Cloud Networks as Platform-based Ecosystems –

Detecting Management Implications for Actors in Cloud Networks

Dissertation

zur Erlangung des Grades eines Doktors der Wirtschaftswissenschaft

der Rechts- und Wirtschaftswissenschaftlichen Fakultät

der Universität Bayreuth

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Tag der mündlichen Prüfung	5. Februar 2019

I. Abstract

English

Platform-based ecosystems are omnipresent in today's world. This doctoral thesis focuses on cloud computing, which is an emerging platform-based ecosystem that companies adopt in their IT strategy quickly. Actors in cloud computing often create value by adding functionality to services already existing in the ecosystem. This development is likely to transform cloud computing toward complex, globally distributed networks, consisting of many different actors and connections. In the doctoral thesis I define those structures as cloud networks.

For general platform-based ecosystems, Tiwana et al. (2010) and de Reuver et al. (2018) each set up a research agenda for platform-based ecosystems. I contribute to four proposed research items:

(1) Tiwana et al. (2010) demand research on how platform architecture influences the dynamics in ecosystems and modules. (2) de Reuver et al. (2018) emphasize research on the question regarding how actors strategize, i.e., think strategically, about a situation or business in platform environments, as interconnected thinking is particularly important for decision makers. (3) de Reuver et al. (2018) demand research on how platform providers can jointly shape platforms with other stakeholders of the platform. (4) Tiwana et al. (2010) emphasize research on how the fit between platform architecture and platform governance influences the dynamics of ecosystems and modules.

The doctoral thesis consists of five papers that directly contribute to these research items. By providing a taxonomy of actors, a taxonomy of risks, as well as a reference model that enables the instantiation interactions between actors in cloud networks, it provides a tool that enables the illustration of dynamics in cloud networks. Next, it illustrates strategies for companies in platform-based ecosystems and provides guidance for IT-governance with respect to the specific characteristics of cloud networks. Also, it analyzes how customers can utilize cloud spot prices to monetarize their temporal flexibility. To illustrate the shaping of platforms, the dissertation describes preliminary design principles for a power flexibility platform that many companies develop jointly in a publicly funded research project. By analyzing the utilization of cloud spot prices and by describing preliminary design principles for the power flexibility platform, the thesis further guides actors on how to utilize digital options in platform environments, and it provides decision support for specific scenarios which could transfer knowledge to the general context of platform-based ecosystems. Finally, the doctoral thesis analyzes how platform governance influences the dynamics in platform-based ecosystems and provides guidance for IT-governance with respect to the specific characteristics of cloud networks.

Deutsch

Plattformbasierte Ökosysteme sind in der heutigen Welt allgegenwärtig. Diese Dissertation konzentriert sich auf Cloud Computing, ein aufstrebendes, plattformbasiertes Ökosystem, das Unternehmen schnell in ihren IT-Strategien aufgegriffen haben. Akteure im Ökosystem Cloud Computing schaffen oft Mehrwert, indem sie die bereits vorhandene Dienste um neue Funktionen erweitern. Dies führt dazu, dass sich die Ökosysteme um Angebote im Cloud Computing zu komplexen, global verteilten Netzwerken entwickeln, die aus vielen verschiedenen Akteuren und Verbindungen zwischen diesen bestehen. In der Dissertation werden diese Strukturen als Cloudnetzwerk definiert.

Für allgemeine plattformbasierte Ökosysteme haben Tiwana et al. (2010) und de Reuver et al. (2018) jeweils eine Forschungsagenda aufgestellt. Die Dissertation beteiligt sich an vier der vorgeschlagenen Forschungsschwerpunkte:

(1) Tiwana et al. (2010) fordern Forschung zu den Auswirkungen der Plattformarchitektur auf die Dynamik in Ökosystemen und Modulen. (2) de Reuver et al. (2018) werfen die Frage auf, wie sich Akteure oder Unternehmen in Plattformumgebungen strategisch sinnvoll verhalten, da vernetztes Denken für Entscheidungsträger besonders wichtig ist. (3) de Reuver et al. (2018) fordern zudem Forschung darüber, wie Plattformanbieter gemeinsam mit anderen Stakeholdern ihre Plattformen gestalten können. (4) Zudem werfen Tiwana et al. (2010) die Frage auf, wie die Übereinstimmung zwischen Plattformarchitektur und Plattformgovernance die Dynamik von Ökosystemen und Modulen beeinflusst.

Die Dissertation besteht aus fünf wissenschaftlichen Arbeiten, die direkt zu diesen Forschungsschwerpunkten beitragen. Durch die Bereitstellung einer Taxonomie von Akteuren, einer Taxonomie von Risiken sowie eines Referenzmodells, das die Instanziierung von Akteuren in Cloudnetzwerken ermöglicht, bietet die Dissertation ein Werkzeug, das die Darstellung der Struktur in Cloudnetzwerken ermöglicht. Anschließend werden Strategien für Unternehmen in plattformbasierten Ökosystemen veranschaulicht und Leitlinien für die IT-Governance in Bezug auf die spezifischen Merkmale von Cloudnetzwerken gegeben. Dabei wird analysiert, wie Kunden Cloud-Spotpreise nutzen können, um ihre zeitliche Flexibilität zu monetarisieren. Um die Gestaltung von Plattformen zu veranschaulichen, beschreibt eine Dissertation zudem vorläufige Gestaltungsprinzipien für eine Plattform zur Monetarisierung von Energieflexibilität, die Unternehmen in einem öffentlich geförderten Forschungsprojekt gemeinsam entwickeln. Durch diese Arbeiten leitet die Dissertation Akteure an, wie sie digitale Optionen in Plattformumgebungen nutzen können. Dabei bietet die Dissertation Entscheidungsunterstützung für spezifische Szenarien, die auf den allgemeinen Kontext plattformbasierter Ökosysteme übertragen werden könnten. Schließlich analysieren zwei weitere Arbeiten der Dissertation, wie Platform Governance die Dynamik in plattformbasierten Ökosystemen beeinflusst und bieten Leitlinien für IT-Governance in Bezug auf die spezifischen Eigenschaften von Cloudnetzwerken.

II. Acknowledgements

First, I would like to express my deep gratitude to Professor Fridgen, my research supervisor, for his patient guidance, enthusiastic encouragement, and useful critiques of this doctoral thesis. I would also like to thank my co-authors for the fruitful discussions and the long, yet mostly enjoyable and productive paper sessions (sometimes until 4 o'clock in the morning).

Next, I would like to extend my thanks to my colleagues at the Fraunhofer Project Group Business & Information Systems Engineering, the Research Center Finance & Information Management, the University of Augsburg, and the University of Bayreuth for offering me the resources and guidance to carry on my research.

Finally, I wish to thank my family, especially my parents for their support and encouragement from early on. Thanks also to my sister for friendly competition in her starting PhD research as well. Most of all, however, I'd like to thank my wife for her patience and understanding for the crazy scientific world into which I disappeared from time to time.

III. Copyright Statement

Several passages of the following sections have been compiled in the context of the following publications and working papers: Keller and König (2014), Keller et al. (2018b), Keller et al. (2019), Keller et al. (2018a), and Keller (2016). To improve the readability of the text, I omit the appropriate labeling of the citations.

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1 Introduction

Digitalization affects all areas of society and embraces all aspects of private and professional life (Legner et al. 2017). Companies utilizing digital trends like Amazon, AirBnB, Ebay, and Uber are some of the world's most valuable companies. In the third wave of digitalization, SMAC (social, mobile, analytics, and cloud) technologies have transformed business and society. They are extremely relevant to the German Business & Information Systems Engineering (BISE) community (Legner et al. 2017). All of these so-called "IT megatrends" (Legner et al. 2017, p. 303) are based on digital platform technology, thus, digital platforms are omnipresent in the modern world (Parker et al. 2017a; Tiwana 2014).

Scientific literature distinguishes an engineering, an economic, and an organizational perspective on platforms (Gawer 2014; Rolland et al. 2018). Considering these perspectives, platforms are identified as socio-technical phenomena centered around software, hardware, organizational processes, and standards (Tilson et al. 2012). Such platforms each have a central cornerstone, which provides "core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate" (Tiwana et al. 2010, p. 686). Each platform also has a layered architecture consisting of a "device layer, network layer, service layer and content layer" (Parker et al. 2017b). There are three different research streams on platforms, which are in line with the above-mentioned perspectives (c.f. de Reuver et al. 2018; Rolland et al. 2018), namely a first stream on multisided platforms related to the organizational perspective (i.e., transactions), a second on technical implications related to the engineering perspective (i.e., software architecture), and a third on ecosystems related to the economic perspective (i.e., value streams and value co-creation). This doctoral thesis focuses on the latter third stream.

Considering this economic perspective on platforms, facilitating transactions enables the co-creation of business value by encouraging complementary invention and exploiting indirect network effects. In this way platform-based ecosystems are enabled (Ceccagnoli et al. 2012; Gawer and Cusumano 2014). Platform-based ecosystems are a collection of complements (i.e., applications) and companies, which contribute to the complements in the nexus of the core platform (de Reuver et al. 2018). They loosely couple its participating actors in an interdependent network, provide products and services (Leimeister et al. 2010; Moore 1993), and push innovation of new products or services (Moore 1997). Ecosystems often result in beneficial interdependency, which implies that actors participating in an ecosystem are better off if their counterparts are better off (van Alstyne et al. 2016). The value of products and services in ecosystems increases as the number of users (Gimpel and Röglinger 2015; Metcalfe 1995) and the level of self-organization (Boley and Chang 2007; Briscoe and de Wilde 2006) increases. Adner (2017) distinguishes between an ecosystem-as-affiliation and an ecosystem-as-structure perspective. Whereas the affiliation perspective focusses on the association to a platform, the structure perspective focusses on ecosystems as configurations of activities defined by a value proposition (Adner 2017).

Identifying a gap in research, Tiwana et al. (2010) and de Reuver et al. (2018) each set up a research agenda for platform-based ecosystems. Four of the proposed research items are of particular interest in the present doctoral thesis:

- First, Tiwana et al. (2010) call for research on how platform architecture influences the dynamics in ecosystems and modules.
- Second, de Reuver et al. (2018) emphasize research on the question as to how actors strategize, i.e., think strategically, about a situation or business in platform environments, as interconnected thinking is particularly important for decision makers.
- Third, de Reuver et al. (2018) insist on research into how platform providers can jointly shape platforms with other stakeholders of the platform.
- Fourth, Tiwana et al. (2010) emphasize research on how the fit between platform architecture and platform governance influences the dynamics of ecosystems and modules.

Following these four research items, this doctoral thesis contributes to the scientific discourse by exemplarily analyzing cloud platforms and their surrounding platform-based ecosystem. The general definition of cloud computing refers to five characteristics, namely on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service (Mell and Grance 2011). In line with the aforementioned platform description, cloud computing provides the assemblage of software (i.e., operating system, with specialized or standardized software), hardware (i.e., servers), and interfaces (i.e., open or closed APIs) as core functionality in a layered architecture, but requires the adaption of organizational processes and standards. In agreement with Cusumano (2010), cloud computing is an emerging platform, which companies have quickly adopted in their IT strategy. The increasing dissemination of cloud computing is indicated by the enormously rising expenses of cloud computing. In Germany, e.g., cloud computing expenses rose from 0.9 bn Euro in 2011 to 4.2 bn Euro in 2015 (Statista 2018).

Taking the ecosystem-as-structure perspective of Adner (2017), actors in cloud computing provide services to other actors and/or consume other actors' services and, thus, shape the ecosystem (Hannah and Eisenhardt 2018). Besides the enormous number of companies in the context of cloud computing, Floerecke and Lehner (2016) identified 27 different roles in cloud ecosystems, which range from consulting companies, developers, and infrastructure providers to end users. Cloud providers often aggregate or enhance existing services (Huntgeburth et al. 2015; Keller and König 2014). Thus, Böhm et al. (2010) introduces the vision of a web of different actors in cloud computing, which replaces the one-step provision model of traditional outsourcing and provides benefits for service providers, as well as for service consumers. For example, Apple, Amazon, or Google use their competitors' cloud services (Dillet 2018). Floerecke and Lehner (2016) describe the on-demand self-service as a facilitator of this development. Thus, all actors jointly create value with the objective of fulfilling the end customers' needs (Leimeister et al. 2010).

Actors in cloud computing often create value by adding functionality to services already existing in the ecosystem (Huntgeburth et al. 2015). This development is likely to transform cloud networks into complex, globally distributed networks, consisting of many different actors and connections (Keller and König 2014). Based on the observations described above, the following definition merges the current definition of cloud platform-based ecosystems with the ecosystem-as-structure perspective on ecosystems of Adner (2017) to enable a network perspective on cloud computing:

> *A cloud network is an ecosystem-as-structure perspective on cloud platform-based ecosystems that illustrates relevant actors and their connection to other actors that transfer value, risks, and products between the actors.*

Now, with knowledge about what a cloud network is, in line with de Reuver et al. (2018), we find it particularly interesting to consider how companies strategize and include the emerging cloud networks in their decision-making. By driving IT-innovation in companies (Berman et al. 2012), cloud computing enables digital options. Sambamurthy et al. (2003, p. 247) describe digital options as "a set of IT-enabled capabilities in the form of digitized enterprise work processes and knowledge systems." Thus, they allow for inter- and intra-organizational automating, informing, and integrating activities (Rolland et al. 2018; Sambamurthy et al. 2003). The emerging platform-based ecosystem enables new roles and business models in cloud computing, using the new digital options of which the implementation has a certain value for organizations (Woodard et al. 2013). I'd like to emphasize two perspectives on realizing digital options in cloud networks:

- First, an organization can realize value on its own, by reducing costs or providing new features (Sambamurthy et al. 2003). In cloud computing, for example, a possible scenario is the reduction of cost by shifting demand between internal IT and cloud resources (Lilienthal 2013). Further, the emergence of spot prices, i.e., Amazon EC2 Spot Instances or cloud exchanges, provide new opportunities. Customers can buy infrastructure services at dynamically adjusting market prices.

- Second, existing ecosystems can enable new ecosystems by realizing new platforms (Tiwana et al. 2010), which can be understood as digital options. In line with the platform-based ecosystem literature, cloud networks facilitate transactions between different users of other platforms (Eisenmann et al. 2006) and enable mediation between different groups of users (de Reuver et al. 2018). In addition, they increase the interconnection among actors (c.f. Huntgeburth et al. 2015). Cloud networks enable the scalable and adaptable operation of platforms for other platform-based ecosystems and thus, can foster the realization of other ecosystems. For instance, Amazon hosts and thus, enables a huge number of services, such as Netflix or Adobe (Amazon 2018). To provide multisided platforms for business-to-business relationships, several research projects, e.g., the German SynErgie consortium (Bauer et al. 2017; Schott et al. 2018) aim to establish multisided platforms.

The described success of cloud computing signifies that many companies generate massive amounts of data, and apply digital business models. These new opportunities shift the economy from a goods-based to a service-based economy (Barrett et al. 2012). However, there is no chance without risk. With the adoption of cloud computing by IT-organizations, new challenges arise for IT-governance. Cloud computing consumers have to rethink the role of the internal IT department (Malladi and Krishnan 2012; Prasad et al. 2014; Willcocks et al. 2012), as well as the characteristics of the outsourcing relationship that defines how customers and cloud providers interact in the era of cloud sourcing (Hon et al. 2012; Schlagwein and Thorogood 2014). In the context of platforms, Rolland et al. (2018) recognize that path dependencies and legal challenges influence, postpone, and in some cases entirely hinder the uptake and use of digital artifacts. Thus, risk management in IT-organizations have to adapt to the new challenges that come with cloud networks.

The calls for research (e.g. de Reuver et al. 2018; Tiwana et al. 2010) affirm that cloud networks as platform-based ecosystems are an emerging topic worthy of extensive research. This doctoral thesis contains five publications (I to V given below) from the context of cloud networks and platform-based ecosystems. I start by first carefully analyzing cloud networks as platform-based ecosystems, taking an overarching perspective and describing its structure and dependencies (Paper I). Second, I illustrate implications for single actors in cloud networks, following which I attend to the customer perspective. More precisely, I take the perspective of a provider (Paper II) and the perspective of a customer (Paper III, IV, V). Figure 1 (below) depicts my research agenda as reflected in the papers that make up the doctoral thesis and guides the structure of the remainder:

In the following section, I illustrate my methodical approach. In Section 3, I introduce the origin of cloud computing and the emergence of supply-chain-like structures in the cloud ecosystem, namely cloud networks. Further, I describe the precursors to cloud computing, and introduce the terminology on roles and structures. This section provides the foundation of the doctoral thesis and illustrates the development of cloud networks (Paper I: Keller and König 2014).

In Section 4, describing two cases, I illustrate how companies utilize digital options provided by cloud networks. The first case illustrates that by providing the possibility to host a platform, cloud networks facilitate the emergence of other platform-based ecosystems, thus creating a multisided platform for power flexibility (Paper II: Keller et al. 2018b). The second case illustrates how emerging cloud spot prices enable the possibility of utilizing a customer's temporal flexibility (Paper III: Keller et al. 2019).

In Section 5, I illustrate management implications that arise from the transition to the on-demand provisioning of cloud services and their underlying cloud networks. First, I analyze the customer-provider relationship and give guidance on how companies can manage their providers (Paper IV: Keller et al. 2018a). Second, I analyze the applicability of risk management strategies for cloud networks (Paper V: Keller 2016).

In Section 6, I conclude with a summary that describes this doctoral thesis's contribution to the aforementioned research items of Tiwana et al. (2010) and de Reuver et al. (2018). Further, I describe the doctoral thesis's limitations and give suggestions for future research, as well as implications of the findings for researchers and practitioners.

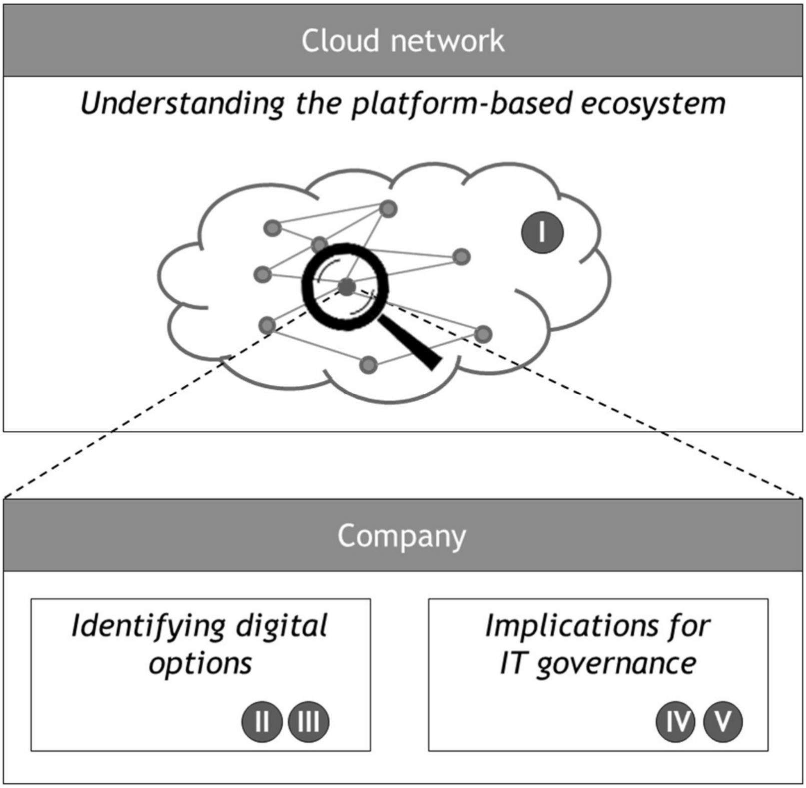

Figure 1: Structure of the doctoral thesis

2 Methodical Approach

In recent years, the demand for researchers developing or contributing to a theory within the Information Systems (IS) discipline is steadily increasing (Gregor 2002; Müller and Urbach 2017). As Weber (2012) has indicated, many researchers state expanding theoretical understanding within their discipline as a main goal. Most theories deal with the what, how and why of phenomena (Gregor 2002; Müller and Urbach 2017; Whetten 1989). Thus, contributing to theory does not mean simply listing data; it goes beyond the data to explain why the data is what it is (Carroll and Swatman 2000; Sutton and Staw 1995). Finding an answer to queries of "why" is what every strong theory aims for (Bacharach 1989; Sutton and Staw 1995).

The construct of IS follows two streams: behavioral science and design science (Buhl et al. 2012b; Buhl et al. 2012a; Hevner et al. 2004). While behavioral science is rooted in natural science research methods and seeks to develop and justify theories, design science is rooted in engineering and seeks to solve problems (Hevner et al. 2004). Researchers are expected to use their identified solutions to contribute to the general understanding of a given problem and related theories (Hevner et al. 2004).

This thesis is closely related to the design science approach. I focus on providing solutions for practically inspired, relevant problems. In our design process, my co-authors and I use insights and explanations from other disciplines and apply them to our context, which is a well-accepted approach in IS research (Gregor 2006). Thereby, I deduct generalizable knowledge that can be applied in similar designs in future research (Gregor and Hevner 2013).

3 From the Origin of Cloud Computing to Cloud Networks

By 2010, consulting companies, bloggers, and whitepapers adopted the term *Cloud Computing* and continuously redefined its meaning, which resulted in considerable confusion (Armbrust et al. 2010) (cf. Figure 2). Similar to other emerging digital technologies, the scope of cloud computing had to be clarified, so that currently, the National Institute of Standards and Technology provides a broadly accepted definition for cloud computing consisting of three different service models (Software as a Service known as SaaS, Platform as a Service known as PaaS, and Infrastructure as a Service known as IaaS) and four deployment models (private, community, public, and hybrid) (Mell and Grance 2011). Cloud computing is made up of five characteristics: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service (Mell and Grance 2011).

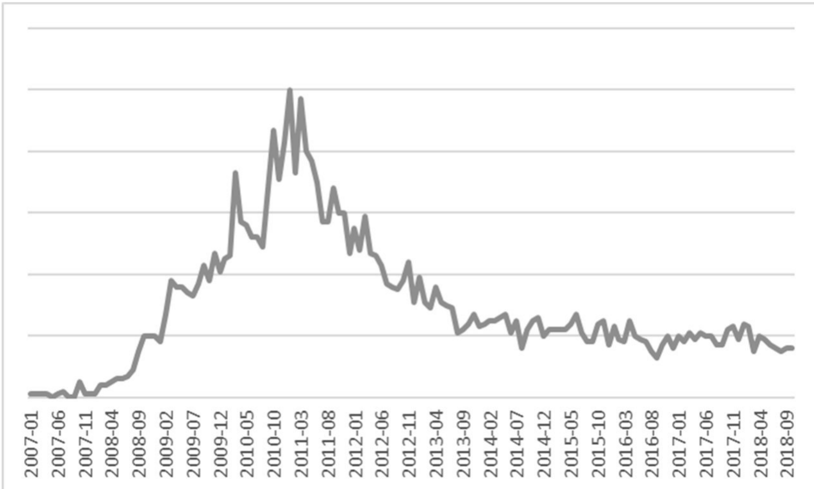

Figure 2: Google Trends for the term "Cloud Computing" in Germany (Google Trends 2018)

Taking a closer look at cloud computing's precursors, the concept of cloud computing is based on the two well-researched concepts of grid computing and service computing. All three concepts share the vision of reduced costs; however, grid computing focusses on increasing accessibility and flexibility for hardware (Bote-Lorenzo et al. 2004), while service computing focusses on software (Papazoglou 2003). Cloud computing considers both (Mell and Grance 2011), and adds an economic perspective (Foster et al. 2008; Leimeister et al. 2010). Thus, grid computing is some kind of technical foundation of cloud computing, while service computing describes communication standards and service descriptions (Papazoglou 2003; Wei and Blake 2010), which provides the foundation of the communication and interconnection in cloud networks.

Table 1: Definition of Grid, Service, and Cloud Computing

	Definition
Grid Computing	Grid computing is "a large-scale geographically distributed hardware and software infrastructure composed of heterogeneous networked resources owned and shared by multiple administrative organizations which are coordinated to provide transparent, dependable, pervasive and consistent computing support to a wide range of applications. These applications can perform either distributed computing, high throughput computing, on-demand computing, data-intensive computing, collaborative computing or multimedia computing" (Bote-Lorenzo et al. 2004, p. 296).
Service computing	Services are self-describing, platform-agnostic, computational elements that support rapid, low-cost composition of distributed applications. Services perform functions, which can be anything from simple requests to complicated business processes. Services enable organizations to expose their core competences programmatically over the internet (or intranet) using standard (XML-based) languages and protocols, and to be implemented via a self-describing interface based on open standards (Papazoglou 2003).
Cloud Computing	Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool

	of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Mell and Grance 2011, p. 2).

The composition of those technologies (grid computing and service computing), as well as the improved maturity level enables cloud computing to co-create value and to emerge as a platform-based ecosystem (Böhm et al. 2010; Floerecke and Lehner 2016). Thus, cloud computing is no completely new concept, but rather a further development and composition of existing technologies (Zhang et al. 2010).

In recent years, the roles of actors, their interactions in cloud networks, as well as their business models have changed drastically. Keller and König (2014) observed a concentration of IaaS providers in only a few large companies, i.e., Amazon, Google, IBM, and Microsoft. Due to scalability (Mell and Grance 2011), as well as the incentives for standardization in offerings (Foster et al. 2008), large providers can outperform smaller providers in terms of quality and price. In 2017, the "big four" (Amazon, Google, IBM, and Microsoft) had a revenue share of 64% (Coles 2018). Thus, small IaaS providers without specialization might quickly vanish. However, providers can extend specialized IaaS offerings, e.g., through addressing specific regulatory requirements.

In contrast to this development, service orientation (Armbrust et al. 2010) and specialization (Hoefer and Karagiannis 2010, 2011) in SaaS led to fine-grained providers for specialized software services. The enormous number of applications resulted in a lack of transparency (Jansen 2011). These developments foster new business models like the Massachusetts Open Cloud project which functions as an exchange platform for standardized infrastructure services, Amazon EC2 Spot Instances with demand-oriented pricing, or VMware Service Market Place and the HP Aggregation Platform which offer software and platform services.

In such highly interconnected and automated environments, it is mandatory for companies to understand their role and to strategize accordingly. Hannah and Eisenhardt (2018) analyzed how companies can position themselves in ecosystems and develop an ecosystem strategy. In general, an ecosystem strategy is defined by "the way in which a focal firm approaches the alignment of partners and secures its role in a competitive ecosystem" (Adner 2017, p. 47). Actors can decide which companies they invite to an ecosystem, which ecosystems they join, and with which other actors they want to align (Hannah and Eisenhardt 2018). In cloud networks, different to the previously existing view on the bilateral provider-customer-perspective, I identified two new archetypes, described below, on how actors utilize the aforementioned trends to strategize.

First, cloud computing enables actors to outsource specialized functions (Troshani et al. 2011). Following Parker et al. (2017b) they decide whether to produce their own output or to orchestrate the output of others. By outsourcing, actors can focus on their core competences, consuming other specialized cloud services to simplify their operational business or enhance their own service offerings. This enables them to follow a component strategy in their ecosystem (Hannah and Eisenhardt 2018), in which they enter one or a number of components, and cooperate with other actors for the remaining components. Service providers, for example, can position as value-adding resellers who use other services (e.g., payment handling and development platforms from other cloud actors) to provide their own applications.

Second, marketplaces can strengthen the bonding between actors in a cloud network, while facilitating a rapid exchange of cloud services (Keller and König 2014). Doing so, they follow a bottleneck strategy (Hannah and Eisenhardt 2018), providing a solution for a bottleneck by providing a survey in a crowded cloud network, for example. One can observe a trend toward standardized interfaces in cloud marketplaces and in standardization in general, pushed forward by organizations such as the "Cloud Standards Customer Council" with important industry players like IBM or Symantec (Cloud Standards Consumer Council 2018). This development will facilitate the marketplace role. Further, the emergence of cloud exchange markets will in turn additionally strengthen the standardization of cloud services (Buyya et al. 2008).

Both approaches to strategizing enable actors to reduce a constraint on the ecosystem's growth (Hannah and Eisenhardt 2018). It is obligatory for companies to survey the ecosystem and develop a viable ecosystem strategy (Hannah and Eisenhardt 2018). Thus, companies must understand the actors in cloud networks, as well as their interactions and newly emerging risks that could impact the ecosystem. Insufficient knowledge on these newly emerging structures emphasizes the following research questions:

RQ1: What actors exist in cloud networks?

RQ2: What risks affect the actors in cloud networks?

In Keller and König (2014), we analyzed cloud networks and identified relevant actors and their interactions. We performed an extensive literature review in the context of cloud computing, supply chain management, and the financial industry to build a taxonomy of actors, as well as a taxonomy of risks in cloud networks. The taxonomies are evaluated through real-world examinations following a conceptual-to-empirical approach proposed by Nickerson et al. (2013). In addition, we interviewed industry experts to guarantee the reflection of existing network structures in the taxonomies and the reference model.

To improve and evaluate our results, we conducted interviews with industry experts. The goal of a reference model is to cover general patterns to "raise the efficiency and effectiveness of specific modeling processes" (vom Brocke and Thomas 2006, p. 502). Based on Hevner et al. (2004), we build our reference model as a specific "artifact" and evaluate it in the course of our search process. To "enhance the quality" of our reference model, we follow the guidelines of modeling by Schuette and Rotthowe (1998). We use a slightly simplified version of UML class diagrams as a semi-formal modeling language for information modeling to describe our artifacts clearly and comprehensibly. Further, we elaborate the reference model through instantiation based on a real-world example to demonstrate its applicability. To improve the taxonomies and the reference model, we further used the new insights gained from the interviews. Figure 3, for instance, illustrates our partial model that describes the interactions in cloud networks on basis of UML. Cloud networks consist of actors and connections. Connections connect actors, which can have the role of a provider, intermediary, or client.

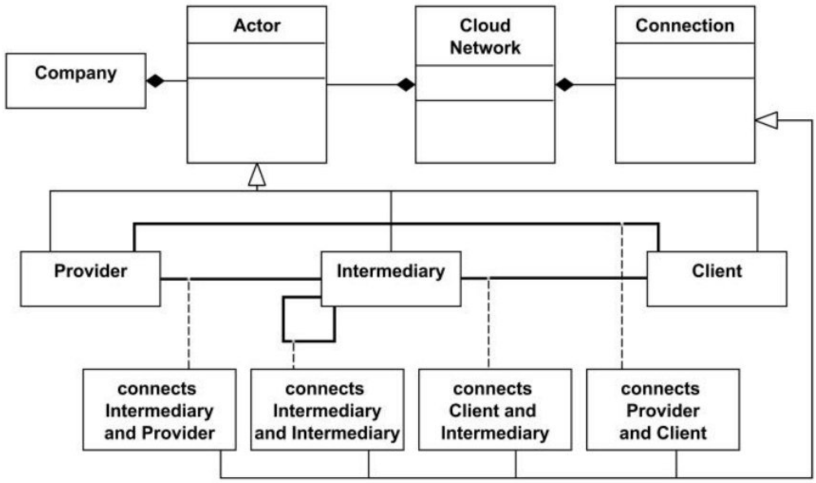

Figure 3: Partial model describing interactions in Cloud Networks (cf. Keller and König 2014)

The paper provides a description of the ongoing developments in cloud computing, such as standardization, specialization, rising dependencies, new actors, and new structures. These developments transform the current cloud landscape into complex, globally distributed cloud networks. To provide a better understanding of the underlying structure and the inherent risks, the paper presents taxonomies of actors and risks in cloud networks. The taxonomy of actors distinguishes the general classes of initial producers, value-added resellers, catalysts (actors that increase the easiness and frequency of interactions), and clients. The taxonomy of risk distinguishes different kinds of risk, hazards that cause risks and reinforcers that reinforce risk. On this basis, the paper provides a reference model based on UML class diagrams that illustrate the connection and the dissemination of risk between actors in cloud networks. It can be instantiated and supports risk identification in cloud networks.

The paper enables the generation of insight from an ecosystem-as-structure (Adner 2017) perspective on cloud networks. By illustrating the dynamics in cloud networks, the reference model provides insight into the architectural structure of cloud networks, and illustrates how the interaction between actors shapes the dynamics in cloud networks from a platform-based ecosystem perspective.

4 Digital Options enabled by Cloud Networks

Digital options describe the level of flexibility provided by IT architectures in response to opportunities (Butler and Gray 2006). They represent a set of IT-enabled capabilities, which are based on past technological investments (Sambamurthy et al. 2003; Woodard et al. 2013). Implementing digital options brings a certain value to the organization (Woodard et al. 2013). Following Rolland et al. (2018) and Sambamurthy et al. (2003), digital options enable inter- and intra-organizational automating, informing, and integrating activities. However, benefiting from digital options require both “consciously generating them […] and suavely exercising them” (Tiwana et al. 2010, p. 684).

Rolland et al. (2018) point out that loose integration with digital infrastructure and other platforms is a digital option. Cloud networks support this digital option by providing standardized interfaces (Vaquero et al. 2008), as well as facilitating deployment (Zhang et al. 2014). This is especially important in the case of multisided platforms that need to “enable direct interactions between two or more distinct sides” that are affiliated with the platform (Hagiu and Wright 2015, p. 163). In the last few years, several multisided platform-based ecosystems, e.g., AirBnB and Uber, emerged on the basis of cloud services (Hagiu and Wright 2015). This opportunity for value co-creation not only benefits the cloud network itself, but also enables the emergence of other platform-based ecosystems by hosting their platforms (Tiwana et al. 2010), as well as specific actors (Keller and König 2014).

Besides focusing on the co-creation perspective, actors in cloud networks can capture value by the realization of digital options for specific actors in cloud networks. From the perspective of the organization, Sambamurthy et al. (2003) describe the ideal role of IT as “options generator,” and thus, quickly detecting and realizing digital options is a huge asset for companies. The characteristics of cloud computing, especially on-demand self-service and rapid elasticity (Mell and Grance 2011) can provide such digital options and could drive IT-innovation in companies (Berman et al. 2012). As cloud networks are complex, companies require decision support.

In the following subsections, I introduce two cases of digital options in cloud networks.

- First, cloud networks can provide a scalable backbone for emerging platform-based ecosystems. The case of a power flexibility platform provides insight on the design of business-to-business multi-sided platforms.
- Second, some cloud service providers offer spot prices, which provide dynamic pricing of cloud services. These spot prices enable the utilization of temporal flexibility. By deferring a cloud service request, customers can benefit from a digital option to reduce costs.

4.1 Enabling the Emergence of Other Ecosystems

In line with existing knowledge on platform-based ecosystems (de Reuver et al. 2018; Eisenmann et al. 2006), cloud networks facilitate the transactions between different users of other platforms and enable mediation between different groups of users. Further, they increase the interconnection among actors (c.f. Huntgeburth et al. 2015). These characteristics of cloud networks enable the quick realization of platforms for emerging ecosystems.

One realization of such platforms is in the form of multisided platforms that connect more than one market (Hagiu and Wright 2015) and mediate an interface between those markets (Adner 2017). By positioning as a hub, the platform provider follows a bottleneck strategy (Hannah and Eisenhardt 2018) that claims market power through its centrality and its ability to control access (Adner 2017). The multi-sided platform captures value for a side that is dependent on the number and quality of the actors on the other side (Helfat and Raubitschek 2018). Platforms also promise to decrease coordination costs, efforts to develop new modules, and the market entrance barriers, while they can increase autonomy (Tiwana et al. 2010). An example is Amazon market place that connects third party markets with Amazon's large customer base. Further, Henfridsson and Bygstad (2013) have found that digital infrastructures in general are reinforcing. In line with these observations, cloud networks enable the emergence of other ecosystems by hosting scalable platforms for them.

One less researched domain for the application of multisided platforms on the basis of cloud networks, relates to critical infrastructures. Adelmeyer and Teuteberg (2018, p. 1345) translate the German IT Security Law, which defines critical infrastructures as “facilities, installations or parts thereof belonging to the sectors of power, health, water, nutrition, information technology and telecommunications, transport and traffic as well as finance and insurance, which are of great importance for the functioning of the community because their failure or impairment would result in significant supply shortages or threats to public safety.” Adelmeyer and Teuteberg (2018) studied cloud services adoption for critical infrastructure. They note that, as yet, companies use cloud computing only partially. However, they also observe that “the use of services hosted in public clouds expands, especially SaaS” (Adelmeyer and Teuteberg 2018, p. 1354).

Power is a critical infrastructure that underlies many current changes. The transition to renewable energy sources will continue to be a global challenge in the coming decades (Figueres et al. 2017). Watson et al. (2010) argue that information systems are a necessity in environmental and sustainable development. One way in which this digital layer can contribute to the transition to renewable energy sources is by utilizing software services to exchange power flexibility for industrial production, as illustrated in Schott et al. (2018).

As an industrial nation, Germany is a leader in the development and uptake of renewable energy sources which, in 2016, provided 31.7 % of Germany's gross electricity consumption (Federal Ministry for Economic Affairs and Energy 2017). However, the energy transition entails several challenges, e.g., transformation from a central to a decentralized energy system, or integrating a weather-dependent (i.e., volatile) amount of supply (Appen et al. 2013). To address such challenges, the SynErgie consortium, which consists of over 100 companies and research associations, works on actively integrating power-intensive industrial processes into the electricity systems of the future. By temporally shifting their consumption, companies can compensate for volatile electricity production triggered by renewable energy sources. This enables the power-intensive industry to use electricity when it is available and cost-efficient, while at the same time renouncing the use of scarce and expensive power. Due to the changing electricity system, the paradigm "electricity supply follows the electricity demand" is no longer valid (Moura and de Almeida 2010). The SynErgie project team has been developing a business-to-business multisided platform that enables the industry's active participation in power markets via faster and more accurate scheduling (consumer role) and by offering flexibility (supplier role).

The offered flexibility can either increase or decrease a company's power demand (Palensky and Dietrich 2011). Figure 4 depicts the architecture of the designed ecosystem, consisting of the market-side platform (in this context the power flexibility platform), as well as the company-side platform that connects companies to the market-side platform. The market-side platform, i.e., power flexibility platform, facilitates the interconnection of companies with existing and emerging power markets and provides easy access to supporting services such as aggregators or price forecasts. Companies, for instance, can commission a price forecast (e.g., based on company, market, and weather data) over the power flexibility platform. On the basis of what the service suggests, the company uses the power flexibility platform to contact the suggested flexibility markets and bilaterally trade their power flexibility.

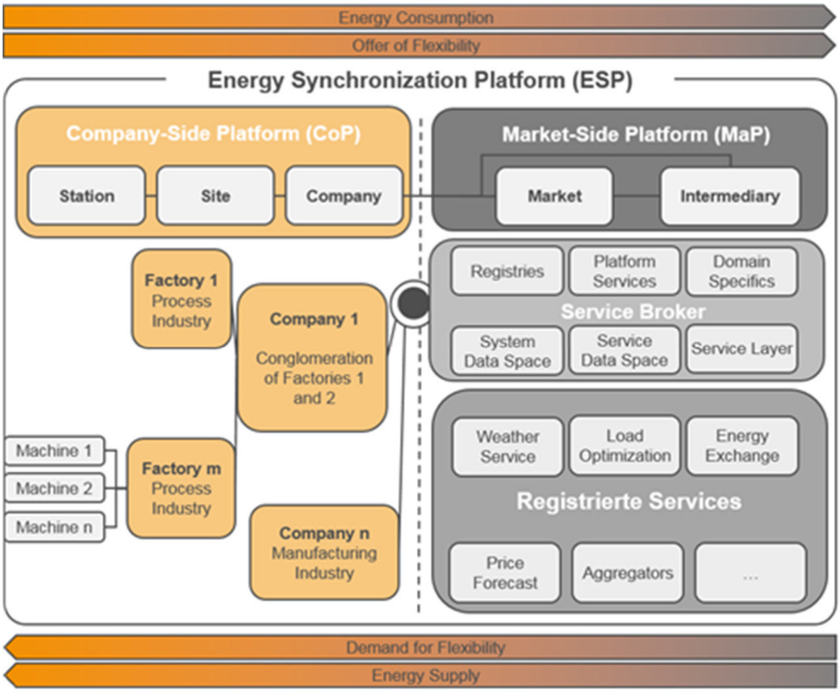

Figure 4: Architecture of the SynErgie platform-based ecosystem from Schott et al. (2018)

Alam et al. (2017) demonstrate that many markets provide possibilities for power flexibility trading. Market entrance barriers hinder companies that aim to increase their potential for flexibility (Alcázar-Ortega et al. 2015). These circumstances determine the need for a business-to-business multisided platform that increases transparency, and thus facilitates the identification and exchange of flexibility in the power sector, also providing opportunities for information exchange and power-related support services.

As illustrated above, and due to technical realities, current power markets focus on specific kinds of flexibility trading. Today, these platforms rarely associate with one another. There is no multisided platform which connects the potential for flexibility of industry to flexibility markets and supporting services. In response to this problem, our project team is developing a multisided platform, which will facilitate such interaction and will reduce transaction costs. Since the success of multisided platforms depends on several economic and technological factors, the following further research question arises:

RQ3: What should be the preliminary design principles for a meta-platform that facilitates the monetarization of industrial flexibility on power markets?

In Keller et al. (2018b) we report on having accompanied the SynErgie project team that develops a multisided platform that connects companies with power flexible processes to power markets and supporting services. Inspired by Sein et al. (2011)'s action design research approach, we iteratively develop preliminary design principles for a meta-platform that facilitates the monetarization of industrial flexibility on power markets.

In contrast to other design research methods, such as March and Smith (1995) or Peffers et al. (2007), which follow the paradigm "build and then evaluate" in a separate phase (Sein et al. 2011, p. 39), action design research instead produces IT artifacts that "emerge from the contexts of both their initial design and continual redesign via organizational use" (Sein et al. 2011, p. 52). Indeed, cooperation between practitioners, end users, and researchers during the development and evaluation of an IT artifact is the central characteristic of this research method. To a large extent, action design research represents “the general understanding of design-oriented research as conducted in the German speaking community of Business and Information Systems Engineering” (Beer et al. 2014, p. 3658). In line with this statement, and suggested for research on platforms by de Reuver et al. (2018), action design research is especially well-suited to problems that are both practically relevant and of scientific interest.

Inspired by this research paradigm, in Keller et al. (2018b), we illustrate the design process, and describe and discuss the implications of the four preliminary design principles: 'enable open integration,' 'provide a harmonized traceable data model for flexibility,' 'ensure power specific security,' and 'comply with regulation.' The first preliminary design principle aims to provide open integration, which will allow companies access to a variety of flexibility markets and to create cross-group network effects (Hagiu and Wright 2015). Further, it facilitates the use of supporting services. To enable interaction between the respective sides, our second preliminary design principle proposes a harmonized, traceable data model that describes the characteristics of the flexibility. The third preliminary design principle addresses the technical and non-technical aspects of security in the power ecosystem. As power provision is a critical infrastructure, platforms have to cope with various regulatory issues as preliminary design principle four signifies.

Companies in the new ecosystem co-create value with domain specific services that build upon each other. Those services benefit from the characteristics of cloud computing, which might foster their emergence. As illustrated, the paper provides insight on how platform-based ecosystems can reinforce the development of other ecosystems. Further, it illustrates how a consortium can arrange to jointly use a digital option and shape a business-to-business platform-based ecosystem. Thus, it contributes to the general understanding of the emergence of platform-based ecosystems.

4.2 Enabling the Utilization of Temporal Flexibility

As illustrated above, and according to Sambamurthy et al. (2003), digital options enable inter- and intra-organizational automating, informing, and integrating activities. Deciding when and how to utilize an identified digital option is crucial for an organization. Cloud networks provide various digital options for its participating actors. One digital option is the rapid elasticity of cloud services (Mell and Grance 2011) which enables flexible adaptation of an organization's demand. This emerging flexibility generates a need for decision support of cloud customers and cloud providers.

In general, flexibility is multidimensional (Suarez et al. 1995). Golden and Powell (2000, p. 377), for instance, identify temporality, range, intention, and focus as dimensions of flexibility in supply chain management. Regarding cloud computing, existing literature does not provide a rigorous definition for the dimensions of flexibility. Authors have only described its characteristics, such as "the ability to respond quickly to changing capacity requirements" (Repschläger et al. 2012, p. 5). The existing literature on cloud computing considers two kinds of flexibility, namely temporal and spatial flexibility (Kong and Liu 2015). Considering spatial load-shifting, (Beloglazov and Buyya 2010), for instance, the focus is on shifting the workload between cloud-scale data centers of the perspective of a provider. In the following, I will consider temporal flexibility in more detail.

In a rather recent development, IaaS providers such as Amazon Web Services (AWS) reflect varying demand patterns of their customers by offering their services at fluctuating spot prices (Karunakaran and Sundarraj 2015). Thereby, providers seek constant server utilization without idle capacities and extensive peaks. The spot prices are volatile throughout the day (Ben-Yehuda et al. 2013), as illustrated in Figure 5. This figure depicts a time series of the Amazon Spot Instance “m1.xlarge” hosted in a North Virginia datacenter (“us-east-1” region), that spans the period from 1 January 2015 through 30 December 2016. As source of this series of spot prices, I acknowledge use of the Spot Price Archive (Javadi et al. 2011) who downloaded a large data set ranging from January 2009 to December 2016 via the Amazon EC2 API. In times of high utilization, providers seek rising prices, whereas in times of low utilization they offer their services at lower prices.

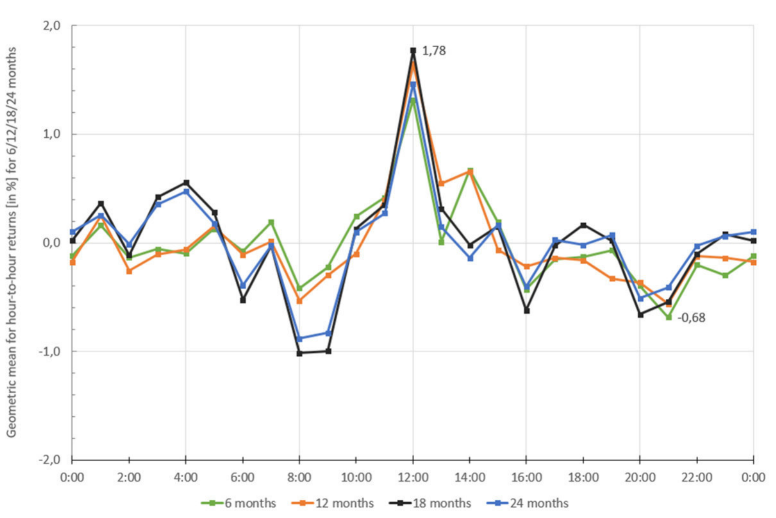

Figure 5: Exemplary geometric mean returns from 2015/2016

At times when relatively low costs apply, spot prices might attract price sensitive customers. Further, there are cases in which customers can defer individual jobs in time, by for instance using simulations, graphical rendering jobs, or scientific computations. If customers do not require a cloud service instantly and they expect cloud spot prices to fall, they can temporally postpone their demand with the objective to realize cost savings. For the period they are willing to wait, their computing job opens a window of temporal flexibility.

Evaluating cost savings potential in a customer's window of temporal flexibility is a complex task, since cloud spot prices can change frequently (Ben-Yehuda et al. 2013). Cloud customers therefore require strategies that account for the tradeoff between service costs, implementation cost, and waiting time (Karunakaran and Sundarraj 2015; Tang et al. 2012). Further, near-real-time decision support and a change in demand behavior are required (Keller et al. 2019).

Other IS research domains have been established as a valuation method for digital options. The so-called real options analysis (Amram and Kulatilaka 1999; Benaroch and Kauffman 1999; Trigeorgis 2002) captures flexibility of action under uncertainty. Such real options serve to determine a value for the right to act or to await another opportunity over a set period of time. Tiwana et al. (2010) describes real options analysis as suitable for the valuation of digital options in platform environments. Thus, one can transfer this method to the context of cloud spot prices and ask the following research question:

RQ4: How can cloud services customers quantify and exploit their short-term demand flexibility's monetary value using real options analysis, in the light of uncertain price development?

In Keller et al. (2019), we adapt and apply multiple option pricing models, the Binomial tree approach of Cox et al. (1979), and the binomial tree approach of Tian (1993) each with price patterns and return patterns, as well as expectation maximization. In doing so, we process a data set of Amazon EC2 spot prices as key information for our real options analysis. Our research objective covers a relevant real-world problem, as cloud customers would profit from decision support on when to purchase cloud services within a temporal flexibility window to optimally exploit existing savings potential.

The paper contributes to the literature by guaranteeing cloud job execution on variable time requests in a single cloud spot market, whereas existing multi-market strategies most likely cannot fulfill requests when outbid. Analyzing a large set of scenarios using real-world data of Amazon EC2 Spot Instances, the paper demonstrates that our approaches exploit existing savings potential to a considerable extent, up to 40 percent. Moreover, it demonstrates that real options analysis, which explicitly considers time-of-day specific spot price patterns, outperforms traditional option pricing models and expectation maximization.

According to existing literature, real options analysis is a classic example of computing the value capture enabled by digital options from an actor's perspective (c.f. Sambamurthy et al. 2003). By illustrating the utilization of temporal flexibility in cloud networks, the paper contributes to the understanding of how companies can value and utilize digital options in platform environments, and strategize accordingly. It further illustrates how companies can organize their individual service provision in cloud networks with dynamic pricing.

5 IT-Governance Implications for Participants in Cloud Networks

Cloud networks are participant governed networks that might best be addressed by a network administrative organization (Provan and Kenis 2007; Zissis and Lekkas 2012). General literature on ecosystems also recommends centralized governance mechanisms for ecosystems (cf. Adner 2017; Tiwana et al. 2010; Wareham et al. 2013). These governance mechanisms should provide control-creativity (an effective balance between control and creativity), standardization-variety (a high level of standardization to enable reusability), and individual-collective (a variety of extrinsic motivations of individuals) (Wareham et al. 2013).

However, as cloud computing is a fairly new paradigm of IT sourcing, no centralized governance mechanism exists. Implementing a governance institution for cloud networks that will provide a holistic cloud network governance could take a couple of years. Meanwhile, practitioners need to address this issue on their own. To overcome this difficulty, single actors must understand the ecosystem and determine strategic opportunities (i.e., digital options) (Sambamurthy et al. 2003). Further, they have to identify and mitigate threats and undesirable results (Wareham et al. 2013). However, there are no properly evaluated governance principles in companies' IT departments as yet, especially when it comes to the network perspective of cloud computing. Zhang et al. (2010) or Martens and Teuteberg (2011), for instance, developed frameworks for risk management in cloud computing, focusing on bilateral relationships. However, existing risk management frameworks neither consider the network perspective of cloud computing, nor address all aspects of cloud governance.

To provide appropriate governance mechanisms, one must draw on the basic characteristics of cloud networks. Cloud providers offer pooled IT resources to their consumers in a flexible and scalable manner without requiring a long-term capital commitment or IT-specific expertise (Armbrust et al. 2010; Marston et al. 2011; Mell and Grance 2011). Due to this characteristic, cloud services can both open up new digital options and reduce IT costs (Etro 2009; Marston et al. 2011). Public cloud services play a particular role in this context, because they allow companies to access high-end IT services without requiring high initial investment (Marston et al. 2011), and they can "respond quickly to changing capacity requirements" (Repschläger et al. 2012, p. 7). Specialized software services (Hoefer and Karagiannis 2010) in the context of software as a service led to fine-grained providers for specialized solutions with varying quality (Wang et al. 2014).

In line with general IT-outsourcing, managing cloud providers also encompasses the management of costs and service quality (c.f. Aubert et al. 2002). However, cloud networks also inherit new risks. Clarke (2010) states that the risks of cloud computing are similar to those of in-house operations, yet more obscure. Jansen (2011) identifies six key security issues, namely trust, architecture, identity management, software isolation, data protection, and availability, while explicitly describing cascading outages in cloud networks when talking about availability. Al Zain et al. (2012) identify three main cloud security risks, namely data integrity, data intrusion, and service availability. Thus, managing cloud computing providers has become a critical success factor for customers, and managing business relationships with cloud providers becomes more and more important.

According to Balaji and Brown (2005), provider management in IT-outsourcing projects can be defined as the customer's activities to plan, control, coordinate, and maintain provider relationships. In IS research, the management of IT-outsourcing relationships is considered to be an essential factor that can make or break the outsourcing project (Lacity and Willcocks 2003; Ruzzier et al. 2008; Urbach and Würz 2012). However, the development from the traditional IT-outsourcing to the cloud sourcing era has changed customer-provider relationships (Huntgeburth 2015; Willcocks et al. 2012). The shift from IT-as-a-product to IT-as-a-service makes enterprise cloud customers constantly dependent on the cloud service provider, the latter representing any producer or value-added reseller of cloud service (Keller and König 2014). Via the internet, customers need to hand over confidential data, as well as their control over critical IT infrastructure and applications (Ali et al. 2015; Chaput and Ringwood 2010; Huntgeburth 2015). Corporate cloud consumers further have to rethink the role of the internal IT department (Malladi and Krishnan 2012; Prasad et al. 2014; Willcocks et al. 2012), as well as the characteristics of the outsourcing relationship that defines how customers and cloud providers interact in the era of cloud sourcing (Hon et al. 2012; Schlagwein and Thorogood 2014).

Without appropriate provider management, the rising number of providers will lead to a lack of transparency in the cloud, which can strongly reinforce risks in customer-provider relationships (Keller and König 2014). While customers typically control the underlying resources in private cloud scenarios (Mell and Grance 2011), public and hybrid cloud scenarios in which customers obtain cloud services that run on infrastructure and systems operated by the cloud service provider, provider management becomes especially relevant.

Thus, the management requirements shift toward interpersonal relationships. Although some approaches that address specific aspects of/for cloud provider management already exist (Armbrust et al. 2010; Fahmideh et al. 2018; Marston et al. 2011; Subashini and Kavitha 2011; Vithayathil 2018), I have not identified a holistic model that addresses all phases from pre-contract to post-contract. Further, existing approaches do not consider the specific realities of specialized and standardized cloud products. Thus, we lack knowledge on how companies can navigate through cloud networks and strategize with their cloud providers. This has prompted the following research questions:

RQ5: What is the existing knowledge on managing relationships between providers and customers?

RQ6: What are management suggestions that support practitioners in governing their cloud provider relationships?

In Keller et al. (2018a), based on the design science paradigm, we propose a framework that structures the processes for achieving effective cloud service provider management. For that purpose, we (1) identify cloud-specific challenges in managing cloud service providers, and (2) develop a corresponding process framework for provider management. Subsequently, we present the results of seven interviews with nine subject-matter experts that we carried out to evaluate the comprehensibility, completeness, operationalizability, and acceptance of the framework. Our research aims at contributing to the knowledge base of scientific research, as well as at providing actionable guidance for practitioners. To align the two aims, we chose a science format design (Gregor and Hevner 2013; March and Storey 2008). The design science approach is a prescriptive paradigm that builds design artifacts to solve managerial problems by using academic and practice-oriented knowledge. The artifact itself can be of technical, or as in this case, organizational-methodological nature (van Aken 2007). In our study, we applied the design science approach on the basis of Hevner et al. (2004) for the further course of the research.

We reviewed both academic and application-oriented literature to determine the challenges in customer-provider relationships, and scrutinized existing approaches to cloud provider management as suggested by vom Brocke et al. (2009) and Webster and Watson (2002). Regarding the purpose of solving practical business problems, application-oriented literature was also included in the reviewing process, because such work represents "the experiences and expertise that define the state-of-the-art in the application domain of the research" (Hevner 2007, p. 89). Based on our screening of academic and practical literature, we collected a first set of pre-selected literature. Next, we synthesized the literature into an initial cloud-provider management framework based on existing knowledge. In several rounds, we challenged our cloud-provider management framework by interviewing practitioners as well as other research colleagues. We then used the evaluation feedback to refine our framework until the design of the artifact met the predefined objectives (Hevner 2007).

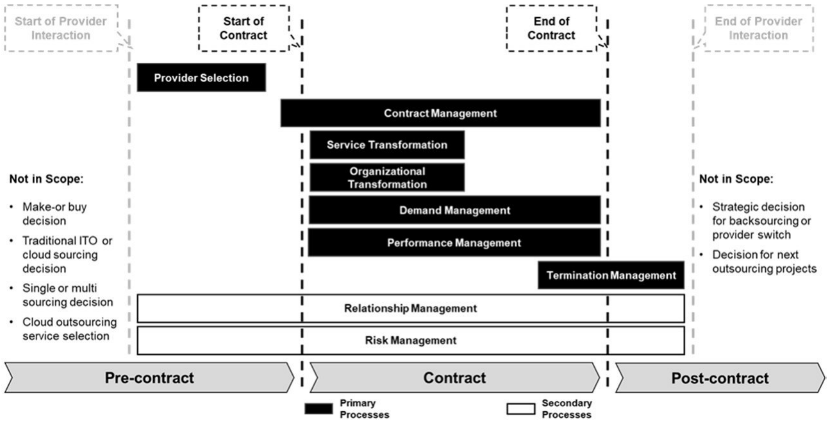

Figure 6: Cloud service provider management framework (cf. Keller et al. 2018a)

As scientific literature previously published very little on the management of cloud providers, our literature review includes papers from more general fields, such as cloud computing, IT-outsourcing, and IT-management. Doing this, the paper gives a framework with a broad focus on cloud provider management. The framework describes all relevant primary process steps (provider selection, contract management, service transformation, organizational transformation, demand management, performance management, and termination management), as well as secondary steps (relationship management, risk management) related to pre-contract, contract, and post-contract phases. The framework contributes to the knowledge base on cloud provider management for practitioners and researchers. The paper could in the process also provide generalizable insights on the governance of providers in platform-based ecosystems from a single actor's perspective and guide their interactions with other actors.

In previous sections, I already alluded to the emerging structures of cloud networks. Those structures have an impact on risk management in companies. External software services, such as multisided platforms, connect with other software services to provide their features. These services are based on other services, as previous sections have mentioned. A multi-sided platform can use some third party payment service, for instance. Thus, risk management might adopt strategies from other disciplines, where the consideration of impending networks already plays an important role. Companies can transfer risk management strategies from supply chain management or the financial industry. As illustrated above, existing literature only considers the bilateral relation between provider and customer. To address the identified research gap, the following research question arises:

RQ7: Which risk management strategies for cloud networks can companies adopt from other disciplines?

Keller (2016) builds upon Keller and König (2014). Following no particular research approach, I summarized the knowledge developed in my previous research projects to provide risk management guidance for practitioners. Using the insight on cloud networks, I examine various risk management strategies used in other disciplines, such as supply chain management or the financial industries, regarding their applicability to cloud networks. Further, in this article I give guidance for IT-governance toward the application of risk management in cloud networks. The paper provides generalizable insights on the governance of platform-based ecosystems from a single actor's perspective as well as from a network perspective.

6 Conclusion

6.1 Summary and Contribution to the Proposed Research Items

The doctoral thesis adds several new insights to existing research on platform-based ecosystems. Here I will explain the contribution of my papers to the four research items proposed by Tiwana et al. (2010) and de Reuver et al. (2018).

First, Tiwana et al. (2010) call for research on *how platform architecture influences the dynamics in ecosystems and modules*. To address this research item, in Section 3, the doctoral thesis illustrates the emergence of cloud networks. There, I describe how the illustrated taxonomy of actors, the taxonomy of risks, as well as the reference model that enables the instantiation interactions between actors in cloud networks contribute to the understanding of cloud networks. The paper provides insight into the architectural structure of cloud networks and illustrates the interactions of actors. By providing an overarching ecosystem perspective as well as an individual perspective on the dynamics in cloud networks, it generates knowledge one can generalize to the context of platform-based ecosystems. Further, it enables the development of new insight on cloud networks from the perspective of an ecosystem-as-structure (Adner 2017).

Second, de Reuver et al. (2018) emphasize the need for research on the question as to *how actors strategize in platform environments*. The doctoral thesis contributes to this research question by illustratively analyzing two cases of digital options enabled by cloud networks, as well as management implications that arise from the transition to the on-demand provisioning of services in cloud networks. In Keller et al. (2019), we illustrate how companies can utilize the emerging spot prices that originate from standardization provided by cloud infrastructure services in cloud networks. Companies can monetize their temporal flexibility by following our approach. Further, the doctoral thesis provides guidance on IT-governance with respect to the specific characteristics of cloud networks that might be transferrable to the general context of platform-based ecosystems with interconnected relationships between actors, and it provides insight on how to adapt a company's strategy to such environments.

Third, de Reuver et al. (2018) suggest more research on *how platform providers can jointly shape platforms with other stakeholders of the platform*. By illustrating how cloud networks enable the emergence of other ecosystems, i.e., a multisided platform for power flexibility, I contribute to this research item.

Fourth, Tiwana et al. (2010) emphasize research on *how the fit between platform architecture and platform governance influences the dynamics of ecosystems and modules*. The management implications of Section 5 indicate how companies strategize with respect to the architecture of cloud networks. This section also describes which individual governance implications result from the latter insights. Further, Keller (2016) provides a first indication as to how the architecture of cloud networks might influence the central governance of cloud networks.

Concluding, the papers on digital options also illustrate how actors can utilize digital options in platform environments and provide decision support for specific scenarios, while they might also enable a transfer of knowledge to the general context of platform-based ecosystems.

6.2 Convergence with my Predecessors

My research is a joint product of working with colleagues at the Finance and Information Management (FIM) Research Center and the Project Group Business and Information Systems Engineering of the Fraunhofer Institute for Applied Information Technology (FIT).

I would like to point out how my research builds upon the previous work of these organizations. My research on cloud computing is grounded in several research papers that also consider cloud computing. Here I especially emphasize Dorsch and Häckel (2014), König (2014), and König et al. (2013). Besides this shared interest in cloud computing, my colleagues already analyzed a huge number of digital options. The path for my research has especially been set by Buhl et al. (2016), Rieger et al. (2016), Fridgen et al. (2016), and Dorsch (2015). There are also a lot of predecessors in the context of IT governance. I'd especially like to emphasize Buhl et al. (2013), Fridgen et al. (2015), Fridgen and Müller (2009), Fridgen and Müller (2011), Urbach and Würz (2012), Urbach et al. (2013), and Zare-Garizy et al. (2018). My doctoral thesis, and especially also Keller et al. (2018b) contributes to a young research stream on platform-based ecosystems, started with the SynErgie project. First publications are Bauer et al. (2017) and Schott et al. (2018), for instance. Many, other research papers are in progress, but not published yet.

6.3 Limitations

The doctoral thesis covers selected aspects of cloud computing, platform-based ecosystems, and IT-governance and contributes new insight relevant to the platform-based ecosystems research domain. However, the results might lack an easy transferability to other platform-based ecosystems. Further, the selected digital options might not represent all kinds of digital options in platform-based ecosystems. Besides these general limitations, the individual research papers also have limitations that need to be mentioned:

Regarding Keller and König (2014), cloud computing has proven to be a highly dynamic ecosystem. Many new actors and roles emerged and vanished again. Therefore, the research results on actors in cloud networks might similarly change in future, and thus will require constant questioning and adjustment. Further, the paper only depicts one real-world example that illustrates the application of the reference model. To collect relevant information is time-consuming, so that applying the reference model more widely might be challenging for researchers and practitioners.

Regarding Keller et al. (2018b), current regulatory frameworks are undergoing change in many countries. Thus, new requirements but also new digital options could be introduced in the near future. The respective designs for power flexibility platforms must be adapted accordingly. Further, the evaluation of our action design research approach involved German companies only. We consulted with European contacts, yet we did not work through all the details of other countries' flexibility markets. Lastly, as the SynErgie research project is still ongoing, we did not perform large scale tests in real world scenarios. Thus, we did not consider all possible market dynamics and their implications for the design of the power flexibility platform. Furthermore, new decentralized approaches may have a strong influence on platform-based ecosystems. Therefore, future research should evaluate the impact new approaches have on the illustrated preliminary design principles.

Regarding Keller et al. (2019), our modeling approaches have some rather technical limitations that could be addressed in future research. First, the research approach demands a normal distribution of returns, which does not necessarily hold true for cloud spot prices. Second, anomalies such as technical issues at the cloud provider might cause immediate and unpredictable price movements (*spikes*) that our stochastic process cannot predict. Third, for reasons of avoiding complexity, we limit our research to discrete-time models, although analytical approximations or numerical solutions for continuous-time models, and therefore decision making, would offer more flexibility of action. Fourth, we limit our discrete-time models to extensions of Cox et al. (1979) and Tian (1993). Additionally, the approach does not consider the bids of other participants in the spot markets, which future research might also take into consideration for an improved understanding of cloud spot markets.

Regarding Keller et al. (2018a) and Keller (2016), we found little earlier scientific literature concerning the management of cloud providers and risk management strategies in cloud networks. Thus, our literature review includes papers from more general topics such as cloud computing, IT-outsourcing, and IT-management. For Keller et al. (2018a), this study we conducted seven interviews with nine experts from six companies. However, the interview partners are all situated in Germany, so that we might have a cultural bias in our evaluation. Only scratching the surface of the research topic, the research stream of Keller (2016) requires in-depth academic research.

6.4 Implications for Researchers and Future Research

In general, the doctoral thesis contributes to the understanding of cloud computing as a platform-based ecosystem. It confirms existing theory on platform-based ecosystems in the context of cloud networks. As indicated in the conclusion, the doctoral thesis also contributes to several already proposed research items. Also, the collected papers provide additional insights that might be taken further on future research.

By providing a taxonomy of actors and risks in cloud networks, Keller and König (2014) provides a solid foundation for future research on cloud networks and lays the foundation for the doctoral thesis a whole. The identified causalities between hazards, risks, and reinforcers and the identified dissemination of risk modeled as a semi-formal diagram forms a basis for future research on cloud networks. The instantiation of real-world cloud networks might contribute to the thread modelling and provide insights for risk management. In line with de Reuver et al. (2018), these instantiations can support data-driven approaches and research approaches regarding platform-based ecosystems. The simulation of cloud networks might contribute to risk quantification or the identification of key actors, for instance. The manifesting structures in cloud networks also seek the identification of patterns that generalize the interaction between actors. Finally, the general role of cloud computing regarding the emergence of digital ecosystems is still few researched.

With the analysis of illustrative digital options in cloud networks, I add insights to a relatively new research domain. The opportunities enabled by cloud networks are manifold, and the present work illustrates only two specific cases. Besides those cases, cloud computing enables various other digital options, such as cloud bursting (Lilienthal 2013), which enables the extension of limited internal IT-resources by cloud computing, or the coupling of cloud resources with power to spatially shift power (Fridgen et al. 2017).

The doctoral thesis also contributes to the research on the emergence of platform-based ecosystems. I illustrate how cloud networks can provide a platform that enables an ecosystem for power flexibility exchange. Yet, the example I introduce has a narrow scope. Although the illustrated preliminary design principles provide new insight regarding multisided platforms in power markets and may guide future research as well as practical instantiations, I analyzed only one specific case. Future research should compare this case to other known cases such as mobile platforms or mobility platforms enabled by cloud networks.

Further, carrying forward the research of the SynErgie project might provide valuable insight for theory and practice by providing data for data-driven research approaches (de Reuver et al. 2018). The current version of the preliminary design principles only addresses the context of industrial power consumers. Researchers might analyze the transferability of the preliminary design principles to the context of non-industrial power consumers, e.g., districts. The illustrated multisided platform is a basis for other related research, e.g., understanding the ecosystem, the design of economic principles, market design, or trading-agent concepts to utilize an organization's flexibility subject to ecological or economic objectives. Thus, as proposed by de Reuver et al. (2018), researchers can analyze new ways of interacting within the existing power ecosystem. Besides the extension of these two examples, researchers might also analyze other digital options (such as new business models emerging through cloud networks, or similarities of digital options provided by cloud networks to other ecosystems), and from various perspectives (such as those of the provider or customer).

In Keller et al. (2019), we analyzed cases that provide insight into the utilization of temporal flexibility on cloud spot markets and transfer the real options approach from other domains to the context of cloud services. Other research indicates that there are other cloud spot instances that exhibit higher return volatilities (Ekwe-Ekwe and Barker 2018) and therefore higher savings potential than the one referred to in our data set. Therefore, future research could analyze and compare different cloud spot instances to identify promising application scenarios for our ROA. Further, we expect return volatilities on multiple cloud spot markets to increase in future. Owing to the rapid standardization of cloud services, market structures tend to promote liberalization. The occurrence of additional cloud providers offering spot prices will increase competition and liquidity on the supply side. On the demand side, new trends like cloud bursting, which prevent peak load in companies' data centers by adding external cloud resources (Lilienthal 2013), will increase demand for cloud services. Therefore, trading volumes grow, which, in turn, raise return volatility (Wang and Yau 2000). Besides temporal flexibility, cloud customers could also exploit their spatial flexibility as prices of cloud services still lack liquidity and are not necessarily arbitrage-free between comparable services from different providers and locations (Cheng et al. 2016). Due to influencing factors such as home bias, prices differ between regions and cloud customers might buy and sell cloud capacity to exploit this situation.

Thus, future research could integrate optimization of temporal and spatial flexibility. Other approaches taken in finance, such as portfolio theory, can provide suitable theory to address the identified price differences.

The IT-governance frameworks for cloud networks proposed in Section 5 (i.e., risk management and provider management), contribute to the domains of IT-governance and IT-outsourcing. They represent comprehensive artifacts, which are applicable in the operational management of cloud service providers. Researchers could implement the proposed frameworks in real-world cases and thereby generate new insight that will improve the illustrated frameworks. However, before applying the models in real-world scenarios, researcher should perform a quantitative test of the applicability of the presented frameworks, for instance by surveying a larger sample of customers and cloud service providers. Thereby, I will test management processes within the frameworks for interdependencies (e.g., how appropriate relationship management influences threats during the risk management). Further, the interviewees in Paper IV described their desired next steps toward a holistic governance framework. They suggested an extension by more strategic questions on issues such as determining suitable services for cloud sourcing or support for prioritizing processes with regard to limited capacity. Researchers could address these questions by developing artifacts, e.g., a maturity model, on the basis of our framework. Such artifacts might contribute to the research demand on how internal architecture and governance influence the evolutionary actors in platform settings (Tiwana et al. 2010). Finally, the illustrated network perspective on cloud computing enables the transfer of network theory. Centrality measures can enable the identification of key actors in cloud networks from a value-adding, as well as from a risk perspective. This analysis could enable the valuation of actors in the ecosystem or the ecosystem as a whole. Finally, researchers might analyze how companies can strategize and take up digital options provided by cloud networks and provide generalized guidance to practitioners.

For the general context of platform-based ecosystem research, de Reuver et al. (2018) also call for research on the scoping of platforms on “different architectural levels and in different industry settings” and to “advance methodological rigor by employing embedded case studies, longitudinal studies, design research, data-driven modelling and visualization techniques” (de Reuver et al. 2018, p. 124). Many emerging platforms can provide insight in the emergence and the operation of platform-based ecosystems and contribute to those research items. Such insights could result in improved theory for platform-based ecosystems.

6.5 Guidance and Implications for Practitioners

As cloud computing is a fairly new paradigm of IT sourcing, there are no well-tried governance principles, especially regarding the network perspective of cloud computing. None of the existing risk management frameworks considers the network perspective of cloud computing. As consequence, the state of the art cloud risk management is incomplete, and companies are unable to monitor and address all of the existing and possibly intensified risks. This problem is not unique to cloud networks. Even in supply chain networks or the financial industry, dependencies between actors or assets are sometimes unclear. Until now, the advantage of cloud networks is their limited depth. Therefore, there is an opportunity for implementing applicable governance structures.

Regarding digital options, the doctoral thesis illustrates the implementation of two cases. Similar to researchers, cloud customers and service providers can integrate the proposed real options analysis in decision support systems to realize their cost savings potential enabled by their temporal flexibility. If a cloud customer intends to apply our real options analysis algorithms, for instance, within their on-premise job scheduler for batch processes, they need to identify suitable computation jobs for deferral (e.g., training machine learning models). Moreover, job schedulers must integrate a respective cloud service provider's application programming interface (e.g., Query API for Amazon EC2, or the Amazon Web Services Software Development Kit) to automatically compare spot prices and the job backlog. This will allow optimal decision-making on which jobs should be outsourced to the cloud service provider, and at which time, considering external conditions such as service level agreements with customers. Further, the doctoral thesis provides an understanding of power flexibility markets and the respective ecosystems companies can utilize. The illustrated preliminary design principles provide guidance for similar platform-based ecosystems. The illustrated digital options might also serve as a blueprint for practitioners on how to detect and utilize digital options in general.

Regarding provider management in companies, the results of this work will be especially important for companies planning to capitalize on the cloud technology and who are still inexperienced in the cloud domain. The distinction between commodity and specialized cloud service providers, as well as the derived managerial implications will help companies successfully access and use cloud technologies. Also, from the perspective of a cloud service provider, our framework helps to identify crucial points for cloud providers within the service delivery process. Hence, the quality of the service delivery process increases, and the customer satisfaction is likely to rise. In general, the framework provides a starting point for organizations to manage cloud service providers. We spell out the managerial implications for how to manage cloud computing providers from the pre-contract to post-contract stage. Moreover, the managerial implications' differentiation into specialized and commodity cloud service providers helps customers to keep an eye on all relevant, but different digital options and challenges.

To conclude, the doctoral thesis contributes to the knowledge base on cloud computing and platform-based ecosystems. Thus, it covers recent trends in BISE research while also providing valuable insights for practitioners.

7 Appendix

7.1 Declaration of Co-authorship and Individual Contribution

Research is teamwork. Nowadays, research papers generally originate from the contributions of more than one author. The five research papers included in this doctoral thesis were compiled in various research settings and in collaboration with colleagues. To assess my contribution to each of the research projects, I shall describe the respective settings.

I developed Paper I, Keller and König (2014), which forms the foundation of the doctoral thesis, cooperating with a second author. As this was my first research project, I was the less experienced researcher, thus my co-author guided the design and writing process. However, I developed the initial idea of the research project. With my co-author's guidance, I was able to engage intensively with the required methodology (taxonomy, reference model, design science) to carry out the study and achieve academic results. My own contribution to the research project accounts for the literature analysis and the data collection in real-world settings. Further, I developed a first draft of the artifact (i.e., the taxonomies and the reference model), which we subsequently discussed and improved. I also prepared the questionnaire for our semi-structured interviews which my co-author and I performed jointly. Thus, the co-authors contributed equally to the paper's conception, elaboration and execution.

Paper II, Keller et al. (2018b), had a different setting. In this research project, building on my experience, I was especially involved in delineating the applied action design research methodology and in conceptualizing the research design. Furthermore, I provided my knowledge on as well as literature related to IT platforms. My co-authors especially complemented the research project with their knowledge on and literature related to power markets and provided an initial draft of the preliminary design principles. One co-author and I attended the publicly funded research project SynErgie which is subject of our research. Hereby, we collected the relevant data. We contributed jointly and equally to carrying out the preliminary design principles, also elaborating the paper's structure and content. Thus, the two co-authors equally contributed to the paper's conception, elaboration and execution.

For Paper III, Keller et al. (2019), we brought together a relatively experienced team. All researchers had already published and contributed from their experience in complementary domains. In sharing our knowledge, we jointly elaborated the idea on which the paper was based. My contribution relied particularly on my knowledge of cloud computing and spot markets. Also, I formulated our hypotheses and did the statistical testing. Further, one co-author and I carried out an extensive literature research on forecasting cloud spot markets. My co-authors contributed their extensive knowledge on real options analysis, data processing and implementation, and the presentation of the research results. Similar to Paper I, we jointly and in equal measure conceptualized and elaborated the paper's structure and content. Thus, the first three co-authors contributed equally to the paper's conception, elaboration and execution.

In Paper IV, Keller et al. (2018a), once again in the role of an experienced researcher, I contributed my knowledge on cloud computing and cloud computing ecosystems and guided the methodical approach. My co-authors especially contributed with knowledge on strategic IT management, as well as their knowledge on interview analysis. Furthermore, one co-author set up an initial draft of the artifact and conducted and transcribed the interviews. My co-authors and I further developed the artifact and we jointly conceptualized and elaborated the paper's structure and content. Thus, the first authors contributed equally to the paper's conception, elaboration and execution.

I developed and wrote Paper V, Keller (2016), entirely on my own. I tried to aggregate my knowledge on cloud networks and provide managerial guidance for practitioners on the basis of my scientific results.

7.2 Publications and Working Papers Relevant for the Doctoral Thesis

7.2.1 Paper I: A Reference Model to Support Risk Identification in Cloud Networks

Authors: Keller, R., and König, C.

Published in: Proceedings of the 35th International Conference on Information Systems, pp. 1–19, 2014.

Abstract

The rising adoption of cloud computing and increasing interconnections among its actors lead to the emergence of network-like structures and new associated risks. A major obstacle for addressing these risks is the lack of transparency concerning the underlying network structure and the dissemination of risks therein. Existing research does not consider the risk perspective in a cloud network's context. We address this research gap with the construction of a reference model that can display such networks and therefore supports risk identification. We evaluate the reference model through real-world examples and interviews with industry experts and demonstrate its applicability. The model provides a better understanding of cloud networks and causalities between related risks. These insights can be used to develop appropriate risk management strategies in cloud networks. The reference model sets a basis for future risk quantification approaches as well as for the design of (IT) tools for risk analysis.

7.2.2 Paper II: A Platform of Platforms and Services: Bringing Flexible Electricity Demand to the Markets

Authors: Keller, R., Schott, P., and Fridgen, G.

Submitted working paper.

Extended Abstract

The transition to renewable energy sources (RES) will continue to be a global challenge in coming decades. As an industrial nation, Germany is a leader in the development and uptake of RES which, in 2016, provided 31.7 % of Germany's gross electricity consumption (Federal Ministry for Economic Affairs and Energy 2017). Nevertheless, since a large share of RES can only be predicted to a limited extent, various measures are required to ensure the current grid stability (Appen et al. 2013).

Power flexibility might address this issue and offer participants two opportunities for monetarization: firstly, it enables power consumers to reduce the cost of the electricity they use by purchasing at times when prices are low. Secondly, consumers can generate revenues by providing system services to stabilize the power grid (Albadi and El-Saadany 2008). Alam et al. (2017) demonstrate that many markets provide possibilities for power flexibility. For instance, the electricity market in Germany comprises three different types of electricity trading: a derivative market, a spot market and over-the-counter-trading (Märkle-Huß et al. 2017). Due to the expansion of RES, the imbalance between power demand and supply, and thereby the resulting price spreads are increasing (Clò et al. 2015). Furthermore, new markets are emerging; most of them regional markets which aim to foster regional trading flexibility (Ilic et al. 2012). Yet, while new markets offer

increased revenue potential, companies connecting to these different markets face high transaction costs. Furthermore, some companies face technical and economic problems that prevent them from practising flexibility (Alcázar-Ortega et al. 2015). Next, market entrance barriers, such as regulatory aspects, may hinder companies aiming to increase their potential for flexibility (Alcázar-Ortega et al. 2015). These circumstances determine the need for a multi-sided platform (MSP) that would lead to greater transparency and thus facilitate the development of potential for flexibility in the power sector.

The German project *Synchronized and Energy-Adaptive Production Technology for the Flexible Adjustment of Manufacturing Processes to a Volatile Energy Supply* (SynErgie) considers how companies can make better use of their flexibility potential. To address this lack of transparency, the project team develops a meta-platform as MSP, which connects the flexibility potential of industrial companies to flexibility markets and supporting services. The meta-platform will be a MSP, that links three distinct sides (Bauer et al. 2017; Schott et al. 2018): the aforementioned markets, the internal power management of companies which allow companies to control and monitor their flexible processes, and supporting services – e.g., forecast services – which support participants in the commercialization of their flexibility. By linking these three distinct sides, the meta-platform in the role of a MSP enables, mediates, and facilitates communication as well as interaction between them. Thus, the meta-platform will reduce transaction costs.

This research paper provides insights into the design and development process of the project's prototype of the meta-platform. In line with action design research (ADR) approaches, we aim for the generalization of knowledge (Sein et al. 2011). Thus, we ask the following research question:

"What should be the preliminary design principles for a meta-platform that facilitates the monetarization of industrial flexibility on power markets?"

Since no meta-platform for the power ecosystem exists to date, our research process is inspired by Sein et al. (2011)'s ADR approach, which aims for the generation of design principles on basis of the development process of IT artifacts. Centering on the development of a prototype for the SynErgie meta-platform as IT artifact, this research approach is well suited for the problem domain. Developers and platform users provide frequent feedback, which can directly be taken into account in the design. Thus, we can consider the interplay between planned design and the context (i.e. stakeholders, technical realities, ...) of the meta-platform, and react with design changes. Nonetheless, the current version of the meta-platform is still a prototype, which is why we call our research results "preliminary design principles". In line with Sein et al. (2011)'s research approach, we relate our findings to a broader set of problems and to develop our preliminary design principles for meta-platforms that facilitate the monetarization of industrial flexibility on power markets. ADR produces IT artifacts that "*emerge from the contexts of both their initial design and continual redesign via organizational use*" (Sein et al. 2011, p. 52).

We identified generalized preliminary design principles. The design of the meta-platform aims to provide open integration, which will allow companies access to a variety of flexibility markets and to create cross-group network effects (Hagiu and Wright 2015). Furthermore, the design facilitates the use of supporting services. To enable interaction between the respective sides, our further developed preliminary design principle proposes a harmonized, traceable data model that describes the characteristics of power flexibility. The preliminary design principles also address security and regulatory requirements. By following those four design principles, our meta-platform can enable better decision making, reduce transaction costs, and provide more flexibility to the power ecosystem, and support the monetarization of flexibility.

In general, the illustrated preliminary design principles provide new insights to multi-sided platforms in energy markets and thus may guide future research as well as practical instantiations. Finally, we can state that multi-sided platforms likely contribute to a global energy transition.

7.2.3 Paper III: Data-Driven Decision Support on Temporal Flexibility of Cloud Computing Customers

Authors: Keller, R., Häfner, L., Sachs, T., and Fridgen, G.

Published in: Business & Information Systems Engineering, online first, 2019.

Abstract

The rapid standardization and specialization of cloud computing services have led to the development of cloud spot markets on which cloud service providers and customers can trade in near-real-time. Frequent changes in demand and supply give rise to spot prices that vary throughout the day. Cloud customers often possess temporal flexibility in executing their jobs up to an individual deadline. In this paper, we apply real options analysis (ROA), which is an established valuation method designed to capture according flexibility of action under uncertainty. We adapt and compare multiple discrete-time approaches that enable cloud customers to quantify and exploit the monetary value of short-term temporal flexibility. We contribute to literature by guaranteeing cloud job execution on variable-time requests in a single cloud spot market, whereas existing multi-market strategies may not fulfill requests when outbid. Analyzing a large set of example scenarios for the use of Amazon EC2 spot instances, we demonstrate that our approaches exploit existing savings potential to a considerable extent of up to 40 percent. Moreover, we demonstrate that ROA which explicitly considers time-of-day-specific spot price patterns outperforms traditional option pricing models and expectation optimization.

7.2.4 Paper IV: Keeping Control in the Cloud – Developing and Validating a Framework for Managing Cloud Computing Providers

Authors: Keller, R., Oesterle, S., Urbach, N., and Xin, Y.

Submitted working paper.

Extended Abstract

Over the past decades, cloud computing has emerged as a technological concept, changing the fundamental characteristics of IT service provisioning (Buyya et al. 2009). IT managers have quickly recognized the opportunities at hand, and thus, cloud computing adoption increased (Everest Group 2013). Public cloud services play a particular role in this context, because they allow companies to access high-end IT services without requiring high initial investment (Marston et al. 2011) and can "respond quickly to changing capacity requirements" (Repschläger et al. 2012, p. 6). Thus, the management of cloud computing providers has become a critical success factor for clients and the management of business relationships with cloud providers more and more important.

The development from the traditional IT outsourcing to the cloud sourcing era has radically changed client-provider relationships (Huntgeburth 2015; Willcocks et al. 2012). While clients usually have the control over the underlying resources in private cloud scenarios (Mell and Grance 2011), provider management becomes especially relevant in public and hybrid cloud scenarios in which clients obtain cloud services that run on infrastructure and systems operated by the cloud service provider. Although some approaches for specific aspects of cloud provider

management already exist (Armbrust et al. 2010; Garrison et al. 2012; Marston et al. 2011; Subashini and Kavitha 2011; Vithayathil 2018), we have not identified a holistic model that addresses all phases from pre-contract to post-contract. Furthermore, existing approaches do not consider the specific realities of specialized and standardized cloud products.

Addressing this research gap, we have two research objectives: (1) to strengthen the scientific discourse on managing relationships between providers and clients, we structure the existing knowledge of managing cloud computing providers, and (2) to support practitioners in governing their cloud provider relationships, we provide management suggestions.

To structure our research, we follow the design science approach (Gregor and Hevner 2013; Hevner 2007; Hevner and Chatterjee 2010) and its application in IT outsourcing research (Urbach and Würz 2012). In this paper, we develop an artifact grounded in the existing knowledge base and evaluate its practical applicability. Based on a literature review as theoretical foundation (Webster and Watson 2002), we developed the framework's initial version. We then discussed our initial framework with other researches, and subsequently, evaluated the framework by interviewing nine subject-matter experts from six companies by conducting semi-structured interviews. In several rounds, we challenged and refined our cloud-provider management framework until the design of the artifact met the evaluation objectives Hevner (2007).

The paper presents a holistic cloud service provider management process framework for companies. To guide clients in management of cloud service provider relationships, we differentiate between commodity CSPs, especially in the context of infrastructure services, and specialized CSPs, especially in the context of software services. Furthermore, the framework distinguishes the CSP management processes into seven primary and two secondary processes with respective sub-processes as illustrated in the following figure.

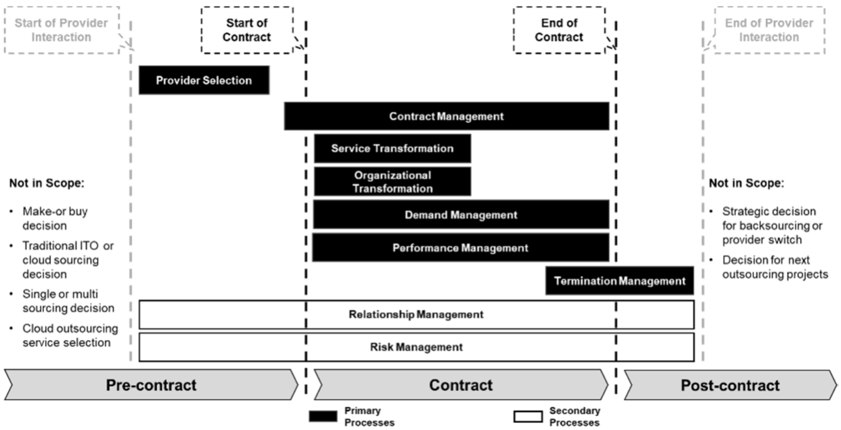

Figure 7: CSP management framework

The primary processes include the day-to-day management areas of cloud service providers. During these processes, clients either directly engage in interactions with the CSP or they will monitor the CSP's actions. Secondary processes, on the other hand, are support processes in terms of relational and risk management aspects. Decision makers must consider these processes in every primary process and thus support their execution.

Overall, the developed CSP management provides insights for theory and practice. From the theoretical perspective, the developed framework contributes to the domains of IT outsourcing and cloud computing research. It represents a comprehensive artifact applicable in the operational management of CSPs. By pointing out management processes throughout the cloud sourcing process, the present study deepens the understanding of cloud sourcing relationships and the successful management. From a practical point of view, the results of this work will be especially important for companies planning to capitalize on the cloud technology and are still quite inexperienced in the cloud domain. In particular, the distinction between commodity and specialized CSPs as well as the derived managerial implications will help companies successfully access and use cloud technologies. Also, from the perspective of a CSP, our framework helps to identify crucial points for cloud providers within the service delivery process. Based on our identified crucial management processes within the CSP framework, specialized as well as commodity CSPs are able to solve potential problems before they occur. Hence, the quality of the service delivery process increases, and the client satisfaction rises. In general, the framework provides a starting point for organizations to manage CSPs. Managerial implications are given on how to manage cloud computing providers from pre-contract to post-contract. Moreover, the managerial implications' differentiation into specialized and commodity CSPs helps clients to keep an eye on all relevant but different aspects and challenges.

Paper V: Analyse von Risikomanagementstrategien in Cloudnetzwerken – Was tun bei verknüpften, voneinander abhängigen Cloud Services?

Author: Keller, R.

Published in: HMD Praxis der Wirtschaftsinformatik (53:5), pp. 674–687, 2016.

Abstract

Cloud Services nutzen zunehmend andere Cloud Services zur Leistungserstellung. Dies führt zu einer immer stärkeren Vernetzung und komplexen Abhängigkeitsstrukturen, in denen Risiken zwischen den Anbietern übertragen werden können. Vor diesem Hintergrund soll sowohl strukturiert als auch anhand von Beispielen aufgezeigt werden, welche Rollen Unternehmen in Cloudnetzwerken einnehmen und welche Risiken auf sie wirken können. Um den aufgezeigten, netzwerkspezifischen Risiken begegnen zu können, gibt es in anderen Branchen, wie z. B. dem Supply Chain Management oder der Finanzbranche, bereits verschiedene Risikomanagementstrategien. Es soll eine Abschätzung darüber abgegeben werden, in wieweit sich diese und bekannte IT-spezifische Risikomanagementstrategien zur Adressierung der Risiken in Cloudnetzwerken eignen. Abschließend sollen konkrete Maßnahmen zur Anwendung in Unternehmen abgeleitet werden.

7.3 Other Publications

Journals

Fridgen, G., Keller, R., Thimmel, M., and Wederhake L. 2017. "Shifting load through space – the economics of spatial demand side management using distributed data centers," *Energy Policy* (109), pp. 400-413. (VHB Jourqual 3: B, 2017 Impact Factor: 4.0)

Schott, P., Ahrens, R., Bauer, D., Hering, F., Keller, R., Pullmann, J., Schel, D., Schimmelpfennig, J., Simon, P., Weber, T., Abele, E., Bauernhansl, T., Fridgen, G., Jarke, M., and Reinhart, G. 2018. "Flexible IT Platform for Synchronizing Energy Demands with Volatile Markets," *it - Information Technology* (60:3), pp.155-164. (VHB Jourqual 3: -, 2017 Impact Factor: -)

Bauer, D., Abele, E., Ahrens, R., Bauernhansl, T., Fridgen, G., Jarke, M., Keller, F., Keller, R., Pullmann, J., Reiners, R., Reinhart, G., Schel, D., Schöpf, M., Schraml, P., and Simon, P. 2017. "Flexible IT-platform to Synchronize Energy Demands with Volatile Markets," *Procedia CIRP* (63), pp. 318-323. (VHB Jourqual 3: -, 2017 Impact Factor: -)

Keller, R. and Berlage, T. 2016. "FIT für die Zukunft," *Laborjournal* (2016:01), pp. 64-65. (VHB Jourqual 3: -, Impact Factor: -)

Afflerbach, P., Fridgen G., Keller, R., Rathgeber, A., and Strobel F. 2014. "The By-Product Effect on Metal Markets – New Insights to the Price Behavior of Minor Metals," *Resources Policy*, (42:1), pp. 35-44. (VHB Jourqual 3: -, 2017 Impact Factor: 2.7)

Conferences

Keller, R., Röhrich, F., Schmidt, L., and Fridgen, G. 2019. "Sustainability's Coming Home: Preliminary Design Principles for the Sustainable Smart District," *Accepted for publication in Proceedings of the 14th International Conference on Wirtschaftsinformatik*. (VHB Jourqual 3: C, 2017 Impact Factor: -)

Unterberger, E., Buhl, H.U., Häfner, L., Keller, F., Keller, R., Ober, S., Paulick-Thiel, C., Reinhart, G., Schöpf, M., and Simon, P. 2017. "The regional and social impact of energy flexible factories," *Proceedings of the 5th Global Conference on Sustainable Manufacturing*. (VHB Jourqual 3: -, 2017 Impact Factor: -)

Fridgen, G., Keller, R., Thimmel, M., and Wederhake L. 2015. "Virtualizing Balancing Power: An Energy-Aware Load Dispatcher for Cloud Computing," *Energy Informatics & Management*. (VHB Jourqual 3: -, Impact Factor: -)

Bookchapters

Duelli, C., Keller, R., Manderscheid, J., Manntz, A., Röglinger, M., and Schmidt, M. 2017. "Enabling Flexible Laboratory Processes – Designing the Laboratory Information System of the Future," *Business Process Management Cases*. (VHB Jourqual 3: -, 2017 Impact Factor: -)

References

Adelmeyer, M., and Teuteberg, F. 2018. “Cloud Computing Adoption in Critical Infrastructures-Status Quo and Elements of a Research Agenda,” in *Proceedings of the Multikonferenz Wirtschaftsinformatik 2018*, pp. 1345–1356.

Adner, R. 2017. “Ecosystem as Structure: An Actionable Construct for Strategy,” *Journal of Management* (43:1), pp. 39–58.

Al Zain, M. A., Pardede, E., Soh, B., and Thom, J. A. 2012. “Cloud Computing Security: From Single to Multi-clouds,” in *Proceedings of the 45th Hawaii International Conference on Service Systems*, pp. 5490–5499.

Alam, F., Alam, Q., Reza, S., Khurshid-ul-Alam, S. M., Saleque, K., and Chowdhury, H. 2017. “Regional Power Trading and Energy Exchange Platforms,” *Energy Procedia* (110), pp. 592–596.

Albadi, M. H., and El-Saadany, E. F. 2008. “A summary of demand response in electricity markets,” *Electric Power Systems Research* (78:11), pp. 1989–1996.

Alcázar-Ortega, M., Calpe, C., Theisen, T., and Carbonell-Carretero, J. F. 2015. “Methodology for the identification, evaluation and prioritization of market handicaps which prevent the implementation of Demand Response: Application to European electricity markets,” *Energy Policy* (86), pp. 529–543.

Ali, M., Khan, S. U., and Vasilakos, A. V. 2015. “Security in cloud computing: Opportunities and challenges,” *Information Sciences* (305), pp. 357–383.

Amazon 2018. https://aws.amazon.com/de/solutions/case-studies/?nc2=h_ql_c&awsm=ql-8. Accessed 28 June 2018.

Amram, M., and Kulatilaka, N. 1999. *Real options*: *Managing strategic investment in an uncertain world*, Boston: Harvard Business School Press.

Appen, J. von, Braun, M., Stetz, T., Diwold, K., and Geibel, D. 2013. "Time in the Sun: The Challenge of High PV Penetration in the German Electric Grid," *IEEE power and energy magazine* (11:2), pp. 55–64.

Armbrust, M., Stoica, I., Zaharia, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R., Konwinski, A., Lee, G., Patterson, D., and Rabkin, A. 2010. "A view of cloud computing," *Communications of the ACM* (53:4), pp. 50–58.

Aubert, B. A., Patry, M., and Rivard, S. 2002. "Managing IT Outsourcing Risk: Lessons Learned," in *Information Systems Outsourcing*: *Enduring Themes, Emergent Patterns and Future Directions*, R. A. Hirschheim, A. Heinzl and J. Dibbern (eds.), Heidelberg: Springer, pp. 155–176.

Bacharach, S. B. 1989. "Organizational Theories: Some Criteria for Evaluation," *Academy of Management Review* (14:4), pp. 496–515.

Balaji, S., and Brown, S. A. 2005. "Strategic IS Sourcing and Dynamic Capabilities: Bridging the Gap," in *Proceedings of the 38th Annual Hawaii International Conference on System Sciences*, 1-8.

Barrett, M., Davidson, E., Fayard, A.-L., Vargo, S., and Yoo, Y. 2012. "Being Innovative About Service Innovation: Service, Design and Digitalization," in *Proceedings of the 33th International Conference on Information Systems*, pp. 433–438.

Bauer, D., Abele, E., Ahrens, R., Bauernhansl, T., Fridgen, G., Jarke, M., Keller, F., Keller, R., Pullmann, J., Reiners, R., Reinhart, G., Schel, D., Schöpf, M., Schraml, P., and Simon, P. 2017. "Flexible IT-platform to Synchronize Energy Demands with Volatile Markets," *Procedia CIRP* (63), pp. 318–323.

Beer, M., Meier, M. C., Mosig, B., and Probst, F. 2014. "A prototype for information-dense it project risk reporting. An action design research approach.," in *Proceedings of the 47th Hawaii International Conference on System Science*, pp. 3657–3666.

Beloglazov, A., and Buyya, R. 2010. "Energy Efficient Resource Management in Virtualized Cloud Data Centers," in *10th International Conference on Cluster, Cloud and Grid Computing*, pp. 826–831.

Benaroch, M., and Kauffman, R. J. 1999. "A Case for Using Real Options Pricing Analysis to Evaluate Information Technology Project Investments," *Information Systems Research* (10:1), pp. 70–86.

Ben-Yehuda, O. A., Ben-Yehuda, M., Schuster, A., and Tsafrir, D. 2013. "Deconstructing Amazon EC2 Spot Instance Pricing," *ACM Transactions on Economics and Computation* (1:3), pp. 1–20.

Berman, S. J., Kesterson-Townes, L., Marshall, A., and Srivathsa, R. 2012. "How cloud computing enables process and business model innovation," *Strategy & Leadership* (40:4), pp. 27–35.

Böhm, M., Koleva, G., Leimeister, S., Riedl, C., and Krcmar, H. 2010. "Towards a Generic Value Network for Cloud Computing," in *7th International Workshop on the Economics of Grids, Clouds, Systems, and Services*, pp. 129–140.

Boley, H., and Chang, E. 2007. "Digital Ecosystems: Principles and Semantics," in *Digital Ecosystems and Technologies Conference*, pp. 398–403.

Bote-Lorenzo, M. L., Dimitriadis, Y. A., and Gómez-Sánchez, E. 2004. "Grid Characteristics and Uses: A Grid Definition," in *Grid computing: first European Across Grids Conference*, pp. 291–298.

Briscoe, G., and de Wilde, P. 2006. "Digital Ecosystems: Evolving Service-Oriented Architectures," in *Proceedings of the 1st international conference on Bio inspired models of network, information and computing systems*, pp. 1–7.

Buhl, H. U., Fridgen, G., and König, C. 2013. "Using financial derivatives to hedge against market risks in IT outsourcing projects – a quantitative decision model," *Journal of Decision Systems* (22:4), pp. 249–264.

Buhl, H. U., Fridgen, G., König, W., Röglinger, M., and Wagner, C. 2012a. "Where's the competitive advantage in strategic information systems research? Making the case for boundary-spanning research based on the German business and information systems engineering tradition," *The Journal of Strategic Information Systems* (21:2), pp. 172–178.

Buhl, H. U., Häckel, B., Probst, F., and Schosser, J. 2016. "On the Ex Ante Valuation of IT Service Investments," *Business & Information Systems Engineering* (58:6), pp. 415–432.

Buhl, H. U., Müller, G., Fridgen, G., and Röglinger, M. 2012b. "Business and Information Systems Engineering: A Complementary Approach to Information Systems - What We Can Learn from the Past and May Conclude from Present Reflection on the Future.," *Journal of the Association for Information Systems* (13:4), pp. 236–253.

Butler, B. S., and Gray, P. H. 2006. "Reliability, Mindfulness, and Information Systems," *MIS Quarterly* (30:2), pp. 211–224.

Buyya, R., Yeo, C. S., and Venugopal, S. 2008. "Market-Oriented Cloud Computing: Vision, Hype, and Reality for Delivering IT Services as Computing Utilities," in *10th IEEE International Conference on High Performance Computing and Communications*, pp. 5–13.

Buyya, R., Yeo, C. S., Venugopal, S., Broberg, J., and Brandic, I. 2009. "Cloud Computing and Emerging IT Platforms: Vision, Hype, and Reality for Delivering Computing as the 5th Utility," *Future Generation Computer Systems* (25:6), pp. 599–616.

Carroll, J. M., and Swatman, P. A. 2000. "Structured-case: a methodological framework for building theory in information systems research," *European Journal of Information Systems* (9:4), pp. 235–242.

Ceccagnoli, M., Forman, C., Huang, P., and Wu, D. J. 2012. "Cocreation of Value in a Platform Ecosystem! The Case of Enterprise Software," *MIS Quarterly* (36:1), pp. 263–290.

Chaput, S. R., and Ringwood, K. 2010. "Cloud Compliance: A Framework for Using Cloud Computing in a Regulated World," in *Cloud computing: Principles, systems and applications*, N. Antonopoulos and L. Gillam (eds.), London: Springer, pp. 241–255.

Cheng, H. K., Li, Z., and Naranjo, A. 2016. "Research Note—Cloud Computing Spot Pricing Dynamics: Latency and Limits to Arbitrage," *Information Systems Research* (27:1), pp. 145–165.

Clarke, R. 2010. "Computing Clouds on the Horizon? Benefits and Risks from the User's Perspective," in *Proceedings of the 23rd BLED Conference*, pp. 569–590.

Clò, S., Cataldi, A., and Zoppoli, P. 2015. "The merit-order effect in the Italian power market: The impact of solar and wind generation on national wholesale electricity prices," *Energy Policy* (77), pp. 79–88.

Cloud Standards Consumer Council 2018. http://www.cloud-council.org/. Accessed 28 June 2018.

Coles, C. 2018. *Overview of Cloud Market in 2017 and Beyond*. https://www.skyhighnetworks.com/cloud-security-blog/microsoft-azure-closes-iaas-adoption-gap-with-amazon-aws/. Accessed 28 June 2018.

Cox, J. C., Ross, S. A., and Rubinstein, M. 1979. "Option pricing: A simplified approach," *Journal of Financial Economics* (7:3), pp. 229–263.

Cusumano, M. 2010. "Cloud computing and SaaS as new computing platforms," *Communications of the ACM* (53:4), pp. 27–29.

de Reuver, M., Sørensen, C., and Basole, R. C. 2018. "The digital platform: a research agenda," *Journal of Information Technology* (33:2), pp. 124–135.

Dillet, R. 2018. *Apple now relies on Google Cloud Platform and Amazon S3 for iCloud data*. https://techcrunch.com/2018/02/27/apple-now-relies-on-google-cloud-platform-and-amazon-s3-for-icloud-data/?guccounter=1. Accessed 28 June 2018.

Dorsch, C. 2015. "On the Sound Financial Valuation of Flexibility in Information Systems," *Business & Information Systems Engineering* (57:2), pp. 115–127.

Dorsch, C., and Häckel, B. 2014. "Combining models of capacity supply to handle volatile demand: The economic impact of surplus capacity in cloud service environments," *Decision Support Systems* (58), pp. 3–14.

Eisenmann, T., Parker, G., and van Alstyne, M. 2006. “Strategies for Two-Sided Markets,” *Harvard business review* (84:10), pp. 92–103.

Ekwe-Ekwe, N., and Barker, A. 2018. “Location, Location, Location: Exploring Amazon EC2 Spot Instance Pricing Across Geographical Regions,” in *International Symposium on Cluster, Cloud and Grid Computing*, pp. 370–373.

Etro, F. 2009. “The Economic Impact of Cloud Computing on Business Creation, Employment and Output in Europe,” *Review of Business and Economics* (54:2), pp. 179–208.

Everest Group 2013. *Enterprise Cloud Adoption Survey 2013: Summary of Results*. http://www.everestgrp.com/wp-content/uploads/2013/03/2013-Enterprise-Cloud-Adoption-Survey.pdf. Accessed 15 August 2018.

Fahmideh, M., Daneshgar, F., Rabhi, F., and Beydoun, G. 2018. “A generic cloud migration process model,” *European Journal of Information Systems* (35:6), pp. 1–23.

Federal Ministry for Economic Affairs and Energy 2017. “Renewable Energy Sources in Figures: National and International Development,” Berlin.

Figueres, C., Schellnhuber, H. J., Whiteman, G., Rockström, J., Hobley, A., and Rahmstorf, S. 2017. “Three years to safeguard our climate,” *Nature* (546:7660), pp. 593–595.

Floerecke, S., and Lehner, F. 2016. “Cloud Computing Ecosystem Model: Refinement and Evaluation,” in *Proceedings of the 24th European Conference on Information Systems*, pp. 1–14.

Foster, I., Zhao, Y., Raicu, I., and Lu, S. 2008. "Cloud Computing and Grid Computing 360-Degree Compared," in *IEEE Grid Computing Environments Workshop*, pp. 1–10.

Fridgen, G., Häfner, L., König, C., and Sachs, T. 2016. "Providing Utility to Utilities: The Value of Information Systems Enabled Flexibility in Electricity Consumption," *Journal of the Association for Information Systems* (17:8), pp. 537–563.

Fridgen, G., Keller, R., Thimmel, M., and Wederhake, L. 2017. "Shifting load through space–The economics of spatial demand side management using distributed data centers," *Energy Policy* (109), pp. 400–413.

Fridgen, G., Klier, J., Beer, M., and Wolf, T. 2015. "Improving Business Value Assurance in Large-Scale IT Projects—A Quantitative Method Based on Founded Requirements Assessment," *ACM Transactions on Management Information Systems* (5:3), pp. 1–17.

Fridgen, G., and Müller, H.-V. 2009. "Risk/Cost Valuation of Fixed Price IT Outsourcing in a Portfolio Context," in *Proceedings of the 30th International Conference on Information Systems*, pp. 1–17.

Fridgen, G., and Müller, H.-V. 2011. "An Approach for Portfolio Selection in Multi-Vendor IT Outsourcing," in *Proceedings of the 32nd International Conference on Information Systems*, pp. 1–13.

Garrison, G., Kim, S., and Wakefield, R. L. 2012. "Success factors for deploying cloud computing," *Communications of the ACM* (55:9), pp. 62–68.

Gawer, A. 2014. "Bridging differing perspectives on technological platforms: Toward an integrative framework," *Research Policy* (43:7), pp. 1239–1249.

Gawer, A., and Cusumano, M. A. 2014. "Industry Platforms and Ecosystem Innovation," *Journal of Product Innovation Management* (31:3), pp. 417–433.

Gimpel, H., and Röglinger, M. 2015. "Digital Transformation : Changes and Chances – Insights based on an Empirical Study," Project Group Business and Information Systems Engineering of the Fraunhofer Institute for Applied Information Technology FIT (ed.), Augsburg/Bayreuth.

Golden, W., and Powell, P. 2000. "Towards a definition of flexibility: in search of the Holy Grail?" *Omega* (28:4), pp. 373–384.

Google Trends 2018. https://trends.google.de/trends/explore?date=all&geo=DE&q=Cloud %20Computing. Accessed 15 October 2018.

Gregor, S. 2002. "A theory of theories in information systems," *Information Systems Foundations: building the theoretical base*, pp. 1–20.

Gregor, S. 2006. "The nature of theory in information systems," *MIS Quarterly* (30:3), pp. 611–642.

Gregor, S., and Hevner, A. R. 2013. "Positioning and Presenting Design Science Research for Maximum Impact," *MIS Quarterly* (37:2), pp. 337–355.

Hagiu, A., and Wright, J. 2015. "Multi-Sided Platforms," *International Journal of Industrial Organization* (43), pp. 162–174.

Hannah, D. P., and Eisenhardt, K. M. 2018. "How firms navigate cooperation and competition in nascent ecosystems," *Strategic Management Journal* (43:1), pp. 39–69.

Helfat, C. E., and Raubitschek, R. S. 2018. "Dynamic and integrative capabilities for profiting from innovation in digital platform-based ecosystems," *Research Policy* (47:8), pp. 1391–1399.

Henfridsson, O., and Bygstad, B. 2013. "The Generative Mechanisms of Digital Infrastructure Evolution," *MIS Quarterly* (37:3), pp. 907–931.

Hevner, A. R. 2007. "A Three Cycle View of Design Science Research," *Scandinavian Journal of Information Systems* (19:2), pp. 87–92.

Hevner, A. R., and Chatterjee, S. 2010. "Design Science Research in Information Systems," *Integrated Series in Information Systems* (22), pp. 9–22.

Hevner, A. R., March, S. T., and Park, J. 2004. "Design Science in Information Systems Research," *MIS Quarterly* (28:1), pp. 75–105.

Hoefer, C. N., and Karagiannis, G. 2010. "Taxonomy of cloud computing services," in *2010 IEEE Globecom Workshops*, pp. 1345–1350.

Hoefer, C. N., and Karagiannis, G. 2011. "Cloud computing services: taxonomy and comparison," *Journal of Internet Services and Applications* (2:2), pp. 81–94.

Hon, W. K., Millard, C., and Walden, I. 2012. "Negotiating Cloud Contracts - Looking at Clouds from Both Sides Now," *Stanford Technology Law Review* (81), pp. 80–126.

Huntgeburth, J. 2015. *Developing and Evaluating a Cloud Service Relationship Theory*, Heidelberg: Springer.

Huntgeburth, J., Blaschke, M., and Hauff, S. 2015. "Exploring Value Co-Creation in Cloud Ecosystems - A Revelatory Case Study," *Proceedings of the 23rd European Conference on Information Systems*, pp. 1–16.

Ilic, D., Da Silva, P. G., Karnouskos, S., and Griesemer, M. 2012. "An energy market for trading electricity in smart grid neighbourhoods," in *6th*

IEEE International Conference on Digital Ecosystems Technologies, pp. 1–6.

Jansen, W. A. 2011. “Cloud Hooks: Security and Privacy Issues in Cloud Computing,” in *Proceedings of the 44th Hawaii International Conference on System Sciences*, pp. 1–10.

Javadi, B., Thulasiramy, R. K., and Buyya, R. 2011. “Statistical Modeling of Spot Instance Prices in Public Cloud Environments,” in *4th IEEE International Conference on Utility and Cloud Computing*, pp. 219–228.

Karunakaran, S., and Sundarraj, R. P. 2015. “Bidding Strategies for Spot Instances in Cloud Computing Markets,” *IEEE Internet Computing* (19:3), pp. 32–40.

Keller, R. 2016. “Analyse von Risikomanagementstrategien in Cloudnetzwerken – Was tun bei verknüpften, voneinander abhängigen Cloud Services?” *HMD Praxis der Wirtschaftsinformatik* (53:5), pp. 674–687.

Keller, R., Häfner, L., Sachs, T., and Fridgen, G. 2019. “Data-Driven Decision Support on Temporal Flexibility of Cloud Computing Customers,” *Business & Information Systems Engineering* (Forthcoming).

Keller, R., and König, C. 2014. “A Reference Model to Support Risk Identification in Cloud Networks,” in *Proceedings of the 35th International Conference on Information Systems*, pp. 1–19.

Keller, R., Oesterle, S., Urbach, N., and Xin, Y. 2018a. “Keeping Control in the Cloud – Developing and Validating a Framework for Managing Cloud Computing Providers,” Workingpaper.

Keller, R., Schott, P., and Fridgen, G. 2018b. "A Platform of Platforms and Services: Bringing Flexible Electricity Demand to the Markets," Workingpaper.

Kong, F., and Liu, X. 2015. "A Survey on Green-Energy-Aware Power Management for Datacenters," *ACM Computing Surveys* (47:2), pp. 1–38.

König, C. 2014. "Gestaltungsspielräume bei Cloud Computing Investitionen," *HMD Praxis der Wirtschaftsinformatik* (51:4), pp. 494–505.

König, C., Mette, P., and Müller, H.-V. 2013. "Multivendor Portfolio Strategies In Cloud Computing," in *Proceedings of the 21th European Conference on Information Systems*, pp. 1–12.

Lacity, M., and Willcocks, L. 2003. "IT sourcing reflections," *Business & Information Systems Engineering* (45:2), pp. 115–125.

Legner, C., Eymann, T., Hess, T., Matt, C., Böhmann, T., Drews, P., Mädche, A., Urbach, N., and Ahlemann, F. 2017. "Digitalization: Opportunity and Challenge for the Business and Information Systems Engineering Community," *Business & Information Systems Engineering* (59:4), pp. 301–308.

Leimeister, S., Böhm, M., Riedl, C., and Krcmar, H. 2010. "The Business Perspective of Cloud Computing: Actors, Roles and Value Networks," in *Proceedings of the 18th European Conference on Information Systems*, pp. 1–12.

Lilienthal, M. 2013. "A Decision Support Model for Cloud Bursting," *Business & Information Systems Engineering* (5:2), pp. 71–81.

Malladi, S., and Krishnan, M. 2012. "Cloud computing adoption and its implications for CIO strategic focus–an empirical analysis," in

Proceedings of the 33rd International Conference on Information Systems, pp. 1–19.

March, S. T., and Smith, G. F. 1995. “Design and natural science research on information technology,” *Decision Support Systems* (15:4), pp. 251–266.

March, S. T., and Storey, V. C. 2008. “Design Science in the Information Systems Discipline: An Introduction to the Special Issue on Design Science Research,” *MIS Quarterly* (32:4), pp. 725–730.

Marston, S., Li, Z., Bandyopadhyay, S., Zhang, J., and Ghalsasi, A. 2011. “Cloud computing — The business perspective,” *Decision Support Systems* (51:1), pp. 176–189.

Martens, B., and Teuteberg, F. 2011. “Risk and Compliance Management for Cloud Computing Services: Designing a Reference Model,” in *Proceedings of the 17th American Conference of Information Systems*, pp. 1–10.

Mell, P. M., and Grance, T. 2011. *The NIST definition of cloud computing*, Gaithersburg: National Institute of Standards and Technology.

Metcalfe, B. 1995. “Metcalfe's law: A network becomes more valuable as it reaches more users,” *Infoworld* (17:40), p. 53.

Moore, J. F. 1993. “Moore, James F. "Predators and prey: a new ecology of competition,” *Harvard business review* (71:3), pp. 75–86.

Moore, J. F. 1997. *The death of competition*: *Leadership and strategy in the age of business ecosystems*, New York, NY: Harper Business.

Moura, P. S., and de Almeida, A. T. 2010. “Multi-objective optimization of a mixed renewable system with demand-side management,” *Renewable and Sustainable Energy Reviews* (14:5), pp. 1461–1468.

Müller, B., and Urbach, N. 2017. "Understanding the Why, What, and How of Theories in IS Research," *Communications of the Association for Information Systems* (41), pp. 349–388.

Nickerson, R. C., Varshney, U., and Muntermann, J. 2013. "A method for taxonomy development and its application in information systems," *European Journal of Information Systems* (22:3), pp. 336–359.

Palensky, P., and Dietrich, D. 2011. "Demand side management: Demand response, intelligent energy systems, and smart loads," *IEEE transactions on industrial informatics* (7:3), pp. 381–388.

Papazoglou, M. P. 2003. "Service-oriented computing: concepts, characteristics and directions," in *Proceedings of the Fourth International Conference on Web Information Systems Engineering*, pp. 3–12.

Parker, G., van Alstyne, M., and Choudary, S. P. 2017a. *Platform revolution*: *How networked markets are transforming the economy - and how to make them work for you*, New York, London: W.W. Norton & Company.

Parker, G., van Alstyne, M., and Jiang, X. 2017b. "Platform Ecosystems: How Developers Invert the Firm," *MIS Quarterly* (41:1), pp. 255–266.

Peffers, K., Tuunanen, T., Rothenberger, M. A., and Chatterjee, S. 2007. "A Design Science Research Methodology for Information Systems Research," *Journal of Management Information Systems* (24:3), pp. 45–77.

Prasad, A., Green, P., and Heales, J. 2014. "On governance structures for the cloud computing services and assessing their effectiveness," *International Journal of Accounting Information Systems* (15:4), pp. 335–356.

Provan, K. G., and Kenis, P. 2007. "Modes of Network Governance: Structure, Management, and Effectiveness," *Journal of Public Administration Research and Theory* (18:2), pp. 229–252.

Repschläger, J., Zarnekow, R., Wind, S., and Turowski, K. 2012. "Cloud Requirements Framework: Requirements and Evaluation Criteria to Adopt Cloud Solutions," in *Proceedings of the 20th European Conference on Information Systems*, pp. 1–13.

Rieger, A., Thummert, R., Fridgen, G., Kahlen, M., and Ketter, W. 2016. "Estimating the benefits of cooperation in a residential microgrid: A data-driven approach," *Applied Energy* (180), pp. 130–141.

Rolland, K. H., Mathiassen, L., and Rai, A. 2018. "Managing Digital Platforms in User Organizations: The Interactions Between Digital Options and Digital Debt," *Information Systems Research* (29:2), pp. 419–443.

Ruzzier, J., Sohal, A. S., Katna, P., and Zyngier, S. 2008. "Success and failure in IT outsourcing by government agencies: two Australian case studies," *International Journal of Business Information Systems* (3:2), pp. 107–119.

Sambamurthy, V., Bharadwaj, A., and Grover, V. 2003. "Shaping Agility through Digital Options: Reconceptualizing the Role of Information Technology in Contemporary Firms," *MIS Quarterly* (27:2), pp. 237–263.

Schlagwein, D., and Thorogood, A. 2014. "Married for Life? A Cloud Computing Client–Provider Relationship Continuance Model," in *Proceedings of the 22nd European Conference on Information Systems*. 2014, pp. 1–9.

Schott, P., Ahrens, R., Bauer, D., Hering, F., Keller, R., Pullmann, J., Schel, D., Schimmelpfennig, J., Simon, P., Weber, T., Abele, E., Bauernhansl, T., Fridgen, G., Jarke, M., and Reinhart, G. 2018. "Flexible IT platform for synchronizing energy demands with volatile markets," *it - Information Technology* (60:3), pp. 155–164.

Schuette, R., and Rotthowe, T. 1998. "The Guidelines of Modeling – An Approach to Enhance the Quality in Information Models," in *Proceedings of the 17th International Conference on Conceptual Modeling*, pp. 240–254.

Sein, M. K., Henfridsson, O., Purao, S., Rossi, M., and Lindgren, R. 2011. "Action design research," *MIS Quarterly* (35:1), pp. 37–56.

Statista 2018. *B2B market volume from cloud computing services (SaaS, PaaS, IaaS) in Germany from 2011 to 2020.* https://www.statista.com/statistics/473256/revenues-from-cloud-computing-services-in-germany/. Accessed 28 June 2018.

Suarez, F. F., Cusumano, M., and Fine, C. 1995. "An Empirical Study of Flexibility in Manufacturing," *Sloan Management Review* (37:1), pp. 25–32.

Subashini, S., and Kavitha, V. 2011. "A survey on security issues in service delivery models of cloud computing," *Journal of Network and Computer Applications* (34:1), pp. 1–11.

Sutton, R. I., and Staw, B. M. 1995. "What Theory is Not," *Administrative Science Quarterly* (40:3), pp. 371–384.

Tang, S., Yuan, J., and Li, X.-Y. 2012. "Towards Optimal Bidding Strategy for Amazon EC2 Cloud Spot Instance," in *IEEE Fifth International Conference on Cloud Computing*, pp. 91–98.

Tian, Y. 1993. “A modified lattice approach to option pricing,” *Journal of Futures Markets* (13:5), pp. 563–577.

Tilson, D., Sorensen, C., and Lyytinen, K. 2012. “Change and Control Paradoxes in Mobile Infrastructure Innovation: The Android and iOS Mobile Operating Systems Cases,” in *Proceedings of the 45th Hawaii International Conference on System Science*, pp. 1324–1333.

Tiwana, A. 2014. *Platform ecosystems*: *Aligning architecture, governance, and strategy*, Waltham: Morgan Kaufmann.

Tiwana, A., Konsynski, B., and Bush, A. A. 2010. “Platform Evolution: Coevolution of Platform Architecture, Governance, and Environmental Dynamics,” *Information Systems Research* (21:4), pp. 675–687.

Trigeorgis, L. 2002. *Real options*: *Managerial flexibility and strategy in resource allocation*, Cambridge: MIT Press.

Troshani, I., Rampersad, G., and Wickramasinghe, N. 2011. “Cloud Nine? An Integrative Risk Management Framework for Cloud Computing,” in *Proceedings of the 24th BLED Conference*, pp. 15–26.

Urbach, N., Buchwald, A., and Ahlemann, F. 2013. “Understanding IT Governance Success And Its Impact: Results From An Interview Study,” in *Proceedings of the 21th European Conference on Information Systems*, pp. 1–12.

Urbach, N., and Würz, T. 2012. “How to Steer the IT Outsourcing Provider,” *Business & Information Systems Engineering* (4:5), pp. 247–259.

van Aken, J. E. 2007. “Design Science and Organization Development Interventions,” *The Journal of Applied Behavioral Science* (43:1), pp. 67–88.

van Alstyne, M., Parker, G., and Choudary, S. 2016. "Pipelines, platforms, and the new rules of strategy," *Harvard business review* (94:4), pp. 54–62.

Vaquero, L. M., Rodero-Merino, L., Caceres, J., and Lindner, M. 2008. "A break in the clouds," *ACM SIGCOMM Computer Communication Review* (39:1), pp. 50–55.

Vithayathil, J. 2018. "Will cloud computing make the Information Technology (IT) department obsolete?" *Information Systems Journal* (28:4), pp. 634–649.

vom Brocke, J., Simons, A., Niehaves, B., Reimer, K., Plattfaut, R., and Cleven, A. 2009. "Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process," in *Proceedings of the 17th European Conference on Information Systems*, pp. 2206–2217.

vom Brocke, J., and Thomas, O. 2006. "Designing Infrastructures for Reusing Conceptional Models – A General Framework and its Application for Collaborative Reference Modelling," in *Proceedings of the 9th International Conference on Business Information Systems*, pp. 501–514.

Wang, G. H. K., and Yau, J. 2000. "Trading volume, bid-ask spread, and price volatility in futures markets," *Journal of Futures Markets* (20:10), pp. 943–970.

Wang, S., Liu, Z., Sun, Q., Zou, H., and Yang, F. 2014. "Towards an accurate evaluation of quality of cloud service in service-oriented cloud computing," *Journal of Intelligent Manufacturing* (25:2), pp. 283–291.

Wareham, J. D., Fox, P. B., and Cano Giner, J. L. 2013. "Technology Ecosystem Governance," *Organization Science* (25:4), pp. 969–1286.

Watson, R. T., Boudreau, M.-C., and Chen, A. J. 2010. “Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS Community,” *MIS Quarterly* (34:1), pp. 23–38.

Weber, R. 2012. “Evaluating and developing theories in the information systems discipline,” *Journal of the Association for Information Systems* (13:1), pp. 1–30.

Webster, J., and Watson, R. T. 2002. “Analyzing the Past to Prepare for the Future: Writing a Literature Review,” *MIS Quarterly* (26:2), pp. 13–23.

Wei, Y., and Blake, M. B. 2010. “Service-Oriented Computing and Cloud Computing: Challenges and Opportunities,” *IEEE Internet Computing* (14:6), pp. 72–75.

Whetten, D. A. 1989. “What Constitutes a Theoretical Contribution?” *Academy of Management Review* (14:4), pp. 490–495.

Willcocks, L., Venters, W., and Whitley, E. 2012. “Cloud Sourcing: Implications for Managing the IT Function,” in *Proceedings of the 6th Global Sourcing Workshop*, pp. 142–163.

Woodard, C. J., Ramasubbu, N., Tschang, F. T., and Sambamurthy, V. 2013. “Design Capital and Design Moves: The Logic of Digital Business Strategy,” *MIS Quarterly* (37:2), pp. 537–564.

Zare-Garizy, T., Fridgen, G., and Wederhake, L. 2018. “A Privacy Preserving Approach to Collaborative Systemic Risk Identification: The Use-Case of Supply Chain Networks,” *Security and Communication Networks* (2018:6), pp. 1–18.

Zhang, Q., Cheng, L., and Boutaba, R. 2010. “Cloud computing: state-of-the-art and research challenges,” *Journal of Internet Services and Applications* (1:1), pp. 7–18.

Zhang, R., Shang, Y., and Zhang, S. 2014. “An Automatic Deployment Mechanism on Cloud Computing Platform,” in *IEEE 6th International Conference on Cloud Computing Technology and Science*, pp. 511–518.

Zissis, D., and Lekkas, D. 2012. “Addressing cloud computing security issues,” *Future Generation Computer Systems* (28:3), pp. 583–592.