developers [2]	Customers	Shared [1, 3]			
	Application Availability	Public [1, 2, 3]	Private [2]	Custom			
	Geographic Targeting	All Countries [2, 3]	Selected Countries [1, 2]				
Compl. Selection	Complementor Types	Commercial Partners [1, 2, 3]	Platform Owner [1, 2, 3]	Employees [3]	Customers [2, 3]		
	Commercial Partner Types	Ind. Soft. Vend. [1, 2, 3]	Man. Serv. Prov. [2, 3]	Reseller [1, 2]	System Integrator [1, 2]	OEM [1, 2]	Service Provider [2]
	Complementor Entities	Company [1, 2, 3]	Individual [3]	Anonymous			
	Selection Criteria	Product [1, 3]	Business Plan [1]	Customer Base	Competitor	Compliance [2]	Strategic Fit [1]
	Commitment Criteria	Terms & Conditions [1, 2, 3]	Marketing Guidelines	Seller Guidelines [2]	Frequent Update [1]		
Compl. Management	Partnership Tiers*	Multiple Tiers [1, 2]	Single Tier	Other [3]			
	Supervision Roles*	Partner Mngr. [1, 2, 3]	Operations Mgr. [2]	Marketing Mgr. [1]	System Engineer [1]	Other	
	Supervision Engagement*	High Touch [1]	Medium Touch	Low Touch [2, 3]			
	Support Responsibility	Platform Owner [2, 3]	Complementor [1, 2, 3]				
Input Control	Targeted Product Maturity	Ready-to-Sell [1, 2]	Concept [1]	Early Idea [3]			
	App Selection Criteria	Market Size [1]	Use Case [1, 3]	Platform Fit [1, 2]	Co-Sell	Time-to-market	Contract Value
	Product Novelty*	Strict Novelty [2]	Reuse Components [1]	Not Checked			
	QA Rigor Level*	High Verification [1, 2]	Low Verification [3]	No Verification			
	Verification Levels	Technical [1, 2, 3]	Security [1, 2, 3]	Functional [1]	UI	Content	
	Verification Criteria	Compatibility [1, 2, 3]	Completeness [1]	Performance	IP Ownership	Policies	Expertise
Monitoring	App Store Statistics	Orders [1, 2]	Usage [1, 3]	Page Visits [2]	Unique Visitors	Revenue [1, 2, 3]	KPIs [1, 2]
	Customer Feedback	Rating [1, 2, 3]	Review [1, 2, 3]	Contact [1, 2]	Feature Request		
Compl. Monetizat	Monetization Model*	Revenue Share [1, 2, 3]	App Publishing Fee	None			
	Listing Transaction*	Transactable [1, 2, 3]	Non-Transactable [1, 2]				
	Development Fees	Paid	Membership Fee	Free [1, 2, 3]			
End-User Monetization	Pricing Model	One-Time Fee	Subscription [1, 2, 3]	Metric	Bring y. own license [2]	Free-Trial [2]	Free [1, 2, 3]
	Consumption Metric	# of Users [1, 2, 3]	Hosts	Data [2]	Bandwidth [2]	Time	
	Metric Selection*	Single Metric [1, 3]	Multiple Metrics [2]	Flat Fee			
	Consumpt. Commitment	Upfront [2]	Pay as you go [1, 2, 3]				
	Discounting*	Volume Discounts [1, 2]	Reseller Discounts [1, 2]	None [3]			
	Pricing Transparency*	Full Price [1, 2]	Price Range	Not Visible [3]			

Table 4: Demand Generation Taxonomy (1=AWS Marketplace, 2=Salesforce AppExchange, 3=Appian AppMarket)

Concept	Dimension	Characteristics				
Marketing	Partner Awarding	Available [1, 2, 3]	Not Available			
	Joint Marketing Initiatives	Campaigns [1, 2, 3]	Press Release [1, 2, 3]	Keynotes [1, 2, 3]		
	App Marketing Assets	Webinars [1, 2, 3]	Blogs [1, 2, 3]	Co-Branding [1, 2]	Press Release [1, 2]	Use Case [1]
Sales	Sales Channels	Digital [1, 2, 3]	Direct [1, 2, 3]	Outsourced Bus. Process. [2]	Reselling [1, 2, 3]	
	AE Compensation	Direct Sale [2]	Digital Sale [1]	Partner Resell [3]		
Feature	App Store Programs	Co-Sell [1, 2]	Consumption	Marketing Benefits [2]	Sales Benefits [2]	Affiliate Program [1, 2]
	Partner Incentives	Revenue [1, 2]	Customer Base [1, 2, 3]	Technic. Validation [2]	Discounting	Co-Selling [1, 3]
	App Recommendation	Based on Usage [1, 2]	Based on History [2]	Not Available [3]		

4.2. B2B App Store Types

Applying qualitative clustering reveals three robust app store governance types, i.e., *Platform Play*, *Transaction Channel*, and *Community Platform*.

4.2.1. Platform Play. The first governance type is represented by the Blue Prism Digital Exchange, Celonis EMS Store, Salesforce App Exchange, SAP Store, Service Now Store and Splunkbase in the examined sample. We exemplified the classification of the Salesforce AppExchange by a superscript "1" in the taxonomy. For these stores the underlying governance principle is to extend the product platform with a significant number of innovative and purpose-built applications. App store owners run a *Platform Play* app store to “increase the adoption of the core offering […], enhance the stickiness of the platform […] [and] differentiate the offering of that from competitors” [In1-In10]. *Platform Play* app store owners attempt to capture and retain end users by offering a diverse set of value-enhancing solutions that differentiates their platform and ecosystem from competitors. For example, the SAP Store offers a variety of add-ons and extensions that enhance core functionality and increase user productivity. Thus, the user becomes dependent on these solutions and ultimately on the app store/platform because, in most cases, the products are only offered on one app store. The guiding principle of the *Platform Play* app store emphasizes ease of use for the end user by handling the fulfillment process entirely through the app store and automatically installing and deploying the procured solutions in the end user's cloud or on-prem environment. Complementors provide solutions that build natively on the platform and extend the core offering with third-party integrations. Platform owners provide developers with a variety of tools, e.g., SDKs, low-code application builders, to internalize external innovation potential. For example, the Salesforce AppExchange provides an API for solution integrations via Apex code and offers a native low-code builder that enables partners to create workflows and list them on the AppExchange. According to an app store owner, the complementors are ranked in multiple partner tiers “[…] to provide incentives to increase their engagement [in the app store] by getting certified and participating in co-selling motions” [In1-In10]. The onboarding and development process for a complementor is defined through a high touch onboarding experience by having the relationship owned by a partner manager, being supported in the development by a system engineer, and receiving marketing support from a marketing manager. The challenge for the app store owner is to balance innovation and control, as they set up a strict quality assurance policy that guarantees compliance with the core offering and increases usability for the end user. The input is controlled on technical, security, and functional levels, whereas the content is reviewed by end users. This creates an additional incentive for partners to deliver high-quality solutions as the open feedback culture circles back to their products. To attract a significant number of complementors, the monetization model for the complementor was simple in all app stores studied; product adoption was favored over direct revenue. A characteristic of the *Platform Play* type is to increase consumption of the main product by offering solutions that extend the core offering through the app store and hence increase usage and indirect revenue. The complementor receives a free development instance and shares a fixed part of the revenue generated through the listing with the app store owner. Among all studied app stores, the end user is presented with a set of different pricing models, e.g., one-time fees, subscription, and metric-based pricing. In all cases, the app store also provided free software, and five out of six offered free trial versions of paid software.

4.2.2. Transaction Channel. The Azure Marketplace and the AWS Marketplace represent the *Transaction Channel* type through which a variety of solutions and services are distributed. We exemplified the classification of the AWS Marketplace by a superscript “2” in the taxonomy. This type is characterized by offering non-platform native solutions that are hosted on their infrastructure alongside solutions that also extend the core offerings of the platform. For example, both AWS Marketplace and Azure Marketplace host solutions that do not extend their core solutions. Complementors use this type of app store to increase their pipeline conversions and leverage co-sell motions offered in joint go-to-market programs. In both cases, the underlying platform is a cloud vendor that hosts third-party solutions together with extensions to the app store’s core offerings. Ensuring seamless integration, an app store owner confirmed that “most of the solutions offered on [the app store] are transactable, which allows them to be billed directly via [the app store]” [In1-In10]. Typically, the *Transaction Channel* type lists the greatest variety of solution types, such as SaaS offerings, applications, use cases, and professional services. It is the only type to offer services. The available applications are commonly packaged as standalone and can be procured as a subsidiary and extension of the product platform. The infrastructure offers dedicated portals for each app store management and to complete partner-related go-to-market activities, as well as dedicated developer portals with a great number of resources. The development tools provided typically include APIs, libraries, SDKs, data models, components, and semantic layers, such as those offered in the AWS Marketplace. This type of app store accepts a variety of commercial partner types and is usually does not apply strict criteria in selecting partners. Product platform customers can act as ISVs and can represent managed service providers, resellers, solution integrators, and original equipment manufacturers. The onboarding process is generic and standardized with a great range of resources available for selfeducation. The input is rigorously controlled, and to onboard complementors offerings, products need to pass several quality assurance levels, including customer experience. Users use the *Transactional Channel* to find, test, and purchase third-party software for production purposes. In the two app stores studied in this category, the user had previously committed to a certain amount of consumption on the product platform and, according to an app store owner, "[…] procures software through [the app store] that counts against their consumption commitment" [In1-In10]. The user is presented with a large variety of pricing metrics as the solutions offered can contain several features and components that are priced independently, and the hosting of the solution is billed separately from the core offering. Demand among users is created by leveraging different app store programs, press releases, and speeches on key features of new programs listed on the app store.

4.2.3. Community Platform. The third governance type, the *Community Platform,* is represented by the Appian AppMarket and the Pega Marketplace and creates a vivid ecosystem of customer-based complementors to contribute to the product platform. We exemplified the classification of the Appian AppMarket by a superscript "3" in the taxonomy. In all examined app store implementations, the external expertise is considered as internal expertise that is productized and listed on the app store by partners, customers or employees. The solutions offered are applications and use cases that comprise templates, modules, or connectors. It is expected that "customers act as complementors as they have gained […] industry-specific expertise through applying [the core offering] in a day-to-day setting" [In1-In10] and contribute to the community of the platform by providing the insights. This is common practice with the Appian AppMarket, where actual customers of their product platform are incentivized to productize and list some content of their business practices on their app store. Often those insights are provided without charge. These app stores profit from the community as they can capture value through the ecosystem from a multitude of free offerings. Differing from the other types, the *Community Platform* also accepts contributions from complementors who are legally acting as individuals rather than companies. Typically, the app store is part of the community portal and access requires a customer or developer account. One of two app stores examined in this category provided a website for the submission of app store products that could be used without requiring an account. The submission page could be accessed without the need to apply or register for any kind of partnership. This is used to decrease the burdens associated with going through onboarding and qualification processes. However, as fewer monetary incentives are involved, the onboarding process is quicker and tied to less stringent criteria than the other types of B2B app stores. *Community Platform*-based app stores offer APIs with documentation and low-code development environments as part of their core offering. This eases the process of developing and productizing knowledge. In all implementations of this type of app store, input control was kept to a minimum and quality was only assured on a security and technical level, but not on a functional or content level. One app store owner stated that the applications on their platform "are community tested" and if "users have issues they kind of discuss on it." [In1-In10]

5. Discussion

As customers of B2B software platforms increasingly rely on third-party solutions that augment the platform's core functionality [47], B2B app stores are rapidly gaining importance. To operate a successful B2B platform, app store owners must be particularly attentive to the specific requirements of complementors and the generally high expectations of customers. Our study aims to provide a detailed understanding of these control concepts in B2B app stores.

There are some limitations to the results of this study. Providing a complete representation all existing B2B app stores was not feasible. However, our study of ten prestigious cases with a multitude of supporting documents supports a substantial body of empirical evidence. Furthermore, some information on control mechanisms is only accessible to commercial customers or users of the platform. We conducted interviews with industry experts to fill this gap. By not assigning companies to the retrieved interview data, we derived three taxonomies that provide a generalist view of the industry. In addition, it may be interesting to conduct a longitudinal study to gain a process view of possible changing B2B app store governance paradigms within this rapidly evolving field. However, we attempted to mitigate this problem by collecting data over seven months.

With our findings on B2B app store governance, we first add to the body of literature on platform ecosystem governance by providing three taxonomies that reveal concrete and tangible dimensions and characteristics on B2B app store governance. Combining findings from research on case study insights and platform governance allows us to enrich the general guidance on governing a digital platform by considering vital characteristics of B2B app stores

[17]. Differing from other studies that consider an app store as an interface between the platform owner and ecosystem actors, we consider the app store as a "digital storefront" and as an integral part of the underlying platform [2]. This perspective allows us to explore the conceptual integration of both constructs and hence provides grounded insights. For example, we show that existing principles for monetization need to be extended with novel commercial models emerging in B2B app stores, e.g., consumption-based pricing models or upfront commitment of usage.
Second, our results highlight the importance of distinguishing between different manifestations of governance concepts for B2B app stores. Ultimately, we derive three robust app store types, each of which provides a different rationale for the interpretation and expression of governance characteristics. All app store types show that they can be distinguished along the derived dimensions in the taxonomies based on the selected characteristics. An important dimension that helps distinguish app store types is complementary management, as some app stores provide extensive support for managing complementors, while others limit dedicated support and rely on the self-sustainability of complementors.

In practice, our findings provide insights for platform owners that guide the implementation and operation of B2B app stores. Specifically, we derive three relevant lessons learned from the study: First, conveying the platforms' identity to users and complementors is a crucial factor in increasing overall engagement and usage [In7]. Complementors that develop, list, and market their solutions in the same fashion as the platform owner primarily create solutions aligned with the platform's core principles, which ultimately lead to higher user satisfaction. Platform owners address this with a business plan that complementors must follow when registering. Second, offering free and publicly accessible development tools, documentation, and enablement assets is essential to attract complementors [In2]. This openness allows complementors to discover integration options and does not create any financial obligations in the exploration and development phase. Third, while ensuring the overall rigor of the applications, platform owners limit quality assurance to functional and security levels while leaving other levels unverified [In8]. App store owners facilitate this by having customers review the solutions they procure, as they have extensive industry experience and can provide detailed and use case-specific insights into the applications. It also favors user-to-user communication, as users tend to have similar backgrounds and can discuss the quality of solutions on a similar level. This trend can be seen in the emergence of third-party platforms for B2B software evaluation, e.g., G2 Crowd or Gartner Peer Insights.

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Digital Platform Ecosystem Performance: Antecedents and Interrelations

Full research paper

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Abstract

The success of many of the world's most valuable companies is based on digital platform ecosystems (DPEs). Their performance depends on integrating autonomous, individually incentivized but highly entangled actors using digital platforms to cocreate values. Extant research uses numerous dependent variables to measure the performance of different actors in isolation. These variables are often limited to the (economic) gains of single actors, where an interconnected perspective on the performance of the whole DPE is lacking. This study extracts all variables and causal links from 132 empirical articles in top information system, management, and economic outlets and aggregates them into ten interconnected antecedents of DPE performance, namely: Heterogeneity, Competition, Engagement, Governance, Quality, Network Size, Generativity, Architecture, Cost, and Motivation/Satisfaction. Based on a nomological network, we contribute an understanding of DPE performance as an interrelated, sociotechnical, and dynamic construct. Our findings aim to support practitioners in effectively navigating and steering their DPEs.

Keywords Digital Platform Ecosystem, Performance, Antecedents, Interrelations

1 Introduction

The growing dominance of digital platform ecosystems (DPEs) has a major impact on today's economy, society, and science (Böttcher et al. 2021). In essence, DPEs comprise a platform owner who implements governance mechanisms (e.g., Floetgen et al. (2022)) to promote value-creating mechanisms between an ecosystem of autonomous suppliers of complementary products and services (e.g., developers or sellers) and consumers (Hein et al. 2020). For instance, Google, which was initially launched as a search engine company in 1998, has developed many successful platform ecosystems from Search and YouTube to Android, the latter powering over 70% of the world's mobile devices (StatCounter 2021). However, whether this number can be considered as a good performance for a platform owner, the resulting consequences to their whole collective ecosystems of all complementors, users, and society have recently come under controversy, with near-monopoly DPEs squeezing both their competitors (Khan 2017), complementors and employees (Karanović et al. 2021). For example, while a growing digital platform has mostly positive implications for its platform owner and users, it can also harm complementors through increased competition and decreasing market power (Rietveld et al. 2020). This renders our understanding of the performance of the whole DPE (comprising the collective of multiple autonomous and individually incentivized actors and platform technology) to an ill-defined, "wicked problem," with no optimal solution (Lowenthal 1992). However, an understanding of the integrated DPE performance is necessary: Looking at the different DPE actors, owners need feedback on their ecosystem's performance to make the best possible governance decisions. Conversely, complementors and users continually need to decide whether to further invest their resources by developing and maintaining complements or using the platform (Floetgen et al. 2020; Floetgen, Mitterer, et al. 2021). Similarly, society should understand how a DPE's performance is interrelated to making effective policy and regulatory decisions for our digital life.

Concomitant, research on DPE performance has not reached a theoretical convergence: First, each of the DPE research fields brings their own isolated foci and lenses to the scene, studying diverse issues such as governance mechanisms and boundary resource design (Karhu et al. 2018), network externalities and competition (Rochet and Tirole 2003), and technology leadership or transitions (Ozalp et al. 2018). Second, financial measures dominate empirical research on performance. It is equated with various metrics, such as market share or transaction volume, thereby mainly taking a profit-oriented, nontechnological governance perspective that neglects anteceding influences. Nevertheless, these isolated measures cannot represent the actual value realized by all ecosystem actors as they favor instrumental over humanistic objectives (Vargo et al. 2017). Conversely, both should be foundational to information system (IS) research (Sarker et al. 2019) and DPEs (Hein et al. 2020). Thus, DPE research and participation require a collective and connected understanding of its performance, as the performance of a DPE now does not lie within a single actor, technical component, or financial measure but in their integrated link (Floetgen, Novotny, et al. 2021; Tiwana 2013). This constitutes a learning opportunity to aggregate the knowledge across the diverse research areas for the DPE, IS and management domain, as their numerous constructs are likely connected. In sum, we aim to increase our understanding of collective DPE performance and its interrelations through causal links that shape their evolution over time based on the existing empirical research. Therefore, we focus on the following research question: *"Which isolated variables have been studied empirically which describe DPE performance, and what are the interrelations between them?"*

This work follows an empirical literature review approach to build a comprehensive and interrelated overview of performance measures for all ecosystem actors and the underlying technology. We extracted all variables and causal links (i.e., empirical relationships) among them from 132 articles in top IS, management, and economic outlets, following the established review approach and coding guidelines pioneered by Lacity et al. (2010). Out of these variables, 10 interrelated antecedents of DPE performance emerged through an iterative coding process, which shape our understanding of DPE performance. Thus, we combine empirical knowledge across largely unconnected areas and showcase boundary constructs within a nomological network that can bridge theories.

2 Theoretical Background

DPE research has not arrived at a consensus regarding the performance of DPE. However, this has not hindered its measurement; DPEs rely on different sets of metrics ranging from financial (i.e., revenue, profit, and market share); engagement (i.e., utilization and adoption rate); and network size to quality or heterogeneity measures (i.e., customer satisfaction, "killer applications", and resilience) (Floetgen, Strauss, et al. 2021; Jacobides et al. 2019). Nevertheless, how exactly do these interrelate in aggregate is unknown. Without setting prior measures into context, we cannot effectively isolate the true effects of independent variables on them nor control for confounding variables, consequently impeding comparisons of studies and building a cumulative body of knowledge (DeLone and McLean 1992).

Two multidimensional theoretical perspectives on ecosystem performance have also been proposed. Drawing on the ecological metaphor of ecosystem health (Rapport et al. 1998), productivity (e.g., ROIC), robustness (e.g., firm survival rates), and innovation or niche creation (e.g., created diversity) are promoted as central measures for ecosystem performance (Iansiti and Levien 2004). However, these are targeted at analyzing business or industry ecosystems composed of networks of firms, which do not have to be centered around a digital platform and, thus, lack technical units of analysis. A framework catering explicitly to platform ecosystems is offered by Tiwana (2013), where a set of nine metrics to analyze a platform's evolution over different timespans is presented. Inspired by systems research, it encompasses *resilience*, *scalability,* and *composability* in the short term; *stickiness*, *platform synergy,* and *plasticity* in the medium term; and *envelopment*, *durability,* and *mutation* in the long term, which are described as emergent properties that capture changes in actor behavior over time. These metrics were developed to help steer DPE evolution by identifying relevant signals and consciously managing tradeoffs. All metrics are observed at the technological level, applying to both platforms and complements. Additionally, some causal links between the measures are proposed (e.g., *composability* influences *plasticity*, which then influences *mutation)*, also described as a necessary condition. Nevertheless, being measured for technical components only caters to platform owners and complementors, omitting the user's perspective which also limits its applicability to innovation DPEs. Many measures (e.g., *composability*) do not apply to transaction contexts, such as product listings on the Amazon.com Marketplace. Moreover, the proposed evolutionary measures correspond mainly to operational (i.e., availability, error rates, integration efforts, system quality) and economic goals (i.e., net revenue, competitive survival/performance). Instead of adding the performance of all local entities toward combined ecosystem performance, a global perspective or ultima on performance is required to account for emergent effects. Moreover, this framework proposes initial connections and causal links between the measures. These also cannot be considered exhaustive and lack empirical evidence. Thus, while the measures capture relevant factors, we still lack a common understanding of the likely interrelated and dynamic nature of DPE *Performance*.

The last perspective on ecosystem performance can be adopted from the literature on value creation. Following Vargo et al. (2017), value-in-exchange (e.g., the price paid for a good or service) has dominated economic and business research since the 18th century. However, the rising importance of customer-centricity and service ecosystems has shifted the focus toward value-in-use. Value is conceptualized as a *phenomenological*, *cocreated*, *multidimensional,* and *emergent* concept. Thus, value is determined by the subjective experience of the beneficiary within its context and emerges from interactions among and exchange of resources across actors, including the beneficiary. Also, value comprises multiple dimensions beyond individual needs, including social and cultural norms. It cannot be determined ex-ante as a temporal and contextual phenomenon. As such, the whole system must be considered to understand the performance of the ecosystem as an emergent concept. This is also central for DPE, where unequal performance distributions, e.g., through a dominating platform owner, can derail entire ecosystems (Iansiti and Levien 2004).

3 Research Approach

We analyzed the empirical literature on DPEs to inductively form an understanding of DPE performance, thereby adopting the empirical study as our unit of analysis. Throughout the study, we followed established review guidelines (Okoli 2015) to ensure the comprehensiveness and robustness of our results. We organize our approach into three phases: *literature selection*, *data extraction,* and *synthesis*. Using a broad search strategy, we first identify a set of 132 empirical articles relating to DPE performance in top IS and management outlets for our analysis. Second, we extract all variables and causal links from them following established coding guidelines by Lacity et al. (2010). Third, we synthesize our data into a list of distinct master variables and causal links. We then inductively cluster into 11 DPE success dimensions. Summarizing their interrelations and impact on value realization, we propose a novel perspective on DPE success:

First, we conducted broad keyword searches in the Web of Science and SCOPUS databases following an inclusive approach, using the search string <<platform* OR ecosystem* OR network*>> in the Abstract/Title/Keywords fields. We limited our search to journals within the AIS Senior Scholars' Basket of Journals and the Financial Times Research Rank, thereby focusing on peer-reviewed information systems, business and economic articles adhering to the highest academic standard without a manual quality appraisal. We gathered an initial set of 1436 studies up to our cutoff date (January 5th, 2022).

Articles had to confirm two criteria to be included in our final set: (1) the article centrally encompasses a DPE according to the definition by Hein et al. (2020), and (2) there has been an empirical analysis of variables and causal links which contributes to research on DPEs and their actors. Thus, 1303 studies did not refer to DPEs (e.g., ideological, organizational, or internal IT platforms and business ecosystems without an IT focus; n = 639) or where the platform was not central to the article (n = 232) were removed from our list. Further articles were excluded as they did not report empirical results (n = 348) or did not contribute to research on DPE performance (n = 84). Of the remaining 133 studies, 16 had to be dropped from our sample during data extraction. They did not specify variables or empirical relationships between them. Including the 15 articles from the forward/backward search, our final set comprises 132 articles. We synthesize empirical knowledge irrespective of research methods, including 97 quantitative, 28 qualitative, and seven mixed-methods studies. In summary, our sample includes 56 transaction, 48 innovation and 28 hybrid platforms (Cusumano et al. 2019). Most analyzed DPEs followed for-profit models and showed centralized ownership structures, where the DPE was synonymous with the firm filling the platform owner role (e.g., Amazon Marketplace, Apple iOS), apart from minor exceptions such as blockchain platforms (Chen et al. 2020) and open-source ecosystems (Moqri et al. 2018). We acknowledge that the included DPEs differ in their architecture, governance, and business models. Therefore, our approach is based on the premise that there are fundamental tenants shared across all included systems relating to the collective performance of their ecosystems (Clark et al. 2007).

Second, all full texts were coded using MaxQDA to extract their variables and causal links following the approach pioneered by Lacity et al. (2010). To focus only on each study's central empirical insights, control variables, variables, and causal links from robustness checks and auxiliary or nonempirical analyses (e.g., simulation studies) were omitted. Two master lists containing all extracted variables (n = 898) and all causal links (n = 1044) were created according to our coding scheme (Table 1).

Code	Meaning
Definition	Name and explain how the variable was introduced in the paper, including how it was calculated or collected.
Unit of Analysis	*Platform*: Extensible codebase hosting digital complements and mediating interactions between complementors and users *Complement*: Digital artefacts extending the value proposition of the focal platform, including software applications, product/service listings and user generated content. *Owner*: Focal platform actor/organization enabling value co-creation among complementors and users through provision of the technical platform and governance mechanisms. *Complementor*: Suppliers of complementary products and services (complements), including developers and sellers. Single actors or organizations. *User*: Service beneficiaries of platform and complements, sometimes provision of user generated content (complements). Single actors or organizations. *Ecosystem*: A study's focal platform ecosystem, i.e., the socio-technical network of actors (complementors, users, owners) and complements spanned up by the digital platform
Variable Role	Variables were employed in three roles, including their causal links: *Dependent (DV):* Endogenous outcome influenced by independent and moderator variable(s). *Independent (IV):* Exogenous effect explaining the change in the dependent variable. *Moderator (MOD):* Exogenous effect influences the strength of the causal link between independent and dependent variables. Only defined for some causal links. *Causal Link:* Directed empirical relationship between an independent and dependent variable.
Causal Links	The effect a change in the causal link's independent had on its dependent variable. It can be quantifiable (variance theories) or a necessary condition (process theories). *Positive:* An increase in the independent variable increased the dependent variable. *Negative:* An increase in the independent variable decreased the dependent variable. *Note:* The link was insignificant/had no effect. *Matter:* A relationship between the two variables mattered.

Table 1. Coding scheme.

Lastly, we synthesized the results by inductively aggregating the extracted variables to a list of distinct master variables, constructs, and higher-order categories (of which we later call 10 "antecedents") with aggregated causal links following grounded theory coding protocols for constant comparison (Corbin and Strauss 2014), thereby arriving at a feasible level of abstraction for theory development without misrepresenting the results of individual studies. By following the approach developed by Lacity et al. (2010), we initially grouped variables referring to the same measure at a common unit of analysis into distinct master variables, e.g., the *Sales* of a single *Complementor* (Li et al. 2019). This reduced our list of 898 extracted variables to 413 master variables utilized across studies. To further reduce the complexity of our data, we then clustered master variables intended to measure the same concept into constructs. As an example, variables, such as *Complementor's Sales* (Li et al. 2019), *Market Share* (Tanriverdi and Chi-Hyon 2008), or *IPO likelihood* (Ceccagnoli et al. 2012), were grouped into a *Complementor Performance* construct, thereby arriving at a list of 85 constructs. Clustering was assumed as an iterative, bottom-up approach without an initial coding scheme to avoid a priori judgments. Following clustering, we again reviewed all causal links to assure that the relationships between clustered constructs were still true to the meaning of the underlying variables.

Thereby, we realized a common theme for numerous constructs across levels of analysis. We summarized them into interrelated higher-order categories (antecedents of DPE performance) that collectively characterize the current empirical body of knowledge on DPEs and serve to organize our review. Finally, we created a nomological network to structure the causal links logically and cohesively between the antecedents of DPE performance supported by repeated empirical data.

4 Findings

4.1 The 10 Antecedents of DPE Performance and their Operationalization

By grouping all empirically studied variables and constructs, we inductively identified *Performance* as the most prevalent higher-level category and the 10 higher-level categories of *Heterogeneity, Competition*, *Engagement*, *Governance*, *Quality*, *Network Size*, *Generativity, Architecture*, *Cost,* and *Motivation/Satisfaction* as antecedents of the performance category.

Variables that directly described *Performance* were analyzed in a third of our studies (86 out of 132), mostly in the role of the dependent variable (79 studies). The *Performance* category itself incorporated a range of variables capturing the value realized by the ecosystem's actors through transactions and usage. Thereby, most measures are related to business performance; capturing sales or downloads of the platform and its complements, sales, market share, or firm survival of the platform's owner and complementors; and its users' purchasing likelihood and expenditures. While only 31 of the 91 studies used variables to capture the ecosystem's value realization, economic measures were similarly prominent. Studies have analyzed overall transaction volume, market share, or complement sales. We found that 431 of the 1044 extracted causal links, or more than 40% of our data on empirical relationships, relate to influences on *Performance* itself. Table 2 shows all the direct causal links that influence the dependent *Performance* category across the other anteceding higher-level categories. Thereby, each causal link is stated with its dependent *Performance* construct, the independent construct of the respective success dimension, the number of studies wherein it was analyzed (#), and the subset of studies that found it to have a direct *positive* (+), *negative* (–), *matter* (M), or *none* (/) effect.

IV Dim	DV Performance Construct	IV Dimension Construct	#	+	–	M	/
Heterogeneity	Platform Performance	DPE Complement Composition	2	2			
		Platform Age	1		1		
	Complement Performance	Complement Age	4	2	1	1	
		Complement Type	5		1	4	
		Complementor Experience	1			1	
		Complementor Portfolio Composition	1			1	
		Complementor Type	1		1		
		DPE Complement Composition	1			1	
		DPE Maturity	1		1		
	Complementor Performance	Complementor Experience	2	2			
	User Purchasing	Complementor Type	1			1	
	DPE Evolution	DPE Tension	1			1	
	DPE Performance	DPE Complement Composition	1			1	
		DPE Maturity	1			1	
Competition	Platform Performance	DPE Complement Multihoming	1		1		
		Owner Strategy	1	1			
	Complement Performance	Complement Multihoming	4	2	1	1	
		Complementor Strategy	1		1		
		DPE Competition	4		1	2	1
		Owner Market Entry	2	2			
	Owner Performance	Owner Capabilities	1	1			
		Owner Strategy	3	1		2	
	Owner Value Capture	Owner Boundary Management	1			1	
		Owner Capabilities	1	1			
		Owner Market Entry	1	1			
		Owner Strategy	1	1			
	Owner Value Cocreation	Owner Capabilities	1	1			
		Owner Resources	1	1			
	Complementor Performance	Complementor Capabilities	1	1			
		Complementor Strategy	4	2	1	1	
		DPE Competition	2	1	1		
	User Purchasing	Complementor Strategy	2		1	1	
		DPE Competition	1			1	
		Owner Strategy	1		1		

IV Dim	DV Performance Construct	IV Dimension Construct	#	+	–	M	/
	DPE Evolution	Owner Boundary Management	2	2			
		Owner Strategy	1			1	
	DPE Performance	DPE Competition	3	1	1	1	
		DPE Complement Multihoming	1	1			
		Owner Market Entry	2		1	1	
		Owner Strategy	2	1		1	
	DPE Resilience	Owner Strategy	1			1	
Engagement	Complementor Performance	Complementor Engagement	3	2	1		
		User Engagement	1	1			
	User Purchasing	User Engagement	2	2			
	DPE Performance	Complementor Engagement	1	1			
		DPE User Engagement	1	1			
Governance	Complement Performance	Owner Governance Mechanisms	3	2	1		
		Owner Input Control	1	1			
	Owner Performance	Owner Governance Mechanisms	1	1			
		Owner Input Control	1			1	
	Owner Value Cocreation	Owner Boundary Resource Distribution	1	1			
		Owner Governance Mechanisms	1			1	
	Complementor Performance	Owner Boundary Resource Distribution	1			1	
	DPE Complement Performance	Owner Input Control	1	1			
	DPE Evolution	DPE Governance	2			2	
	DPE Performance	DPE Governance	1			1	
		DPE Openness	2			2	
		Owner Boundary Resource Distribution	1	1			
		Owner Governance Mechanisms	1	1			
		Owner Input Control	1		1		
Quality	Platform Performance	Platform Quality	1	1			
	Complement Performance	Complement Information	3	3			
		Complement Quality	9	8		1	
	Complementor Performance	Complementor Reputation	3	3			
		User Reputation	1	1			
	User Purchasing	Complement Information	1	1			
		Complementor Reputation	1	1			
		Platform Quality	1				1
		User Reputation	1	1			
Network Size	Platform Performance	DPE Complement Base	5	4	1		
		DPE User Base	1	1			
	Complement Performance	Complementor Portfolio Size	2	2			
	Complementor Performance	Complementor Portfolio Size	1			1	
	User Purchasing	DPE Complement Base	2	2			
		DPE Complementor Base	1	1			
		DPE User Base	1	1			
Generativity	Complement Performance	Complement Updates	6	5		1	
	User Purchasing	User Innovation	1		1		
	DPE Performance	DPE Generativity	1	1			
Architecture	Complement Performance	Complement Architecture	2	1	1		
	Owner Performance	Platform Architecture	1			1	
	Owner Value Capture	Platform Architecture	1			1	
	Complementor Performance	Platform Architecture	1		1		
	User Purchasing	Platform Features	1		1		
	DPE Complement Performance	Platform Features	1	1			
	DPE Evolution	Platform Architecture	2			2	
	DPE Performance	Platform Architecture	1		1		
		Platform Features	2			2	
Cost	Platform Performance	Platform Price	4		4		
	Complement Performance	Complement Price	4	1	3		
		User Effort	1			1	
	Owner Value Cocreation	Owner Effort	1			1	
	User Purchasing	Complement Price	2		2		
Motivation/ Satisfaction	User Purchasing	User Motivation/Expectations	1			1	

Table 2. Direct influences on DPE performance by the 10 antecedents.

4.2 Interrelations among the Antecedents of DPE Performance

We summarized the primary drivers of value realization studied in DPE research by detailing the causal links directed toward *Performance* from our 10 performance antecedents. Extending this view, our DPE performance model (Figure 1) details all direct causal links between the performance category. Thereby, nodes represent the DPE performance construct and its antecedents and edge the causal links. Both scaled proportionally to the number of studies wherein they were analyzed. Similar to Delone & McLean

(1992), we did not integrate aggregated trend measures ("positive", "negative" or "matter") into our Figure 1, as we cannot propose universally valid links yet. While some links exhibit strong patterns (e.g., *Engagement*, *Generativity,* or *Quality* are generally beneficial for *Performance*), they may not be valid across all platform contexts. To reduce complexity and visualize all causal effects in DPEs, we aggregated causal links from all actors, as is common for such causal models when aiming to show overall system behavior (Clark et al. 2007).

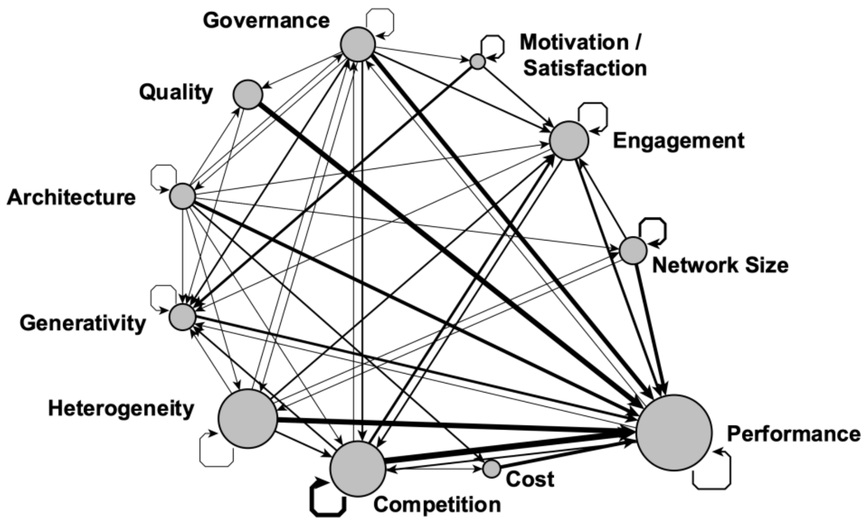

Figure 1. Nomological network of the antecedents of DPE performance

We make three observations. First, we found that the antecedents of *Performance* are not only direct antecedents of *Performance* but also antecedents of each other, thereby contributing to value realization in various ways and mediating their effects. For example, *Motivation/Satisfaction* was a major driver of *Engagement* and *Generativity*, thereby ultimately, *Performance*. Exemplary studies have shown how a user's motivation (Chen et al. 2018) drove their content contributions and loyalty. This underscores that humanistic goals in IS research may not only be an end in themselves (Sarker et al. 2019) but also drive future innovation and value realization. Second, several dimensions show self-reinforcing feedback loops, the most prevalent being *Competition*, *Network Size, Motivation/Satisfaction,* and *Performance*. For example, several studies about *Competition* have shown how actors use strategic moves in sequence, including owner's successive deployment of capabilities (Tan et al. 2015). Additionally, complementors may adapt their strategy based on competitive changes in their ecosystem (Pervin et al. 2019), such as owner's market entry (Wen and Zhu 2019). On the ecosystem level, strategic moves of competing platform owners, such as platform forking, may be intensified due to their potential to simplify multihoming (Karhu et al. 2018). Third, dimensions can also strongly moderate the causal links between them. Thereby, *Heterogeneity* was the most common moderator, followed by *Competition* and *Quality*. Regarding *Heterogeneity*, several studies have shown, for example, how the impact of reviews on sales varied across the platform and product types (Rosario et al. 2016; You et al. 2015).

5 Discussion

Extracting all variables and causal links from 132 empirical articles on DPE retrieved from top IS and management outlets, we inductively identified 10 interrelated antecedents of DPE *Performance* analyzed across individual social actors and technological entities and its collective ecosystem. We realize the need to study DPE *Performance* as an interrelated, sociotechnical, and dynamic concept.

Interrelated: Looking at our aggregate set of empirical studies, the 10 antecedents of DPE *Performance* affected value realization directly and indirectly (Figure 1); thus, all of them should be considered when analyzing a DPE's current *Performance* and future potential. Conversely, individual studies generally show a unidimensional conception of *Performance*, with single financial measures dominating as dependent variables across levels and units of analysis. Each study only considers a subset of our antecedents. Also, theoretically proposed evolutionary metrics, such as those by Tiwana et al. (2013, Chapter 7), do not cover the value realized by all ecosystem actors (i.e., users) and were not prevalent in our sample. Thus, while more holistic perspectives of DPE *Performance* may be theoretically acknowledged, empirical analyses are largely reduced to single, specific measures. This leads to logical discrepancies when abstracting findings based on financial measures to DPE *Performance*, as it is also criticized in management research on firm performance (Chet Miller et al. 2013). Instead, an interrelated perspective is imperative for both theory and practice. Academically, it aids the formation of a cumulative body of knowledge, as we cannot isolate the effects of independent variables on *Performance* if we measure it with different dependent variables without knowing their interrelations (DeLone and McLean 1992). Practically, the literature on performance measurement and management has long proposed multidimensional perspectives that combine past-oriented financial measures with operational metrics shaping future performance (Neely et al. 1995), such as customer satisfaction, process quality, and innovativeness, exemplified in established instruments like the balanced scorecard (Kaplan and Norton 2005).

Sociotechnical: DPEs are sociotechnical systems composed of collectives of social actors and technological entities. Our findings also show that DPE *Performance* needs to be understood as a sociotechnical construct, as our dimensions comprised variables measuring both social actors' behavior (e.g., governance mechanisms and user engagement) and technical properties (e.g., platform or complement architecture) that influence value realization. Simultaneously, DPE *Performance* measurement cannot be reduced to technical systems as in Tiwana (2013, Chapter 7). The technical attributes of the digital platform and its complements are what separate it from business ecosystem success frameworks (Iansiti and Levien 2004). This sociotechnical perspective should also capture the achievement of both instrumental and humanistic goals across actors, with the latter, however, being understated in our data, just as in larger IS research (Sarker et al. 2019). To illustrate, nine studies analyze *Performance* measures relating to users' purchasing likelihood and expenditure without estimating the value they realize from DPE adoption and participation, which will concern users in real life. Nevertheless, considering our *Performance* antecedents in aggregate can address both humanistic and instrumental goals through dimensions, such as Motivation/Satisfaction.

Dynamic: Figure 1 reveals how all our antecedents of DPE *Performance* are interrelated, thereby showing the potential for self-reinforcing and larger, more complex feedback loops. Introducing changes in single antecedence is likely to set off different effects, which are difficult to anticipate. For instance, changes to Governance mechanisms, such as input control, might increase complement *Quality* in a DPE (Song et al. 2018). However, they can also raise developer costs, promoting desertion and reducing engagement (Tiwana 2015). Thus, linearly extrapolating from prior findings is inadequate to predict future system behavior (Benbya et al. 2020). Further complexity is introduced as actors are likely to change their behavior depending on the value. They realize that in DPE participation (e.g., causal links outgoing from our *Performance* dimension) is understated in prior work. This shows the need for more systems approaches in DPE research, which are virtually nonexistent today beyond studies of network effects (Gretz et al. 2019), to help us understand how the interplay of the different antecedents shapes DPE *Performance* over time. Research is needed on, e.g., the ending conditions (i.e., balancing loops) of these self-reinforcing effects since these effects most likely do not increase to infinity but might end at some point.

6 Implications, Limitations and Future Research

Our findings have profound **implications** for both DPE **research** and **practice**. From a theoretical perspective, our understanding of DPE *Performance* provides a novel, comprehensive view of DPE performance's interrelated, sociotechnical, and dynamic nature. The 10 identified antecedents of DPE *Performance* affected value realization directly or indirectly and should be considered together to eliminate confounding variables and make research results more comparable. Second, the antecedents highlight DPE *Performance* because of interactions between both social actors and technological entities and cover instrumental and humanistic goals, thereby strengthening the sociotechnical perspective of IS for DPE research (Sarker et al. 2019). Third, we underscore how the dynamic nature of DPE success introduces challenges for its measurement and management through complex feedback dynamics and highlight the need for systems approaches in its further study. Our DPE success model contributes to a holistic understanding of the interrelated antecedents relevant to a collective ecosystem's performance from a practical perspective. This is relevant for all DPE actors, such as for platform owners, our framework contributes to improved DPE governance, as our analysis has shown that managers often misjudge cause–effect relationships in complex systems (Sterman 1989). Our model allows platform owners to measure the drivers of value realization in their ecosystem to combat this complexity. Thus, identifying further levers for growth and anticipating the possible effects of improved decision making. Also, complementors and users can leverage our framework to increase their value realization in DPEs. It provides an overview of measures that may impact their *Performance*. Thus, they can judge the attractiveness of a DPE when making adoption, multihoming, or continued usage and development decisions.

Naturally, our approach is not without **limitations**: Just as prior studies following our approach (Lacity et al. 2010), we prioritize the significance of causal links over their effect sizes, the actual strength of the causal relationship between two variables (Cohen 2004), which would be important when comparing causal links that implicate variables in diverging ways. While we agree that establishing effect sizes should be the end goal of empirical inquiries, this is not possible when integrating quantitative and qualitative studies. We aimed to cover both the process and variance theories on DPE *Performance*. Moreover, although we covered a large body of research in our review (132 studies), our dataset is not exhaustive. While a larger forward/backward search could have been conducted, we were able to attribute exemplary articles published beyond our cutoff date to them. Thus, our work mainly aimed to form an initial understanding of DPE *Performance*.

Our findings open three avenues for **future research** on DPE performance. First, we want to encourage future research to go beyond a single DPE's *Performance* by studying, e.g., the coevolution of DPEs and their environments. In our sample, levels of analysis beyond the focal platform's ecosystem, such as its encompassing market or "category ecosystem," were included only in 16 of 132 studies and, thus, largely excluded. However, ecosystems do not exist in the cavity. Thus, they are necessarily also shaped by the environments and ecosystems. While we excluded exogenous influences from our analysis due to lack of data and to focus on our approach, they are important. DPEs can also shape their larger category ecosystems, e.g., by enabling the emergence of competitors through platform forking (Karhu et al. 2018) or through co-evolving in exchange with external heterogeneous actors through a distributed tuning of boundary resources (Eaton et al. 2015). Thus, we encourage the DPE research field to aim to study performance and value creation within single platform ecosystems and explore their emergent dynamics at higher levels of analysis, and thus their contributions to society as a whole. Second, researchers could gain further insights into the generalizability of knowledge across platform types and contexts by incorporating (i.e., positive, or negative) trends of causal links. However, our findings uncovered a common core of relevant causal links explaining the interrelations of antecedents of DPE *Performance*. We also found that causal links were not neutral across contexts. As an example, direct network effects on the complementor side ranged from negative trend for video game consoles (Kretschmer and Claussen 2016), over no significant effect for Taobao (Chu and Manchanda 2016), to a positive trend for Kickstarter (Thies et al. 2018). Thus, analyzing the trends of causal links across different platform contexts could ultimately reveal which dimensions are especially imperative for the performance of the transaction, innovation, or hybrid DPEs and may also lead to the formation of new DPE typologies based on shared sets of causal links and their trends driving their evolution. Lastly, the establishment of effect sizes for causal links between performance antecedents at the ecosystem level could be leveraged for future systems research on the evolution of DPE using approaches, such as System Dynamics (Fang et al. 2018).

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