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Exploring uncertainties in a marketplace for cloud computing: a revelatory case study

Sabrina Hauff · Jan Huntgeburth · Daniel Veit

Abstract Today, highly standardized information technology (IT) resources such as storage and processing power are becoming available and affordable to all. Therefore, IT managers evermore focus on reducing the costs and risks that these resources entail rather than on the benefits or competitive edge they provide. A marketplace for cloud computing represents a promising alternative for obtaining standardized IT resources in a highly flexible and scalable manner. Based on a revelatory case study of a cloud market project, we show that uncertainties are prevalent in cloud markets and that the principal-agent theory is an adequate perspective to study and explain these uncertainties. By triangulating data from formal and informal interviews, documentations and project meetings, we develop a second-level contextual understanding of uncertainties in the relationships between market operator, cloud providers and users. Our analysis reveals that while cloud market operators have capabilities to mitigate uncertainties between cloud provider and user, they also cause new uncertainties from the cloud provider and user perspective. As an outcome, we present a framework that sheds light on the uncertainty trade-offs involved in the decision to adopt a cloud market by cloud providers and users.

Keywords Cloud computing · e-Markets · Adoption · Case study · Uncertainty · Principal-agent theory

JEL Classification M15

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1 Introduction and motivation

Cloud computing causes fundamental changes within the IT industry and IT service delivery. Hence, it has received much attention in research and practice over the last years. Current trends show that the market for cloud computing has an immense potential: Gartner expects that the public cloud services market grows from 2012 to 2016 worldwide from $109 billion to $206.6 billion (Gartner 2012). The German Federal Association for Information Technology, Telecommunications and New Media (BITKOM) predicts a double-digit growth rate from 2012 to 2016 within the German cloud computing market, growing from 5.3 billion euro to 17.1 billion euro in 2016 (BITKOM 2012). Nonetheless, many researchers think that cloud computing is still in its infancy because challenges like data privacy, security management, virtual machine migration, or a market-oriented resource management have not yet received sufficient attention (Armbrust et al. 2010; Buyya et al. 2009b; Zhang et al. 2010).

A research topic that emerged only recently deals with the idea of an electronic marketplace (e-market) for cloud computing. Buyya et al. (2008) first introduced the concept of a cloud exchange that allows participants to locate cloud providers and users with an appropriate offer. Cloud providers can use marketplaces as additional sales channels to increase the utilization of their existing infrastructure. Cloud users can benefit from an improved price transparency and reduced search costs for suitable trading partners since a marketplace can preselect suitable providers based on a user's preferences and list them all clearly, to name but a few examples. However, though there is considerable research on e-market adoption examining the phenomena in various contexts—most of it focuses on studying e-markets in scenarios where tangible goods are traded (e.g., Chang and Wong 2010; Gengatharen and Standing 2005; Joo and Kim 2004; Quaddus and Hofmeyer 2007; Tao et al. 2007).

We believe that the motives for adopting a transparent, two sided and independently managed marketplace for cloud computing are partly distinct from those identified in previous research on e-markets. First of all, traditional economic market theories are not applicable in this context. Especially in economics, markets have been researched for a long time. They can provide an optimal allocation mechanism for supply and demand. This idea can be dated back to Smith (1937) who developed the idea of an "invisible hand" guiding an efficient resource allocation. Yet, theories about efficient markets only hold under certain simplifying conditions: full information transparency has to be given and all information has to be included in the market price, so that no uncertainties are prevalent (Malkiel and Fama 1970). Beyond these simplifying assumptions, markets are especially well working for highly standardized goods (Williamson 1985) and it has to be assumed that security and data privacy challenges are absent. Yet, these conditions are not given in a real-world cloud computing context, as various information asymmetries and uncertainties that arise from those asymmetries exist. We think that they can be largely attributed to the interesting characteristics of a cloud computing product which differentiate it from many traditional goods traded on marketplaces: As nowadays highly standardized IT

resources have become available and affordable to all, IT managers evermore focus on the risks and costs that these IT resources entail rather than on the benefits or competitive edge these computing resources can provide (Carr 2003). In cloud computing, vendor lock-in and non-availability of a service pose such risks and thus cause large obstacles in cloud computing adoption, for example. Besides that, when enterprises use a cloud product, they have to transfer their business data to the cloud which is under control of the provider. As remotely hosted data can never be fully protected against unauthorized access, additional uncertainties like privacy and security concerns can explain the reluctance of some organizations to engage in cloud computing (Armbrust et al. 2010). In consequence, the level of involvement and risk regarding cloud computing products is much higher than for tangible products or highly standardized services (e.g. electricity or package tours) traded on other marketplaces, where no massive amounts of data are transferred to third-party hosted infrastructures.

Thus, we propose that the success of a marketplace for cloud computing highly depends on the robustness of the marketplace's properties to manage uncertainties influencing the business relationship between providers and users. This implies especially that the way the marketplace operator designs, implements and operates the marketplace is critical for its success. Therefore, we focus on the research question: *How do uncertainties influence the decision to adopt either a transparent, two sided and independently managed marketplace or a direct provisioning mode for cloud computing*?

Overall, this paper is expected to make the following contributions to the literature on cloud computing. To our best knowledge, our study presents the first framework for understanding the uncertainty trade-offs involved in the decision to adopt a public, two sided and independently managed marketplace for large-scale, commoditized computing resources such as clouds. This framework extends previous research on e-markets by examining in-depth the uncertainties surrounding cloud markets and the way they influence the marketplace adoption decision from a cloud provider and user perspective. Thus, we provide a comprehensive picture which takes into account not only all participants, namely providers, users, as well as the marketplace operator, but also the various relationships between them and the uncertainties arising out of them. Drawing on principal-agent theory, we show that agency problems are prevalent in cloud markets and that their management is critical for the feasibility of a cloud market. From a practical perspective, our framework can be utilized to inform the design of a marketplace for cloud computing, e.g. using experience operating a public market from other domains.

The remaining parts of the paper are structured as follows. The next section positions the paper in the field by introducing the key concepts and the literature-based pre-understanding of the phenomenon. Section three presents the context of the study and gives a methodological overview of our revelatory case study. In section four, our results and interpretations are presented. Finally, the last section discusses the key findings, theoretical contributions, areas for future research and practical implications.

2 Theoretical foundation

2.1 Cloud computing: service and deployment model

Cloud computing is a global, distributed, service-centric model for delivering IT-based solutions which offers to users a new elasticity of resources without paying a premium for large scale (Bakos 1991). Cloud services provide computing resources in different levels of abstraction. Infrastructure-as-a-Service (IaaS) provides hardware resources like processing and storage. Platform-as-a-Service (PaaS) offers, in addition to the infrastructure, a cloud software development environment to build, test, and deploy cloud applications (Foster et al. 2008). Lastly, Software-as-a-Service (SaaS) provides complete applications running on cloud infrastructure which is completely managed and controlled by the provider. Next to these three well established service types, the term Everything-as-a-Service (XaaS) is often used as generalization to show that not only infrastructure, platform, and software is offered as a service but also Business, Data, or Human, for example (Lenk et al. 2009). The idea of a cloud market—as examined in our study—is to trade highly-standardized computing resources such as processing capacity and storage. Therefore, we only focus on IaaS in the following.

Three types of deployment models can be differentiated, namely private, public, and hybrid clouds which differ in organizational aspects like ownership and the degree of control while they rely on the same technology (Zhang et al. 2010). Private clouds are typically owned and managed by a single company. While they offer the highest degree of control over performance, security, and reliability, private clouds do not offer the typical advantages of clouds like no up-front capital costs (Grance and Mell 2011). In contrast, public clouds are typically owned, built and managed by a third party and available to the general public. While there is no fundamental difference in the underlying technical concepts compared to private clouds, the consumer's control over data, network, and security is limited (Armbrust et al. 2010). Moreover, hybrid clouds are a composition of the deployment models described above. The distinct cloud infrastructures remain unique entities, but are linked to enable data and application portability (Grance and Mell 2011). As the idea of a marketplace for cloud computing is to match third party cloud providers' excess capacity and users' demand of computing resources, within our study we focus on public clouds.

Armbrust et al. (2010) argue that three aspects are new in public cloud computing from a user perspective. First, public clouds offer the illusion to users of having access to an infinite amount of resources when needed. Second, computing resources can be elastically provisioned and released outward and inward commensurate with demand in a pay-as-you-go manner. Third, up-front investments are eliminated allowing companies to start small and increase resources only when there is an increase in their demand. These aspects promise a faster time to market (Grance and Mell 2011), lower upfront IT costs (Venters and Whitley 2012) and an easier scale out (Alford and Morton 2009). Compared to conventional data centers, public clouds benefit from higher economies of scale due to very large data centers. Moreover, they exploit higher utilization by multiplexing of workloads from

different organizations, simplify operation and increase utilization via resource virtualization (Armbrust et al. 2010).

2.2 Marketplaces for cloud computing

A marketplace is a space where goods and services are traded. An e-market is an inter-organizational information system that is designed to establish provider-user relationships (Bakos 1998). It facilitates communication and transactions between its participants, often supported by additional services (Stockdale and Standing 2004). The activities normally are trilateral including users, providers, and the firm operating the marketplace, often referred to as the intermediary or marketplace operator (Chang and Wong 2010).

Literature discusses different functions and characteristics of markets (Bakos 1998; Coase 1937; Wigand 1997). Bakos (1998) distinguishes three main functions of markets; namely matching buyers and sellers, facilitating transactions and providing an institutional infrastructure. In the setting of cloud economics, these market functions have to be adapted to the concrete nature of cloud computing. In concrete, cloud markets aim to match users' demand of IT resources with supply, i.e. providers' excess capacity (Li and Jeng 2010). Second, cloud markets stem from the facilitation of transactions between the user and provider of IT resources (Buyya et al. 2008). To fulfill the transaction, the service has to be provisioned to the user while the payment must be transferred to the provider. Cloud markets typically incorporate mechanisms for these logistic and settlement activities. To protect users and providers from the opportunistic behavior of other market participants, cloud markets normally ensure a certain level of trust, e.g. through including banks issuing letters of credit, credit reporting bureaus, or rating agencies. Finally the institutional infrastructure of cloud markets, which provides a legal and regulatory framework to govern market transactions, is of high importance for the market's success (Rossbach and Welz 2011). In particular, this relates to issues about contract law, dispute resolution, and data privacy protection, but also offers mechanisms for their enforcement. Seen in light of Wigand (1997), we characterize the cloud market as competitive, due the variety of buyers and sellers, the homogenous nature of computing resources, easy entrance to and departure from the market, low switching costs for consumers and close to perfect information.

Table 1 gives an overview of the literature that deals with marketplaces for cloud computing. This literature has been gathered by conducting a literature review in the top eight IS journals based on the Association for Information Systems (AIS) Senior Scholars' Basket of Journals (AIS 2011) using the search strings "market" or "trading platform" in combination with "cloud computing" in a full text search. We then manually checked all papers for their relevance. Since this yielded almost no results, we conducted a broader literature review using the search engines EBSCOhost, ScienceDirect, ProQuest, and Google Scholar. Thereby, we used the search terms "market" or "trading platform", again both in combination with "cloud computing", and, in the case of Google Scholar, also the terms "marketplace" and "cloud computing" as well as "market exchange" and "cloud computing" to further limit the results. Moreover, we conducted a backward and

Table 1 Literature regarding marketplaces for cloud computing

References	Topics
Buyya et al. (2008)	Motivation, architecture
Buyya et al. (2009a)	Architecture, technologies
Buyya et al. (2009b)	Motivation, architecture
Krieger et al. (2010)	Motivation, challenges, architecture, technologies, API, prototype
Li and Jeng (2010)	Architecture, negotiation mechanisms
Garg et al. (2011)	Requirements, architecture, prototype
Breskovic et al. (2012)	Standardization, SLAs
Calheiros et al. (2012)	Architecture, prototype
Grilo and Jardim-Goncalves (2013)	Architecture

forward search with all identified papers. As can be seen, the topic has not received much attention so far. The focus of the research is on generally motivating the topic, on architecture and on technological aspects like standardized application programming interfaces (APIs), software components that handle the reservation and allocation of resources, and other implementation issues. However, to our best knowledge no study exist which empirically examines the adoption of a marketplace for cloud computing. We aim to fill this research gap through our study, focusing on the role of uncertainties that are prevalent between the different parties of a marketplace scenario.

There is considerable research on e-market adoption (e.g., Chang and Wong 2010; Quaddus and Hofmeyer 2007; Rask and Kragh 2004). As e-marketplaces evolved from EDI systems (Angeles 2000) and are supported by information and communication technologies (Malone et al. 1987), researchers have drawn possible determinants of e–market adoption from these areas.

We believe that the motives for adopting a marketplace for cloud computing are partly distinct to those identified in previous research on e-markets. On the one hand, uncertainties play a major role for a decision-maker whether to adopt cloud computing or not and thus explain the reluctance of some organizations to engage in cloud computing (Armbrust et al. 2010). On the other hand, IT is nowadays the backbone of commerce and its core functions—storage, processing and network—have become available and affordable to all. As argued by Carr (2003), if resources are essential to competition but inconsequential to strategy, the uncertainties they create become more important to companies than the advantages they provide. The diminishing role of IT has important implications for understanding the adoption of a marketplace for cloud computing. We propose that the market success of a cloud market will highly depend on the ability of the market operator to manage and mitigate uncertainties between cloud providers and users compared to bilateral cloud service scenarios. Today, disruptive IT innovation can paralyze a company's ability to produce its products, deliver its services and connect with its customers (Carr 2003). Hence, IT managers—at least for infrastructure technology—often focus on vulnerabilities, rather than opportunities for gaining competitive advantage. In many cases, this creates an atmosphere of fear-driven IT-management rather

than a challenge oriented leadership. However, little is known about cloud-specific uncertainties derogating the provider-user relationship and cloud-market-specific uncertainties introduced and mitigated by the marketplace operator. Therefore, we will focus on these aspects in the following.

2.3 Uncertainties surrounding cloud marketplaces

We draw on the principal-agent theory to develop a legitimate frame and potentially useful vocabulary to enter the field (cf. Fig. 1). We have chosen principal-agent theory because it particularly allows us to address the relations between the cloud provider, user and market operator. It focuses on the existing information asymmetries in these relations and the arising uncertainties and involved trade-offs when parties evaluate whether or not to enter into a contract. Other theories are not so suitable in shedding light on these issues. For example, Eisenhardt (1989a) contrasts several organizational theories with agency theory, like the contingency theory or the transaction cost theory. While they share some underlying assumptions, several others are not met by all these contrasted theory. We will not discuss all of them in detail here (see Eisenhardt (1989a) for more information). However, especially the transaction cost theory has similar assumptions like information asymmetries, goal conflicts, bounded rationality, or self-interests of all parties. Yet, it differs in the aspect of risk preference by assuming risk neutrality as opposed to an often assumed risk aversion of the agent. Moreover, it offers an explanation as to which governance structure (market vs. hierarchy or hybrid form) is chosen based on the occurring transaction costs to reach an agreement between parties that exchange goods. Transaction costs can be divided into production costs and costs associated with operation risks and opportunism risks. In addition, the transaction cost theory deals with demand uncertainty and market volatility as sources of uncertainty or economic theories that represent a future benefit as a form of uncertainty (Williamson 1985). Before we contrast principal-agent theory and transaction cost theory, we first introduce the former one in detail.

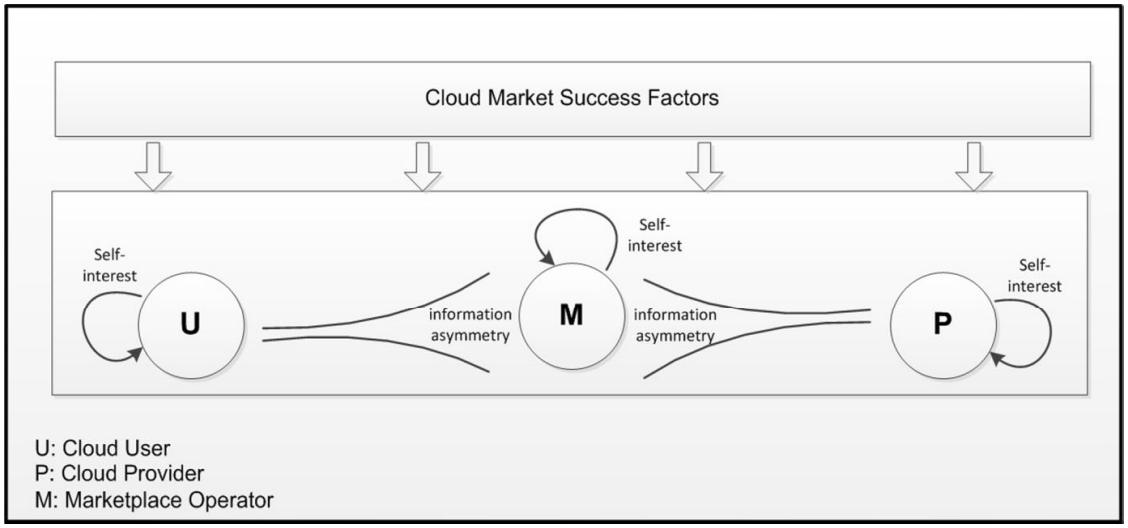

Fig. 1 Pre-understanding of uncertainties surrounding cloud markets

Agency problems befall almost all kinds of economic transactions where bounded rationality, fears of opportunism and information asymmetry exist (e.g., employment: Schepers et al. 2012; relationships of psychiatrists with industry: Appelbaum & Gold 2010; financial policy: Mügge 2011). An agency problem occurs when one party (the principal) delegates work to another party (the agent) and the welfare of the principal is affected by the choices of the agent. Principal-agent theory applies to any variation of relationships where one party is offering a service and the other party is providing compensation for the service. Agency problems can arise from two sources, adverse selection and moral hazard. Adverse selection arises due to a pre-contractual misrepresentation of providers' true abilities and qualities as well as the presentation of false service quality information (Akerlof 1970). In the context of cloud computing, providers can be seen as agents and users take the role of principals. Thus, while providers have hidden information about their true qualities, cloud users cannot easily determine a suitable cloud provider out of a pool of high-quality and low-quality providers. Thereby, the quality of a provider can for example relate to the effort he puts into fulfilling agreed upon service level agreements (SLAs) as well as the quality of his data centers. A moral hazard occurs due to a post-contractual shirking of the provider by not accomplishing a task as promised (Jensen and Meckling 1976). Even more, it also includes provider's deliberate deception of users since they cannot easily evaluate providers' performance.

Principal-agent theory suggests three measures to overcome the agency problem. Agents can design and send signals to the principal to expose private information about their true qualities (e.g. in-depth information about how they operate their service) (Bakos 1997). The principal examines these signals and may change concerns on using the agent's service (Rao and Ruekert 1994). Incentives are designed to prevent opportunistic behavior of the agent by making any hidden actions irrational or costly (Pavlou et al. 2007). They can help to align the interests of cloud users and providers more closely. For example, the user can offer monetary incentives to the provider based on the quality of the outcome (Vermillion et al. 2002). Finally, principals can also reduce uncertainties by monitoring the agents' activities, e.g. by auditing and controlling the principal randomly (Strausz 1997). In a nutshell, while signaling provides one solution to adverse selection problems, incentives as well as monitoring can especially help to resolve moral hazard problems (Mishra et al. 1998).

Overall, the principal-agent theory can help us to analyze the relationship between cloud users, cloud providers and the market operator as follows: First of all, it can guide us to understand the potential uncertainties which may exist in the cloud provider-user relationship by revealing the motives and interest of users and providers and by interpreting the information asymmetries between the two parties. Especially the quality of cloud services can hardly be evaluated by the user at any point in time since the technological details and the behavior of the marketplace operator and the cloud provider are hidden from him. Therefore, these services are best described as credence goods. Cloud users' on-going assessment whether or not to continue using a cloud service whose quality is hard to discern puts special emphasis on the importance of uncertainty in our scenario. Large information asymmetries characterize the prevalent situation in today's cloud computing landscape: While the cloud provider has perfect information about his services, the user does not know about many aspects like future availability of a service, the way

his data is used by the cloud provider, etc. Even more, the user has no chance in gaining access to this information, even if he has a high willingness to pay for it (e.g. for monitoring services). The described situation relates well to the concepts of hidden information and hidden action of the principal-agent theory and is thus considered as a well-suited theoretical perspective to guide our data collection and analysis. Principal-agent theory has been successfully used as a theoretical lens to study uncertainties with regards to search goods (Pavlou et al. 2007) and experience goods (Dimoka et al. 2012) traded on online markets. In contrast to cloud services, the quality of the search and experience goods can be either evaluated before the purchase decision or upon consumption (Nelson 1970). Therefore, we believe that principal-agent theory is an appropriate lens to study bilateral information asymmetries between different actors on the cloud market. Moreover, the perspective allows us to analyze how the introduction of a marketplace influences this relationship. Yet, a marketplace does not only reduce uncertainties between cloud users and providers, it also establishes two new agency problems: one between the user (principal) and the marketplace operator (agent) and another one between the provider (principal) and the marketplace operator (agent). As in these relationships goal conflict, fears of opportunism and asymmetric information are again prevalent, the principal-agent theory can be also utilized to interpret the uncertainties introduced by the marketplace operator and to understand how these uncertainties can be successfully reduced.

The transaction cost theory can be clearly demarcated from this: In this theory, uncertainties are described as arising from market volatility and demand uncertainty. Even more, the focus of the two theories is different: While the output of the transaction cost theory is a decision about which governance structure should be favored (hierarchy vs. market or hybrid forms), the principal-agent theory offers insights into the relationship of a principal and an agent and investigates what tactical situations might occur between them by considering potential conflicts, trade-offs, incentives and control mechanisms. We are especially interested in the latter point and thus see the principal-agent theory as very valuable for guiding our research. Yet, our intention is not to test the principal-agent theory in the context of cloud markets or find instantiations of the concepts in our data. Rather, the principal-agent theory can be seen as a "snapshot of our theoretical sensitivity" (Sarker et al. 2012, p. 320) to guide data collection and interpretation.

3 The context of study and methodological overview

3.1 Context: case background

We examine the acceptance of a marketplace for cloud computing in the unique context of a financial marketplace operator specialized in trading shares and other securities (MarketMaker) who is located in the EU. MarketMaker has decided to launch a marketplace for IaaS-resources after a 1-year evaluation phase. In this evaluation phase, a prototype was set up and cloud providers and users were involved to examine the feasibility of such a marketplace. We name the prototype

CloudMarket in the following. During this phase, we were able to accompany the marketplace operator and conduct this case study by in-depth experience at any stage of the evolution of the project.

CloudMarket is a trading platform for highly standardized computing resources. MarketMaker provides this platform and thereby has the role of a neutral third-party marketplace operator. It acts only as an intermediary between cloud providers and users and therefore does not sell own cloud resources. The marketplace mainly arouses interest among medium and large sized companies since it allows high volume trading of cloud resources. In the following, we explain the functionality of CloudMarket in detail and outline the services MarketMaker offers as intermediary.

To become a player on the marketplace, cloud providers and users have to fulfill certain admission criteria. Cloud providers have to prove that they offer high-quality services with respect to data security, privacy and reliability based on certificates issued by third party auditing. Cloud users have to prove that they have sufficient liable equity to pay for cloud services. In addition, both cloud providers and users have to agree to the terms and conditions as well as the code of conduct established by MarketMaker. Once they have been accepted as marketplace participants, the cloud providers can enter bids while the cloud users can enter requests for resources. CloudMarket offers two types of markets: a spot market, where cloud services are sold and delivery takes place immediately, and a derivatives market, where a gap between trading and delivery is present. The spot market allows for a flexible, short-term allocation of resources with a referenced price while the derivatives market enables securing prices through the hedging of future demand. Thus, it also offers an indicator of future prices. In each of these markets, computing power and storage resources can be traded. The definition of standards for IaaS resources as well as contracts is one key requirement for the marketplace. It enables transparency and allows for a comparison of services on the one hand and reduces the effort for negotiations on the other hand. As currently no standards exist, MarketMaker wants to set standards for each cloud service class. While technical parameters like I/O-performance and security requirements are fixed, the participants can choose between predefined values for tradable units, SLAs, the allocation model, and the product location. The SLAs are kept very simple and define the quality of service to be expected, metrics for user support, and a refund policy in case SLAs are violated. The allocation model can have two types: open and fixed end. Open end means that the contract period is unlimited, has a certain cancellation period for the contract partners, and includes a scalable function. It allows users an increase of their contracted resources up to a predefined size under the same conditions. In a fixed end allocation model, the contract duration is fixed, no cancellation period exists, and no scalable function is included. Concerning the product location, the CloudMarket differentiates between data centers located in the European Union and data centers located within US territory. All these variable parameters can be combined. To give an example of one occurrence: A product from the asset class “storage” might have a tradable unit of one terabyte, is located in the EU, the allocation model is open end, and the SLA used is “SLA1” which is the highest quality available on the marketplace.

CloudMarket supports four phases: pre-trading, trading, clearing, and settlement. We explain the phases and the services MarketMaker offers in each of these phases. Aim of the pre-trading phase is to allow for an adjustment of the product portfolio as well as specific parameters, e.g. the adjustment of product benchmarks or bandwidth due to technological progress. In the trading phase, a provider or a user can select such a product and enter the quantity he wants to trade on the marketplace as well as the price he is willing to pay or sell the resources for. A two-sided auction mechanism is used to determine the matching of bids and asks. Once the trading has been done, the trade has to be cleared. In the spot market, the participants clear bilaterally, e.g. via a clearing bank, while in the derivatives market, a central counterparty (CCP) handles the clearing. A CCP is an entity which steps in between user and provider. Thereby, it acts as provider for each user and as user for each provider. Introducing a CCP has efficiency related reasons because every participant has only one party to interact with. Next, the settlement takes place. In this step, the user and the provider who have entered into a contract are connected dynamically and securely by a self-developed software. Once the connection is established, the consumer can utilize the resources. At the same time, the settlement software is also monitoring the provider to check whether he is fulfilling the contract. In case he is violating the agreement, the refund policy as defined in the SLAs takes effect. This is an improvement from the current situation where users have to monitor the service themselves and make claims against the providers.

While the CloudMarket project team has clear ideas about the overall design and has developed a prototype with a technology partner, a fully implemented and launched solution of the marketplace does not yet exist.

3.2 Methodology

We believe that the CloudMarket project is a revelatory, unique and exemplary source of insight on our topic (Yin 2009). MarketMaker is a successful marketplace operator in the financial sector with a strong reputation. As trustworthiness of the marketplace operator may be seen as a necessary condition to establish a cloud market, the CloudMarket project is seen by both providers and users as a serious alternative to obtain and dispose computing resources. Thus, the ecology of the CloudMarket project team and its potential business partners represents a fascinating context where the topic of interest could be investigated in depth. The goal of our study is to generalize our empirical insights to a theory on the phenomenon under investigation based on analytical generalization (Yin 2009).

Our engagement with the CloudMarket project contributed to our broader understanding of the cloud market business case. The first author was accompanying the project scientifically for half a year. She was present at team meetings and had access to all internal documents. In addition to reviewing internal documents, many informal conversations with the team members helped her to establish a fundamental knowledge of how the marketplace will work and to understand the opportunities and risks involved in this project. Even more, she

was allowed to participate in some of the meetings with potential consumers and providers which provided her with additional valuable insights from the participants' perspectives.

Moreover, the first author conducted twelve formal interviews with project team members, cloud providers and users. Overall, twelve interviews were conducted between April and July 2012: six interviews on the cloud user side, four interviews on the cloud provider side, and two interviews with representatives of the marketplace operator. The companies interviewed belong to different branches and the interviewees held different positions. Aim of this spread of interview partners was to gain as many insights as possible and triangulate data from different sources as suggested by methodologist (Patton 2002).

Table 2 provides an overview of the interviews conducted, describing the industry of the company interviewed, the position of the interviewee in his company, whether the interview was carried out face to face or via telephone, and information about the length of the interview.

Each interview was recorded and conducted based on an interview guide (Yin 2009). The interview guide kept interactions focused while allowing individual experiences to emerge and thus, best used the limited time available in the interview situation (Gordon 1980). Interview partners were asked questions about their understanding of cloud computing, their current usage or provision of cloud resources as well as the opportunities and risks of using cloud computing from their perspective. Moreover, the marketplace prototype was introduced and the opportunities and challenges it offers were discussed in depth. The interview guide served as a "reminder regarding the information that needs to be collected" (Yin 2009, p. 86). After each interview, the interview guide was adapted in case new uncertainty concepts have emerged.

Overall, our approach can be characterized as interpretive in that sense that it takes the interview partners' experiences with cloud computing to develop a "second-order theoretical understanding" of uncertainties surrounding cloud markets (Lee 1991; Sarker et al. 2012). In doing so, we applied a less procedural version of the grounded theory methodology as proposed by Sarker and Sarker (2009) to develop our understanding of uncertainties surrounding cloud markets. This involved constant comparison of the data "[…] to see if [they] support and continue to support the emerging categories" (Holton 2007, p. 277) and then to link this evolving set of concepts to higher level categories of uncertainties (Walsham 1995). This process led to the discovery of cloud- and market-specific uncertainties surrounding the market. Finally, based on the experiences of our interview partners, we identified capabilities of the market place that could help to reduce the uncertainties surrounding cloud markets (Walsham 1995). Once, concepts and patterns emerged we enfolded previous literature to support our interpretations which involved to ask "what is this similar to, what does it contradict, and why" (Eisenhardt 1989b, p. 544).

Table 2 Interview partners

Role in the market	Industry	Position of interviewee(s)	Way of communication	Length of interview (min)
User	Information technology	*Interview partner 1* Enterprise Account Manager & Partner Relations	Face to face	40
User	Bank	*Interview partner 2* Manager of the Architecture Department *Interview partner 3* Enterprise Architect	Face to face	60
User	Logistics	*Interview partner 4* Management position in R&D	Telephone	60
User	Automobile	*Interview partner 5* Leader Vitas & Cloud Computing, *Interview partner 6* Assistant of Cloud Team	Telephone	40
Provider	Internet service provider	*Interview partner 7* Chief Operating Officer	Telephone	50
Provider	Internet service provider	*Interview partner 8* Product Manager	Telephone	45
Provider	Internet service provider	*Interview partner 9* Management position in R&D	Telephone	40
Provider	IT-consultancy, IT-services	*Interview partner 10* Business Developer	Telephone	55
Market operator	Equity-, equity index-, interest rate derivatives, clearing services	*Interview partner 11* Project leader of the CloudMarket team *Interview partner 12* Consultant—responsible for the functional work stream of the project	Face to face	45

4 Interpretation and results

In the following, we present our results and interpretations of uncertainties prevalent in cloud markets and ways to successfully mitigate these uncertainties. We start with cloud-specific uncertainties which exist between the cloud provider and user. Next, we discuss capabilities of the market operator to reduce these uncertainties. As the way the marketplace platform has been designed, implemented and is now operated by the market maker not only reduces but also introduces new uncertainties, we analyze cloud-market specific uncertainties between the market

operator and its participants up next. Finally, we discuss how a cloud market operator can successfully mitigate these cloud-market specific uncertainties. The outcome is a framework which can be used by cloud market operators, cloud providers and users to understand and successfully manage uncertainties surrounding cloud markets.

4.1 Cloud-specific uncertainties

Cloud-specific uncertainties arise through user's disbelief about the cloud provider's ability (adverse selection) or willingness (moral hazard) to provide the computing resources as agreed upon (Pavlou et al. 2007). Interviewees expressed several types of concerns that may hinder the adoption of cloud computing. An overview of the identified uncertainties is depicted in Fig. 2. The concerns presented in the following are not specific to cloud markets but may occur in all kinds of cloud computing service scenarios.

First of all, interviewees argued that users have information privacy concerns in adopting cloud computing. According to Westin (1967, p. 7), privacy refers to "the claim of individuals, groups or institutions to determine for themselves when, how and to what extent information about themselves is communicated to others". In the context of cloud computing, users want several types of data to be protected by the cloud provider. These include identity information, transaction histories, and, probably most important, all business critical data which might be transferred to the provider for processing or storage (Takabi et al. 2010).

> *"[…] we have repeatedly tested cloud usage in certain business areas. However, we have repeatedly shied away because we realized that some internal bank data would be stored in the cloud. We did not want to take this risk." (interview partner 3)*

Privacy concerns arise in both types of agency problems: Ex ante, users may find it difficult to analyze a cloud provider's mechanisms to ensure data privacy. Ex post, a user cannot easily check whether the cloud provider is disclosing his data to third parties or whether he is using it otherwise without the user's consent, for example.

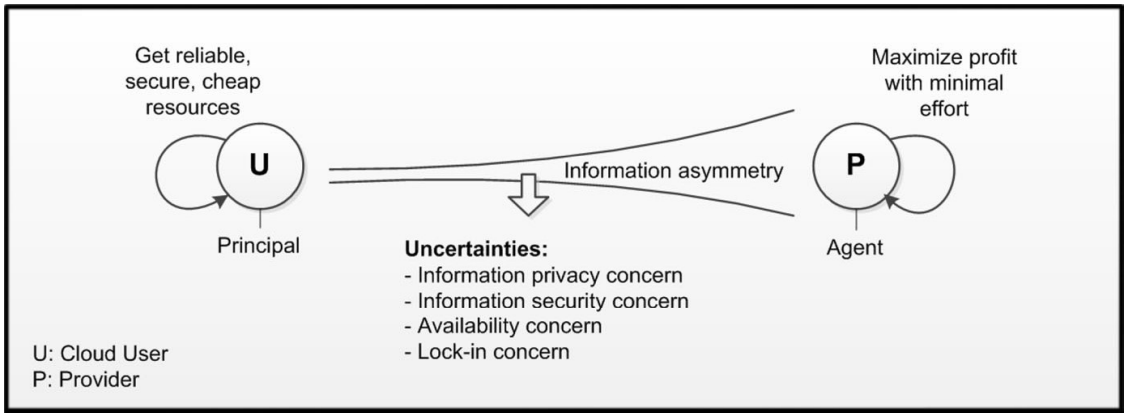

Fig. 2 Uncertainties between cloud provider and user

These concerns have been confirmed by several interview partners on the cloud provider side.

> *"One aspect of virtualizing storage is that we need the trust of users. They have to be confident that we handle their data according to their data privacy requirements without telling them where the data is actually stored." (interview partner 6)*

The important role of information privacy is also supported by previous research on e–commerce. E.g., Pavlou et al. (2007) show that purchasing behavior in online exchange environments is influenced by information privacy concerns. Thus, we may generalize their findings to the context of cloud computing.

Apart from information privacy concerns, interviewees also mentioned information security concerns. Information security relates to the secure transmission and storage of information and the prevention of information theft (Miyazaki and Fernandez 2000). The topic is closely related to information privacy and the uncertainties which arise are similar. Again, adverse selection and moral hazard problems can be identified: Pre-contractually, it is difficult to examine the installed security mechanisms of the provider and thus to judge the provider's ability of safeguarding all information. Post-contractually, the user cannot observe whether the cloud provider is successfully protecting the data from hackers and espionage attempts, for instance. This is a major concern of most users.

> *"[…] the amount of data passed to [the provider] needs to be highly technically secured." (interview partner 4)*

Also previous cloud computing opinion papers stressed the importance of data security for cloud computing. E.g. Kaufman (2009, p. 62) emphasizes the necessity of establishing security measures in the cloud as they "[…] offer the opportunity for simultaneous attacks to numerous sites, and without proper security, hundreds of sites could be comprised through a single malicious activity […]". These concerns have been confirmed by several interview partners on the user and cloud provider side.

Furthermore, availability concerns constitute another fear of users. Availability refers to the "reliable and predictable delivery of services from the cloud" (Sandhu et al. 2010). In this case, especially adverse selection problems are prevalent: The consumer cannot evaluate a provider's effort and investments in the reliability of his infrastructure, e.g. whether he really mirrors all data to a second data center. Having entered into a relationship, he can measure the actual uptime of the service. However, he still cannot predict the future availability and thus faces uncertainty

> *"We have in general much higher availability requirements as those offered by typical cloud providers. […] But here is the problem: the requirements, or that what is delivered from a cloud provider is certainly not enough. […] However, availability and confidentiality are important criteria for choosing our [IT] products." (interview partner 3)*

While availability concerns have not been connected to user's uncertainty in previous research, our findings indicate that, in the context of cloud computing, availability is a major source of uncertainty (Sandhu et al. 2010).

The fourth user concern which emerged in our interviews is provider lock-in. Since cloud products are currently not standardized, e.g. proprietary APIs are prevalent, users may not as easily extract their data and change from one provider to another (Armbrust et al. 2010). In this case, uncertainty arises due to adverse selection problems: users know that choosing one cloud provider will result in a lock-into a particular technology. Since a migration to another provider is very costly, consumers are dependent on the provider and therefore vulnerable to price increases and availability problems, for instance. Moreover, the triability of a service is not given which increases the pressure on the consumer to select an appropriate provider. These aspects are supported by several interview partners but have also been discussed in the literature (Armbrust et al. 2010).

> *"And then there is another important problem: how is my vendor lock-in, i.e. how can I extract my data that belongs to me out of the data center again." (interview partner 7)*

To sum it up, key requirements for storage and processing power are services that are compliant, secure, reliable and interoperable. Whether these requirements are sufficiently met is highly dependent on the decisions of the cloud provider. As goal conflict, fears of opportunism and asymmetric information are prevalent between cloud provider and user, these types of uncertainties will influence the users' decision whether to adopt and use cloud computing.

4.2 Mitigating capability of a cloud marketplace operator

E-commerce and electronic markets came with the claim of disintermediation: the elimination of mediating roles such as wholesalers, retailers, or brokers, which allows for a direct linkage of buyers and sellers (Wigand 1997). Currently, the cloud landscape is organized mostly without intermediaries. Yet, as discussed in the previous section and as outlined by Datta and Chatterjee (2008), an e-market still faces uncertainties, even in the light of reduced search and communication costs. This can lead to a reintermediation, the introduction of an online intermediary. Research shows that an intermediary is seen as a source of trust and integrity of an e-market (e.g., Giaglis et al. 2002; Son et al. 2006).

Thus, in our case, the introduction of a marketplace with a third-party independent operator can serve as an uncertainty mitigator between users and cloud providers. An overview of the mitigating capabilities of a cloud marketplace is depicted in Fig. 3. Signaling can be one effective method of overcoming uncertainties. Through the way the marketplace is implemented, it supports cloud providers in signaling: When providers participate in the marketplace, they automatically show that they have a certain quality because the marketplace operator has defined admission criteria they have to fulfill; otherwise they are not allowed to participate. Moreover, providers can just easily list all of their product

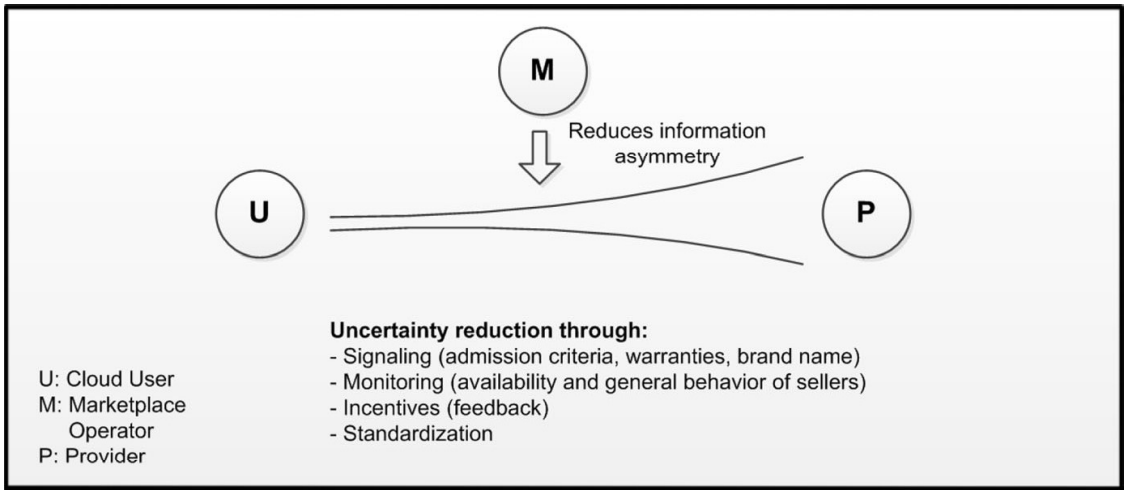

Fig. 3 Uncertainty reduction through marketplace operator

characteristics at the marketplace to show that they do not fear the comparison but offer a sufficiently high level of quality.

> *"I do think that this has advantages. So if a company is in such a business case, I would say, not only information about prices, but also information about the providers, would be a big advantage for this company. So as an example: […] How are its computer centers distributed around the world? Who is the provider? Where does the provider operate? What are his priorities?" (interview partner 5)*

Providers could still try to deceive consumers by not delivering the promised quality. Nonetheless, at least the perceived uncertainty is reduced by increased transparency. These two signaling methods help to reduce uncertainties. In addition, the marketplace anticipates some of the risks and uncertainties by supporting further signaling activities, e.g. providing warranties to consumers if services are not available and thereby reducing the availability concerns.

> *"So, it's about the guarantee granted by the marketplace operator. […] There can't be something like, 'No, we cannot deliver right now. You receive money, or something like a coupon as compensation.' […] It must be delivered in any case; the guarantee must be given. And I think if that's the case, then you have again a very important added value that you sell here, namely warranty." (interview partner 1)*

Even more, marketing research shows that there is a strong relationship between brands and trust. Delgado-Ballester and Munuera-Alemán (2001) confirmed that, on the one hand, high satisfaction with a brand creates trust and, on the other hand, trust leads to a higher commitment to and involvement with a brand. Thus, the brand name of the marketplace operator is a good signal. MarketMaker has a good reputation and is known as a trustworthy partner. Therefore, it does not want to risk this image by providing a marketplace where low quality products are traded. This is confirmed not only by the marketplace operator, it is also the perception the

interviewees from the provider and user side had. Thus, it successfully decreases existing concerns.

> *"So I think if the right brand operates the marketplace, simply more trust is created. As customer, I would assume that if a provider is admitted to the marketplace, […] the provider has been tested and meets a certain level of quality." (interview partner 10)*

Monitoring and incentivizing are further methods of mitigating user concerns. On the one hand, the marketplace operator can implement a functionality which monitors the actual availability of a cloud service that has been traded over the marketplace. If the availability requirements are permanently not fulfilled, they have to face consequences like suspension. Moreover, the marketplace operator can also monitor privacy or security breaches, at least if they become publicly known, and exclude the involved providers. In addition, the marketplace operator could establish feedback functionalities where users can share their experiences with certain providers. Although this functionality is currently not planned to be implemented on the CloudMarket, it has been mentioned in interviews as potential uncertainty mitigation mechanism.

> *"I think, seen from a user perspective, it would be great if I could get in touch with other users of this cloud provider. […] You can contact another reference, […] without the providers' active control, which of course makes the entire thing transparent again." (interview partner 10)*

While incentivizing can help to reduce all types of concerns discussed above, monitoring can especially help to reduce information privacy and information security concerns as well as availability concerns.

Furthermore, MarketMaker intends a standardization of IaaS-resources and a migration functionality to easily switch from one provider to another. If this standardization is widely accepted and the migration functionality is working, it would have a huge impact on the user-provider relationship since it can eliminate all lock-in concerns.

> *"So, I believe that standardization can only be good for the market. I believe that the entire cloud industry is currently struggling with the fact that the forecasts are huge but volume does not turn out as planned. I think the reluctance of the German market is right on this issue." (interview partner 10)*

4.3 Cloud-market-specific uncertainties

The marketplace operator also introduces new uncertainties. First, the relationship between the marketplace operator and the consumer is analyzed: While the user still has the same goals as before when trading resources over the marketplace, namely buying resources based on criteria like price, privacy, security, and availability, the marketplace operator is new in this whole picture. He is offering several services to the user, the most important one being the matching of the consumers' requirements and the providers' offerings. The marketplace operator aims at earning money with

these services with as little effort as possible. Thus, his goals are profit-oriented and not congruent with the user's goals. Moreover, the activities of the marketplace operator are difficult to assess by the user, e.g. how the operator is selecting suitable trading partners and how the monitoring of the providers' cloud services is working. Therefore, the chance for opportunistic behavior is given: The marketplace operator could select providers for the matching based on where he can make the largest profits and not based on suitability, for instance.

The uncertainties in the user-marketplace-operator relationship take many forms and comprise adverse selection as well as moral hazard problems. Concerns about the neutrality of the marketplace operator were issued by the interviewees. Neutrality refers to "not taking sides, impartiality and indifference in the scientific sense of an impartial disinterest with respect to the outcome of any conflict" (Hoffer 1985). In this case, the interviewees were especially concerned about the neutrality in the selection process of the provider which cannot be assessed upfront.

> *"I also think is important that it is a very reputable and solid marketplace operator, one who is neutral. A marketplace operator, of which I do not expect to make the most profit out of its services, but simply compares the companies in a neutral way." (interview partner 6)*

Moreover, the interview partners mentioned concerns about the technological ability of the marketplace operator and his ability to set standards. The marketplace operator also confirmed the existence of these concerns. They exist especially pre-contractually: Users cannot easily evaluate the technological ability to build the marketplace and therefore its quality. In addition, at least shortly after the marketplace goes live, consumers are uncertain whether the standard of the marketplace will prevail. While the marketplace operator can reduce the availability concerns inherent in the user-provider relationship, the users named additional availability concerns regarding the marketplace.

> *"One disadvantage is: what happens if I rely mostly or solely on the marketplace? […] It is possible that the marketplace is not available and in case a company is used to lease resources on a short-term base, then it could run into a bottleneck." (interview partner 4)*

These concerns exist ex ante and ex post since the user can never determine the future uptime of the marketplace and the operator's efforts to ensure a high availability rate.

Lastly, the soundness of all functionalities of the marketplace and the activities of its operator are also seen critical because their evaluation is neither pre-contractually nor post-contractually possible in an easy way. This also includes concerns about information security and privacy.

> *"[…] it must be possible to assure that the service provided by the marketplace operator is working in terms of reliability, risk management, market supervision and all the other topics." (interview partner 12)*

Concerning the cloud provider-marketplace operator relationship, the provider still has the same goals as before: He wants to maximize his profit with minimal

efforts, while the marketplace operator wants to maximize his profits as well. However, these goals are not congruent, since the provider wants to sell as many of his cloud resources as possible while the marketplace wants to conduct as many matchings as possible, yet, not necessarily with the same provider. The provider cannot easily observe the behavior and the activities of the marketplace operator, e.g. how the marketplace operator is selecting suitable trading partners and whether he can really evaluate the quality of a provider and his services. Thus, the chance for opportunistic behavior is again given.

The uncertainties which arise out of this principal-agent relationship are very similar to the ones existent in the user-marketplace relationship. Providers are also concerned about the neutrality of the marketplace operator, about his technological ability, his ability to set standards as well as the soundness of the marketplace functionalities and of the behavior of the marketplace operator.

> *"Yes, exactly, the neutrality of the marketplace operator is of course questionable. I do not think the operator can be neutral. […] For example, just as an insurance broker can't be neutral, as he also has his favorite customers and that is just the way it is. […] With open, transparent quality criteria, which are regularly reviewed, there will be trust." (interview partner 9)*

Since all these aspects have already been discussed in the context of the user-marketplace-operator relationship, they are only mentioned here but not elaborated in detail. In addition, the interview partners mentioned two more types of uncertainty: The first one deals with concerns about a loss of responsibilities, e.g. concerning the product design, the contract design, and the design of the interfaces. This concern is existent pre- and post-contractually: The interviewees are especially afraid of changes in the offerings' design they are not in accord with and cannot influence. The second uncertainty relates to a potential loss of reputation through the participation in a malfunctioning marketplace and thus unsatisfied customers.

> *"I would thoroughly inquire what is behind the marketplace, what kind of intention MarketMaker has and […] elicit this significantly. It is a piece of our reputation, which is transferred there. […] Since we have made the conscious decision to become a serious supplier in the market […] we do not want to mess anything up, if we go in cooperation with amateurish marketplace operators." (interview partner 7)*

This concern also comprises adverse selection and moral hazard problems since the provider can never be sure whether complications with the marketplace happen. Figure 4 provides a comprehensive picture of all uncertainties introduced through the marketplace operator.

4.4 Cloud-market success factors

In the following, mechanisms which can help to mitigate the uncertainty introduced by the marketplace operator are presented. Since the mitigators are very similar for

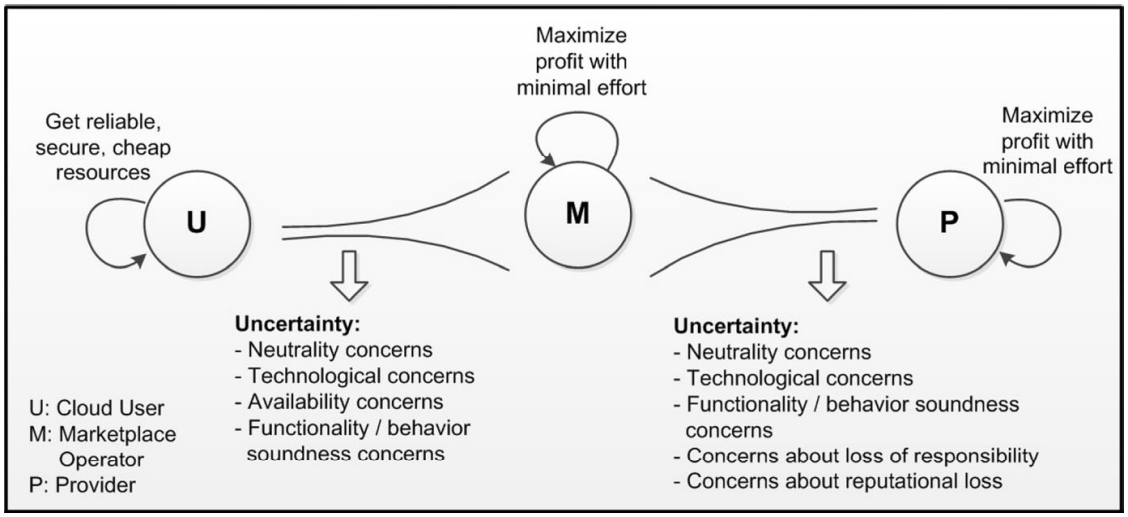

Fig. 4 Uncertainties between marketplace operator and participants

both relationships, they are discussed in combination. A high level of transparency constitutes the first possibility of uncertainty reduction.

> *"To get this, it is a crucial success factor […] to make the structure of the marketplace, our admission criteria, our SLAs and so on, transparent and also communicate this to our all market participants." (interview partner 12)*

For instance, the marketplace operator can openly communicate the structure of the marketplace, his matching mechanisms, the admission criteria, and the SLAs, to name but a few examples. Thereby, he can show that he is a neutral instance and that users and providers can trust in him. Moreover, the marketplace can offer a transparent feedback mechanism where providers as well as users can see the feedback about other participants. This enhances the perceived transparency and neutrality. In addition, external control mechanisms of trusted third parties can create trust in the marketplace, e.g. certificates issued by an auditing organization with an excellent reputation.

> *"I think everything should be a third-party-certified or it should at least be assured that everything is above board […], in terms that nothing is tricked in the background, for example that one provider gets more information than another and so on. […] of course there has to be a certificate on it somehow […]." (interview partner 10)*

Furthermore, the marketplace operator can offer potential participants to include them in the conceptual as well as in the implementation phase of the marketplace as MarketMaker currently plans to do. This constitutes a further signal: On the one hand, all parties can represent and articulate their interests so that they might be considered in the design. On the other hand, they can also gain detailed insights into the marketplace design and check the soundness of the functionalities. Thus, it can increase the trust in the marketplace. An excellent reputation is a fourth signaling construct which can reduce uncertainty. As discussed above, an organization aims at keeping its good reputation since it is an important asset for future business.

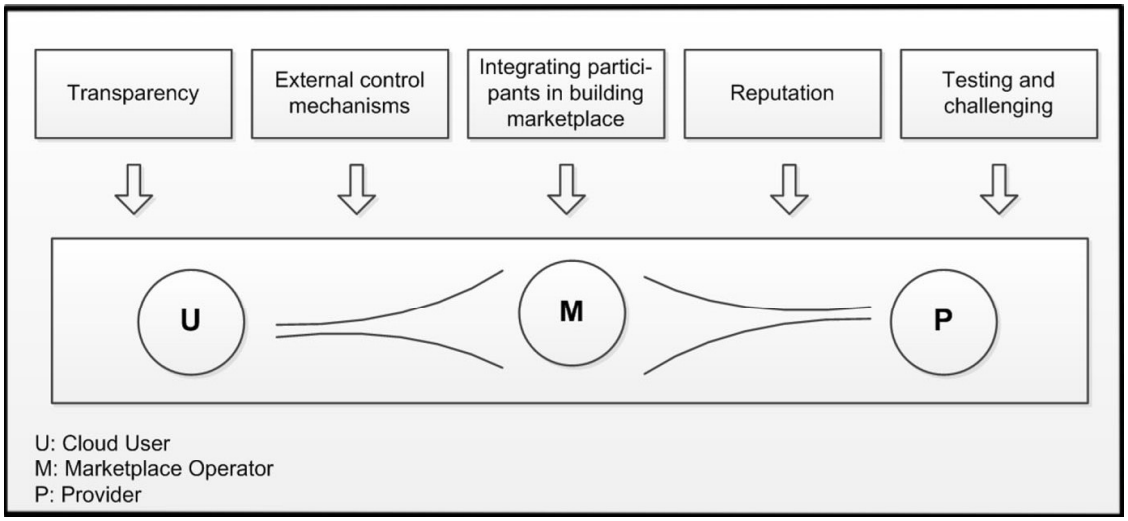

Fig. 5 Uncertainty mitigators between marketplace operator and participants

Moreover, especially for consumers who are currently only hesitantly using cloud computing and for providers who have no experience with marketplaces, a marketplace operator with a well-known brand name can establish trust in his services.

> *"But I think because it is MarketMaker you know that you can rely on them. So if you can handle transactions in shares, then maybe you should be able to do a few transactions on a cloud market." (interview partner 10)*

Allowing the participants to test and challenge the marketplace can also increase confidence in the system because they do not have to believe in another party but can test the functionalities themselves. This might not only include trying out the functionalities but also penetration tests to assess the security of the marketplace.

> *"Therefore, we would be happy if we could conduct security penetration tests with the interfaces of the marketplace system, because everything is transferred over these." (interview partner 4)*

This last mitigator belongs to the category of monitoring mechanisms. Figure 5 summarizes the mitigators graphically.

5 Discussion

The objective of this study is to develop a theoretical framework for understanding uncertainties surrounding cloud markets for highly standardized computing resources and the trade-offs they imply for an adoption decision. Overall, our results and interpretations show that agency problems are prevalent in cloud markets and that the principal-agent theory is a well chosen theoretical perspective to contribute to understanding participants' behavior. It is particularly suitable as a theoretical scaffold for our study, since information asymmetries between cloud provider and user play a major role in the existence of uncertainties preceding the

adoption of a cloud market by participants. The key findings that provide new insights on uncertainties surrounding cloud computing marketplaces are discussed in detail in the following. Subsequently, the theoretical and practical contributions as well as suggestions for future research are presented.

5.1 Key findings

Our study corroborates previous research on cloud computing that has also identified information privacy (e.g., Takabi et al. 2010), information security (e.g., Miyazaki and Fernandez 2000), availability (e.g., Sandhu et al. 2010), and lock-in (e.g., Armbrust et al. 2010) concerns as the major sources of uncertainties in cloud computing service scenarios. Also, the mitigating opportunities of a cloud market operator are similar to what has been discussed in previous research on success factors of cloud providers (e.g., Armbrust et al. 2010; Parameswaran and Chaddha 2009).

In contrast, our empirical findings provide new insights on cloud-market-specific uncertainties that are introduced by the cloud market and insights on how these uncertainties can be successfully managed by the marketplace operator. Based on our findings, we are able to better assess whether a cloud market is a more attractive alternative for cloud providers and users as opposed to a direct and bilateral cloud provider-user business relationship. Our key findings have important implications for the feasibility of a cloud market in a business-to-business context and the question how organizations will obtain highly standardized IT resources in the future.

5.1.1 The cloud market from a user perspective

Users currently face a variety of uncertainties in bilateral relationships with cloud providers which have also been examined in previous research (Armbrust et al. 2010; Venters and Whitley 2012). Using the principal-agent perspective, we describe in Sect. 4.1 that uncertainties exist between users and providers: Users are especially concerned about data privacy and security, but also fear non-availability and a provider lock-in. A marketplace operator who steps into this relationship can help to mitigate these uncertainties through mechanisms like admission criteria and monitoring as presented in Sect. 4.2. The acquisition of cloud resources gets easier and more attractive for users and thus can be an improvement of the current situation. Overall, our analysis reveals that a marketplace has a better ability to mitigate uncertainties compared to cloud providers as the marketplace serves as a neutral and competent instance between cloud provider and user.

Besides these positive effects, our findings also show that such an intermediary introduces additional uncertainties from a user perspective, e.g. regarding the functionality and availability of the marketplace or its neutrality, as discussed in Sect. 4.3. Therefore, obtaining cloud resources becomes again more risky for users on the marketplace. On the other hand, the market operator has abilities to reduce these uncertainties. Our study reveals that users are more likely to adopt and use a cloud market which operates under a trustworthy brand, they rely on well-

established external control mechanisms and favor an early integration of users in the design and building phase of the marketplace, to name some mitigators presented in Sect. 4.4. Overall, our study indicates that a cloud market can be an attractive alternative for cloud users compared to a bilateral and direct business relationship with cloud providers.

5.1.2 The cloud market from a cloud provider perspective

For cloud providers, the situation is quite different compared to the user perspective discussed in the previous section. In a bilateral relationship with cloud users, a provider faces only minor uncertainties like the user's financial solvency. Thus, being the agent in this relationship is fruitful for the provider and rather risk-free.

The introduction of an intermediary into this picture arouses many potential uncertainties for a provider: as our analysis in Sect. 4.3 shows, providers are especially concerned about the functionality of the marketplace as well as the neutrality of its operator. Moreover, they fear a potential loss of responsibility and reputation since they no longer have full control over the way and the reliability in which their services are delivered. The uncertainty mitigators we present in Sect. 4.4 are also relevant to the cloud providers. For them, the transparency of the marketplace mechanisms and a strong reputation are of major interest.

Overall, the cloud market causes several types of uncertainties for the provider but offers only risk reduction for cloud users. However, some compensation or benefit could be gained by using a cloud market. Cloud providers can use it as an additional sales channel for customers that only rely on the CloudMarket but not on the cloud providers' reputation. Also, small data centers which only have limited capacity can fulfill large orders because they have to provide only a part of the service, the rest can be served by another provider in a way that is transparent to the user. Thus, in the end, the provider has to decide whether these benefits really compensate for all additionally introduced uncertainties and whether he wants to participate in the marketplace. Therefore, seeing it from an uncertainty perspective, the marketplace presents a less attractive alternative to the current bilateral relationships.

5.2 Theoretical contribution and implications for research

Our paper presents the first empirical study on a conceptualized multi-vendor, multi-buyer, third party operated marketplace for cloud computing. Some conceptual studies have been carried out on the technical feasibility of such markets (e.g., Buyya et al. 2008; Schnizler et al. 2008). However, the conceptual evaluation of such market mechanisms showed that the clearing of the market is far too complex to carry it out in practice in the way the authors propose. Also, major issues of data privacy, risk mitigation and service level enforcement remain open. Our study shows that the motives for adopting a transparent, two-sided and independently managed marketplace for cloud computing are distinct to those identified in previous research on e-market adoption and that uncertainties between cloud provider, user and market operator play a major role for the feasibility of such a

market place. Even more, while the marketplace is an attractive alternative to the bilateral relationships for users, providers also experience new uncertainties in these constellations. Nonetheless, if satisfying compensation can be offered to providers, a cloud marketplace might be a promising way of trading cloud computing resources in the future. Yet, this trilateral contract as efficient governance structure might contradict some elements of the transaction cost theory: The theory says that trilateral contracts are only the most suitable solution in case of occasional transactions and mixed or idiosyncratic asset specificity (Williamson 1975). The marketplace, however, is also used for frequent transactions and the related asset specificity is non-specific or mixed due to the intended high degree of standardization on the marketplace. Thus, this tentative finding should be subject of further investigations in the near future.

Overall, we provide three major-contributions to the literature on cloud computing. First, our study shows that agency problems are prevalent on cloud markets and that the principal-agent theory is a fruitful perspective to study these uncertainties. Since the perspective has hardly been used to study the adoption of e-markets, we encourage future research to re-examine other theoretical e-market contexts based on this perspective. Second, while cloud markets have capabilities to mitigate uncertainties between cloud provider and user, they also cause new uncertainties in this relationship. This supplements previous studies which have emphasized and theorized the mitigating capabilities of e-markets but did not focus on their negative effects on uncertainty perceptions of participants. Third and as presented in the previous section, our study presents a second-level theoretical understanding on uncertainties surrounding cloud markets and thereby sheds light on the trade-offs involved in the decision to adopt a cloud market by cloud providers and users. The framework can be utilized by future research to study the role of uncertainty for other relevant behavioral outcomes in the context of cloud computing and cloud markets in particular.

5.3 Implications for practice

Several implications for practitioners can be given. First, the framework can help market operators in the design of the marketplace. Since uncertainty demonstrably plays a dominant role, we want to raise market operators' awareness for this topic: They can reduce the uncertainties inherent in the bilateral relationships between users and providers like offering warranties and monitoring. Thus, it is advantageous to clearly communicate all mitigating capabilities a marketplace offers. Moreover, the marketplace's potential of uncertainty reduction is also an interesting aspect for cloud providers since they are not only competing for current cloud users but also for new user segments which are currently not using cloud services due to the existing risks.

On the other hand, market operators have to keep in mind that they and their marketplaces are also a source of uncertainty. Therefore, they should concentrate on mitigating the concerns, e.g. by building up trust and openly and transparently communicating all functionalities of a marketplace. Moreover, an early integration of potential participants in the conceptual phase can increase the probability of

acceptance. While the overall degree of uncertainty is reduced for users, market operators should carefully consider the compensations they offer to providers since they face a higher degree of uncertainty when participating in the marketplace compared to trading in bilateral relationships.

The third implication deals with the differences of cloud users and cloud providers. Market operators should address both groups separately as they have different concerns when participating in the marketplace. Therefore, market operators should carefully think about how to present the idea of their marketplace to each of these groups in order to get the best out of each meeting or advertising campaign, for instance.

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