I. Introduction

The first section of this chapter, A.I.1, introduces the motivation and the relevance of the investigated research topic. Thereafter, a concrete description of the associated research gaps and questions (A.I.2) is provided. Section A.I.3 then presents the resulting structure of the thesis, followed by Section A.I.4 informing on the research context and chosen design. Finally, Section A.I.5 ends Chapter A.I by explaining the anticipated contributions for research and business practice.

I.1 Motivation

In 2019, the Internet celebrated its 50th anniversary. Since its emergence, it has significantly changed how people, communities, and societies behave, interact, and live (de Reuver et al., 2018). Whereas in previous decades people were used to buying goods for their daily lives in local stores, borrowing films from the nearby video library, or making new friends through personal encounters, they are now accustomed to fulfilling their needs by taking advantage of giant online places for the exchange of goods, video streaming, or social interaction offered by prominent tech companies, such as Amazon, Netflix, or Facebook. Besides the fact that most of these organizations have developed into the most powerful firms on Earth and have initiated far-reaching transformations of formerly established life habits (Yoo, 2010), a key element of their success lies in their ability to connect billions of people worldwide and to concentrate and orchestrate a nearly limitless portfolio of co-creators.

A driving force within this powerful phenomenon is represented by the growing diffusion of digital technologies that are “viewed as a combination of information, computing, communication, and connectivity technologies” (Bharadwaj et al., 2013, p. 471). Having been embedded in isolated systems and mainly applied for enterprise-related back-office functionalities for a long time (Beath et al., 2013; Gannon, 2013; Gregory et al., 2018; Venkatraman, 1994), digital technologies have been able to leave their niche status behind due to the increasing miniaturization of hardware, and improvements in processing power, network connectivity, storage capacity, and more effective power management (Fichman et al., 2014; Yoo, 2010). Today, nearly every artifact is or can be equipped with digital technologies, leading to either the full digitization of the physical object—observable, for example, in the context of entertainment and printing (Yoo et al., 2010)—or to a significant expansion of the artifact’s physical capabilities, such as household appliances now being able to independently communicate and order ingredients when needed (Nambisan, 2013; Yoo, 2010). However, along with this increasing digitization and hybridization of physical objects (Yoo et al., 2010), new challenges arise with regard to the process of product (and service) innovation.

From a traditional point of view, product development has been carried out in closed settings—meaning that companies have managed the innovation process mainly on their own and internally—stemming from integral or modular product architectures (Yoo et al., 2010). However, by implementing digital technologies for physical products, this approach is now

brought into question, as digitalization-specific characteristics—a modular layered architecture, generativity, and convergence (Yoo et al., 2012)—bear the potential of being able to deal simultaneously with a digitalized device as both a product and a platform (Yoo et al., 2010). Recapitulating the transition of the former mobile phone sector exemplifies the radical consequences of such a development: In contrast to traditional mobile phones that were mainly in the hands of one dominant producer (e.g. Siemens, Nokia, or Motorola), today's successful manufacturers are faced with the physical and digital decoupling of their smartphones. Popular products such as the Galaxy S20 are dominated by Samsung with regard to the hardware layer but are fundamentally dependent on Google's Android operating system (OS) serving as a digital platform for countless independent developers who define the smartphone's digital functionalities via applications (Jacobides et al., 2018). This illustration highlights that with accelerating digitalization, the success of one company's innovation is increasingly reliant on how it conforms to infrastructures, complements, or the innovations of others (Adner and Kapoor, 2010). The manner in which new products and services are developed is changing as never before, and, as a result, it requires the rearrangement of established innovation and commercialization philosophies in order to deal with the growing inter-company relatedness (Priem et al., 2013; Yoo et al., 2010).

Against this background, recapitulating prominent manifestations, such as Amazon, Netflix, Facebook, Apple, Airbnb, etc., highlights the emergence of a new business philosophy in which third-party contributors, such as aftermarket suppliers, end users, content providers, and app developers deliver essential complements that are orchestrated via a digital platform and carefully considered in the core firms' innovation activities (Gawer and Cusumano, 2014). Instead of following a traditional value-chain logic, these organizations cultivate an ecosystem perspective—a concept relying on a holistic understanding of economic cooperation and competition, accounting for direct value-creation and -capturing structures but also reflecting upon more indirect value links such as the aforementioned independent developer community in the context of Android smartphones, social media interactions on Facebook, or the peer-to-peer community principles of Airbnb (Adner, 2017).

However, although having a history of nearly three decades and providing valuable specifications for the application and contextualization of the concept in business practice, the most widely accepted ecosystem characterization by Moore (1993)—defining a business ecosystem as the complex interplay between diverse resources, actors, and their actions that are interconnected by the objective of developing new value propositions—does not consider the specific characteristics of digitality that have stimulated its recent prominence (de Reuver et al., 2018). Against this background, this cumulative thesis aspires to explore, first, the ecosystem concept and its particular relation to information systems (IS) in order to shed light on its recent prominence and characteristics, as well as to stimulate a better understanding of the ecosystem concept in general. Besides that and with regard to its manifold application fields and associated situations in which new players such as Amazon, Tesla, and Airbnb have struggled with incumbents such as Walmart, General Motors, or Marriott International for supremacy, a growing demand exists for clarifying emerging divergences between born-digital ventures and the traditional, industrial-age incumbents (Svahn and Henfridsson, 2012; Yoo et

al., 2010). More precisely, experiencing the shift in industry structures from tightly controlled value chains and networks toward vibrant, heterogeneous, and platform-based ecosystems implies that there are serious adaption challenges for every market actor (de Reuver et al., 2018). However, in contrast to digital-native organizations, incumbents are particularly shaped by their past as well as by the decisions they have made, and accordingly, they are faced with different conditions when dealing with the ecosystem phenomenon (Sydow et al., 2009). To expand existing research in this regard, this cumulative thesis secondly sets out to investigate the specific situation of industrial-age manufacturing contexts characterized by a physical core product that cannot be digitally substituted and that bears the potential to simultaneously become a product and a platform (Yoo et al., 2010). Within this context, the aim is to add to the knowledge base by applying a macro-level perspective concentrating on the transformative impact of digital technologies on a traditional, asset-heavy ecosystem, as well as an micro-level perspective with the goal of distilling an incumbent's individual challenges related to the development and management of digital platform-based ecosystems for the Internet of Things (IoT). Lastly, by examining shifting product architectures, decomposing organizational hierarchies (Schilling, 2000; Ulrich, 1995; Yoo, 2010) as well as the emergence of combinatorial innovation (Arthur, 2009; Yoo et al., 2012), the rapid distribution and broad contextual success of digital platform ecosystems (DPEs) (Hirth, 2018) serving as a new hub for joint co-creation and value commercialization (Yoo et al., 2012) comes into focus. Within this context, this thesis particularly seeks to unravel a DPE's specific nature and, more precisely, its compositional constellations in order to shed light on one of the most prominent ecosystem manifestations of today.

Additionally, this thesis aims to provide valuable implications for business practice. In this vein, one of the main goals is to clarify the ecosystem concept's meaning and added value with regard to the traditional, dominant value-chain perspective. Another main concern of this work is to inform the managers of incumbent organizations about change processes within established ecosystems due to digital technologies and, moreover, about how to deal with the challenges associated with DPEs.

In sum and on a more abstract level, this cumulative thesis strives to explore the transformational impact of pervasive digital technologies on industrial-age business contexts and incumbent firms while applying an ecosystem perspective. In doing so, it seeks to achieve two overarching research goals: (1) to improve the ecosystem concept's clarity and its compositional understanding and (2) to advance existing ecosystem research by exploring the concept's relevance for business sectors characterized by a physical core product. Within this context, it concentrates on traditional, industrial-age incumbents, reflects upon the specific characteristics of digital technologies, and favors contexts characterized by a physical core product that cannot be digitally substituted. Figure A:1 offers a concluding illustration of the overarching goals.

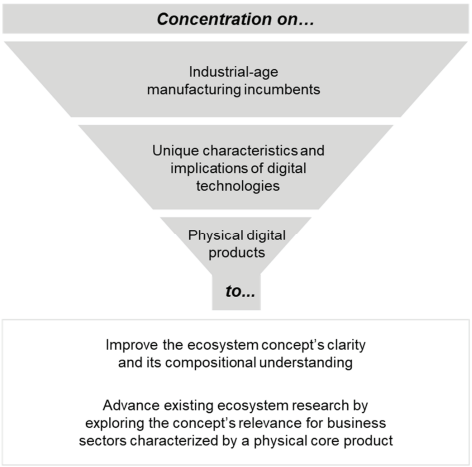

Figure A:1. Research funnel and underlying goals of this cumulative thesis.

I.2 Research Gaps and Research Questions

As outlined above, this thesis is dedicated to the ongoing diffusion of digital technologies fostering a new ecosystem perspective in IS research and business practice as well as the associated challenges and consequences for traditional business contexts. To deal with this topic, the study is divided into four fundamental research questions (RQs). In the following, a brief explanation of each RQ is provided concluded by Figure A:2 offering a final overview.

Digital technologies have increasingly penetrated areas of everyday life (Yoo, 2010). Driven by prominent examples, such as Apple, Google, or Facebook, the notion of ecosystems has received growing attention in business practice over the past few years (Yoo et al., 2010). Accordingly, management and IS research have increasingly focused on the topic of ecosystems in both the academic- (Adner and Kapoor, 2010; Eaton et al., 2015; Priem et al., 2012; Tan et al., 2015) and in the practitioner-oriented literature (Anderson and Vakulenko, 2014; Iansiti and Levien, 2004; Weill and Woerner, 2015; Zeng, 2015). While valuable knowledge has been generated, the current literature demonstrates the lack of a clear and overarching understanding of the ecosystem concept with regard to its definition, building blocks, and relevance. Additionally, contemporary research has not focused on the specific interactions with IS that embody an important driving force behind the recent ecosystem phenomenon to enable an understanding of today's market leaders and business environment. Consequently, the first RQ is:

RQ 1: How is the ecosystem concept defined and applied in business and what interactions with information systems do exist?

Apart from actual concept clarity, current ecosystem research faces the challenge that the phenomenon itself is not limited to a certain context but is also relevant within manifold business fields. A first indication in this regard is provided, for example, by early management

research highlighting that companies—regardless of their particular value proposition—are not only affected by their core industry, but also by various other sectors, and thus should be understood as a tessera within an industry's overarching business ecosystem (Moore, 1993). Studying, for example, a new airplane's development, makes it obvious that its successful air traffic implementation is substantially dependent on the available, associated infrastructure innovations offered by airports, maintenance facilities, etc. (Adner and Kapoor, 2010). This interdependence is even more visible in such contexts determined by a high level of digital technologies (Yoo et al., 2010), for example, in the app economy, with its countless customers and app developers, and their close relation to Apple's iOS or Google's Android.

However, when reviewing the associated literature in more detail, it becomes evident that management research as well as IS research approach the ecosystem phenomenon with different foci. Whereas management research seems to be particularly interested in the ecosystem concept in pre-digital times (e.g. Iansiti and Levien, 2004; Moore, 1993) and, thereby, does not consider the impact of digitalization (de Reuver et al., 2018), IS research, in contrast, is especially dedicated to relatively young ecosystem entities, such as Facebook, Apple iOS, Google Android, etc., and direct IT industry manifestations (e.g. Huang et al., 2018; Huber et al., 2017; Tiwana, 2016). Accordingly, business contexts characterized by a strong physical component typically originating from an industrial-age era that experience the pressure of digitalization but do not experience an all-embracing digitization of their respective core asset or service have not yet been sufficiently considered (e.g. household appliances, connected cars, smart homes, or energy). However, recapitulating today's top-100 companies illustrates that although tech companies are among the top-ranked firms with regard to profit, a majority of value creation, as indicated by absolute sales numbers, actually comes from industrial-age, non-digital entities (Fortune, 2020). Thus, exploring the effects of digital innovation in these traditional business sectors and understanding the challenges faced by the associated companies represents an important gap within current ecosystem research.

Studying the pre-existing literature indicates that—from an industrial-age firm's perspective—the increasing availability of digital technologies offers promising opportunities to improve existing business models (Yoo, 2010). However, on the other hand, academic works as well as practical examples also illustrate that, at the same time, these companies are struggling to apply these new possibilities and work them to their advantage (Loebbecke and Picot, 2015). This dichotomy, in turn, can imply far-reaching consequences for the overarching ecosystems in terms of productivity, robustness, and niche creation (Iansiti and Levien, 2004). In order to shed light on this complex situation in industrial-age business contexts, this thesis applies two specific lenses of analysis: a macro-level and a micro-level perspective.

Following O'Sullivan and Sheffrin (2007), a macro-level perspective is, in general, dedicated to the observation of the structure, behavior, performance, and decision-making of an economy as a whole. Transferred to the thesis's research context, the examination of a traditional, industrial-age ecosystem from an overarching point of view to understand the actual impact of digital technologies and digital innovations regarding the ecosystem's appearance and evolution is implied. To date, relatively little literature exists considering ecosystem change

from such an angle—with some noteworthy exceptions, such as Basole's (2009) observation of the mobile phone market or Pagani's (2013) investigation of the broadcasting sector. Therefore, the second RQ is formulated as follows:

RQ 2: How do industrial-age ecosystems change, from a holistic perspective, in the era of digital innovation?

A micro-level perspective, in contrast, is generally concerned with the study of individuals and firms with regard to their behavior and decision-making (O'Sullivan and Sheffrin, 2007). In ecosystem research, this approach pays particular attention to economic individuals and companies experiencing the force of digital technologies and the related implications for their management behavior. From recent research, it is known that most valuable companies such as Netflix, Facebook, Apple, Microsoft or Google respond on the growing digitalization of value propositions by initiating individual platform based ecosystem structures in order to concentrate and orchestrate countless co-creators and customers, spur on digital innovativeness and achieve an outstanding level of competitiveness. Inspired by the successful experiences of these companies, industrial-age firms are also increasingly interested in cultivating extendable and shared digital platforms to leverage the emerging opportunities of digital technologies (e.g., Van Alstyne et al., 2016). However, in contrast to the aforementioned instances, incumbents face the challenge of integrating digital technologies into their established physical offerings confronting them with shifting product architectures and innovation principles as well as an increasing relevance of digital platforms to manage the resulting IoT (Arthur, 2009; ITU, 2012; Schilling, 2000; Ulrich, 1995; Yoo, 2010; Yoo et al., 2012). Being shaped by their past as well as implemented structures and culture (Sydow et al., 2009), they witness significant challenges to adjust their organizational routines and to re-learn how to compete in these digitalizing market environments forming a complex IoT (e.g., Fitzgerald et al., 2014). To shed light on this crucial situation within one of the most important parts of the world's economic (Fortune, 2020), the third RQ is:

RQ 3: What are the main managerial challenges that industrial-age firms face in building a platform ecosystem for the Internet of Things (IoT)?

Finally, this thesis pays particular attention to the concept of the DPE itself. As already mentioned, a substantial proportion of today's largest companies (e.g. Google, Apple, and Amazon) have successfully cultivated individual platform ecosystems consisting of diverse actors with the ability to offer thousands of different value propositions (Gawer and Cusumano, 2014). Additionally, an increasing proportion of industrial-age companies are interested in the development of such a network structure. Consequently, to shed light on the principles of DPEs, including their configuration and composition, IS research has begun to examine various instances and their specific characteristics, such as boundary resources (Eaton et al., 2015), actor co-creation and governance (Foerderer et al., 2018; Huber et al., 2017), as well as platform owner strategies with regard to value commercialization and monetization (Parker et al., 2016; Parker and Van Alstyne, 2018). However, the increasing application of the platform ecosystem concept—from enterprise software contexts to the smartphone sector up to the IoT in business practice—argues for an interconnection of those fragmented ecosystem studies

and facets to develop a holistic picture (de Reuver et al., 2018; Hein et al., 2019). In order to make progress in this regard and to foster an overarching understanding, the fourth RQ is:

RQ 4: How can digital platform ecosystems be differentiated, and what are relevant the dimensions and characteristics?

As already mentioned at the beginning of this section, the following Figure A:2 provides a final overview about the research questions and their underlying motivation.

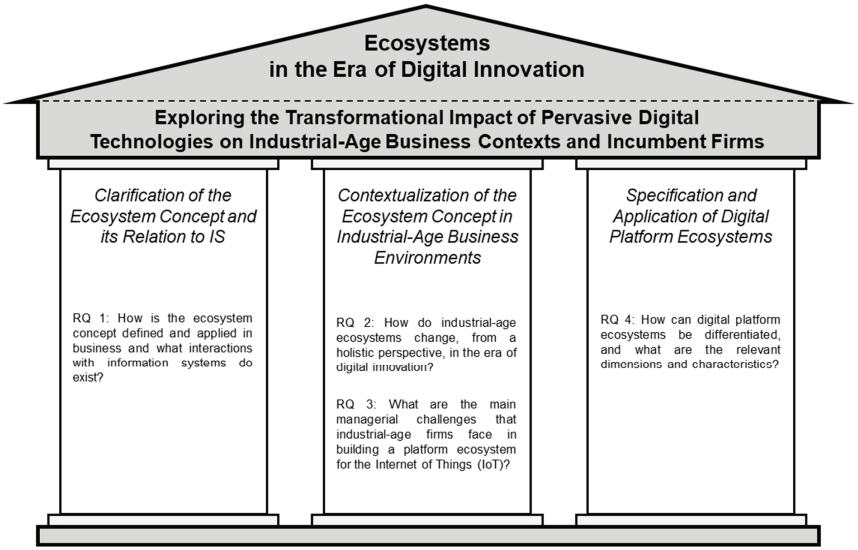

Figure A:2. Overview of main research questions.

I.3 Structure of the Thesis

This thesis is cumulative in nature and contains three major parts. Part A elaborates on the dissertation's foundations. Therefore, Chapter A.I initially depicts the underlying research motivation (A.I.1) and associated RQs (A.I.2). Afterwards, it continues with additional descriptions on the overall thesis structure (A.I.3), research context and design (A.I.4), as well as the anticipated contributions (A.I.5). Chapter A.II concentrates on the study's core topics and related background information by presenting the development of digital technologies from isolated back-office functionalities to an all-embracing digital transformation (A.II.1), the associated implications for established innovation logics and incumbents' routines (A.II.2), as well as the need for a new ecosystem business logic (A.II.3).

Part B embodies the centerpiece of this thesis and is organized in line with Section A.I.2. It contains three chapters and four studies. The first chapter (B.I) is explicitly dedicated to the topic of concept clarity and emphasizes the synthesis of existing knowledge from management and IS research. Thereby, this chapter is closely related to Study 1. Chapter B.II particularly concentrates on industrial-age ecosystems and companies experiencing the emergence and

force of digitalization and digital innovation. Its structure is intended to provide insights into the change in traditional ecosystems from a macro-level perspective (Study 2), as well as the associated challenges of incumbent firms while managing these shifts by developing DPEs for the IoT from a micro-level perspective (Study 3). Lastly, Chapter B.III is dedicated to one specific approach that has become prominent in recent years for dealing with ongoing digitalization and digital innovativeness; namely, DPEs and their overall gestalt and configuration (Study 4). Table A-1 displays an overview of each study, including details such as the publication outlet, Verband der Hochschullehrer für Betriebswirtschaft (VHB) ranking, publication status, associated RQs, and a brief summary of the main contributions.

Table A-1. Overview of studies included in this thesis.

No	Outlet	Status	Ranking (VHB)	Chapter	RQ	Main Contributions
1	International Conference on Information Systems 2017	Published	A	B.I	1	Identification and analysis of high-quality literature on ecosystems and information systems (IS) to summarize the current state of knowledge and highlight important gaps in the literature. Derivation of valuable insights into the role of IS in ecosystem genesis, as well as, by drawing on the origins in biology, the development of an overarching digital business ecosystem definition.
2	International Conference on Information Systems 2019	Published	A	B.II	2	Investigation of the automotive ecosystem's evolution as a role model for industrial-age ecosystem change due to digital innovation. Visualization of the constituting companies and relations as well as the calculation of key measures for the network structure. Contrasting empirical results with knowledge on biological ecosystem change to derive initial implications for an IS-specific ecosystem change theory.
3	European Conference on Information Systems 2020	Published	B	B.II	3	Exploration of the challenges perceived by industrial-age firms when building a digital platform ecosystem (DPE) for the IoT. Identification of key challenges associated with DPEs in general, as well as the distillation of unique struggles faced by incumbent firms.
4	European Journal of Information Systems	3rd Round Revision	A	B.III	4	Development of a rigorous taxonomy for DPEs. Application of cluster analysis to an enlarged set of real-world DPEs to derive five DPE archetypes and interdimensional patterns. Illustration of the most relevant design dimensions and their interactions, holistic configurations, and patterns.

In Part C, a summary of the findings from Part B is provided and further completed by an overall synthesis of the results (C.I). Thereafter, Chapter C.II continues with the implications developed for theory and practice. Lastly, Chapter C.III contains a conclusion as well as information about limitations and further research opportunities. Figure A:3 illustrates the final structure.

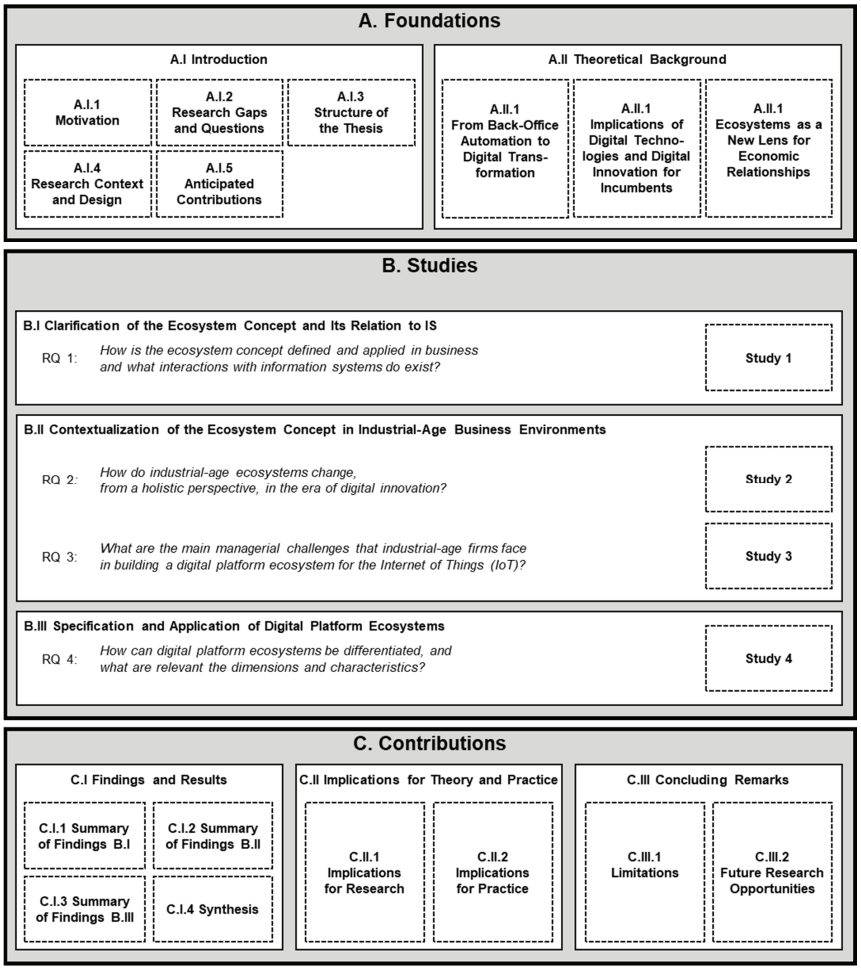

Figure A:3. Overview of the overarching structure.

I.4 Research Context and Design

IS research is motivated by the idea of advising researchers and practitioners on the interaction between IS and human enterprises (Grover and Lyytinen, 2015). Accordingly, the domain itself can be assigned to the field of social science (Bhattacherjee, 2012). However, as a relatively young and interdisciplinary field of academic investigation, IS research has been influenced by several other disciplines, such as management, biology, sociology, psychology, philosophy, computer sciences, etc. (Gregor, 2006). Thus, it is essential to clarify general assumptions that guide this dissertation and the included studies to account for the domains' respective beliefs

and philosophical positions. Therefore, the following paragraphs will concentrate on the chosen epistemology, research paradigms, and applied methods.

Turning initially toward the epistemological orientation, three general positionings can be distinguished: positivism, interpretivism, and critical realism (Gregor, 2006). Positivist scholars expect the presence of an objective reality (Hudson and Ozanne, 1988) that can be used to test theories in order to better explain real-world phenomena (Wynn and Williams, 2012). They assume the a priori existence of fixed relationships within a certain phenomenon and are convinced that there are objective descriptions for events of interest. Interpretivism, in contrast, holds to the philosophy that an objective reality is nonexistent as it is subjectively created by every individual, thereby outlining a conception of the world that is characterized by many perceived realities (Orlikowski and Baroudi, 1991). Accordingly, the investigation of social phenomena requires a consideration of those subjective realities (Bhattacherjee, 2012). Lastly, critical realism represents a combination of the aforementioned orientations. It follows positivism's approach in the sense that an overarching, objective reality exists. However, unlike this research perspective, it questions humankind's ability to fully observe and understand this reality, thereby incorporating aspects of interpretivism (Wynn and Williams, 2012).

When considering the topic of research paradigms, two different approaches exist in IS: design science and behavioral science (Hevner et al., 2004). The design science-oriented research paradigm is, in general, focused on the creation, design, and evaluation of technology-oriented artifacts in order to improve activities in enterprise-related situations (Hevner et al., 2004; Wilde and Hess, 2007). Thereby, it is characterized by a strong motivation to solve problems in the context of real-world phenomena (Kuechler and Vaishnavi, 2008). In contrast, behavioral science stems from natural science (March and Smith, 1995) and is dedicated to the development and justification of theories to clarify, discuss, and predict phenomena related to interactions between humans, organizations, and IS (Hevner et al., 2004).

This dissertation takes a positivistic stance from an epistemological perspective and a behavioral science approach regarding the research paradigms. A positivistic orientation is chosen as it implies the existence of an underlying, objective reality, and thereby views the observation of the ecosystem phenomenon, its relation to IS, and the consequences for incumbents as a single, tangible, and fragmentable research object (Hudson and Ozanne, 1988; Orlikowski and Baroudi, 1991). Each included study is value-free and conceptualized to shed light on a relevant aspect of the ecosystem reality. The latter is ensured by a mixed-method approach representing the application of qualitative and quantitative research methods. Although this thesis develops design science-oriented artifacts (e.g. with regard to Study 4 and its taxonomy for DPEs), the main focus of the dissertation is to learn about the relation between ecosystems and IS, as well as the associated challenges and consequences for incumbents. Thus, the primary focus of this work is the behavioral paradigm. Table A-2 provides a summary of the research design.