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Market Acceptance of Cloud Computing - An Analysis of Market Structure, Price Models and Service Requirements

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Abstract

As an emerging technology and business paradigm, Cloud Computing embeds fairly large amount of unexplored fields, from technological definition to business models. While the market of Cloud Computing is expected to expand in the near future, few studies of the actual market acceptance of the Cloud Computing services are done. It may be interesting, especially for the Cloud Computing service providers, to know more about the preferences of transaction forms and price models from the users and potential users. From an academic research's point of view, we want to know whether the development of Cloud Computing market can be explained or even predicted by certain theoretical frameworks. Therefore, a summary of the current market situation of Cloud Computing is given in this thesis, and an empirical analysis of the market acceptance of Cloud Computing, based on a customer survey, is conducted. This survey and the empirical analysis aim to verify certain existing theories from the academic world about the customer preferences of market structures and price models; and to deliver further hints for the researches on this topic.

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Index of Abbreviations

ARPANET	Advanced Research Projects Agency Network
ASP	Application Service Provider
AWS	Amazon Web Service
BIRN	Biomedical Informatics Research Network
CAGR	Compound Annual Growth Rate
CERN	European Organization for Nuclear Research
CRM	Customer Relationship Management
Df	Degree of Freedom
EC2	Elastic Cloud Computing
ECM	Enterprise Content Management
ERP	Enterprise Resource Planning
FPS	Flexible Payment Services
IaaS	Infrastructure as a Service
LED Team	Light Engineering Development Team
LHC	Large Hadron Collider
OS	Operation System
P2P	Peer-to-Peer
PaaS	Platform as a Service
PAYG	Pay-as-You-Go
QoS	Quality of Service
R&D	Research & Development
S3	Simple Storage Service
SaaS	Software as a Service
SLA	Service Level Agreement
SOX	Sarbanes Oxley Act
SP	Service Provider
SQS	Simple Queuing Service
VPN	Virtual Private Network

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1 Introduction

During the recent years, Cloud Computing is gaining ever more attention from academic as well as commercial world. While most people agree that Cloud Computing has a big potential of changing the IT landscape, even other aspects of our work and life in the coming future, there are still a lot of discussion about what exactly the term “Cloud Computing” should stand for, and how it can be developed into a set of useful applications, instead of a pure theoretical trend, or even a “marketing buzzword”.

The term “Cloud Computing” used in this thesis will be defined thoroughly in the next chapter. In brief, it is a computing environment or service model that enables real time delivery of products, services and solutions over the Internet, or some other centralized access points. While the Cloud Computing technology is gaining ever more attention from the public, the variety of Cloud Computing services, including forms of market coordination, price models, service level requirements etc., is growing too.

The main propose of this thesis is to study the current and future market acceptance of Cloud Computing. To notice is, before Cloud Computing, there are already several technical trends with similar characteristics, like Application Service Provider (ASP), Grid Computing etc. Despite the differences between these technologies, the main focus of academic researchers at that time was on the "technical" topic, such as like load balance, resource allocation etc. But the pure technical maturity (given that is already available) does not necessarily lead to a wide acceptance of a new technology, because there are other forces and mechanism influencing the market development of it: on one hand, the market mechanism could probably solve the resource allocation problems in systems [SNP+05, 2-3], and on the other hand, a technical trend will be of little use if it cannot gain enough commercial exposure. One of the best ways to find out the market acceptance is asking directly the users and potential users of Cloud Computing services. For this reason, a *survey* about the attitudes of current and potential users toward Cloud Computing was designed as a basis research material for this thesis. Based on this survey, analyses are done in several aspects, including general knowledge about Cloud Computing, expectations and concerns, preferred market structures and price models.

Besides the practice-oriented character, this thesis differs from other literature in many other ways. We believe the main contributions of this thesis are following: a) this thesis focuses *explicitly* on the Cloud Computing services, which are defined clearly in comparison with other "Cloud-like" technologies, such as Grid Computing, Utility Computing and so on; b) we have applied certain *theoretical frameworks*, such as the Transaction Cost Theory, on the current Cloud Computing market, trying to figure out whether these existing theories are able to deliver an framework to understand the new Cloud Computing paradigm; c) we have conducted a state-of-the-art online survey to test the prediction power of those theoretical frameworks; and d) we have provide latest information about the customers and market of Cloud Computing via this survey, such as the customers' concerns about Cloud Computing services, and the stage of market development etc.

The rest of this thesis is organized as following: Chapter 2 will provide a comprehensive definition of Cloud Computing as well as a comparison with other similar concepts like Grid Computing and Utility Computing; Chapter 3 will give a review of the status quo for the current market of Cloud Computing, as well as both theoretical frameworks related with market structures and price models; Chapter 4 will focus on the research methodology of this thesis, which mainly includes a online survey; at the core of this paper, Chapter 5 will demonstrate the survey results and provide an analyses regarding the choice of market structure and price model, based on the survey results.

2 Term Definitions and Classification

2.1 Cloud Computing

2.1.1 What is Cloud Computing

In a 30-page-report from Massachusetts Institute of Technology published in 1997, the term "*Cloud*" was firstly used as a metaphor of Internet, i.e. "*the 'Cloud' of intermediate networks*" [GiKa97, 11]. Later on, companies like Dell and NetCentric tried to trademark the term "*Cloud Computing*" but the idea was either rejected or abandoned later. The term "Cloud Computing" became known by more people after Eric Schmidt, the CEO of Google Inc. claimed in 2006 in a Search Engine Strategies Conference that Google was going to call its new business model "Cloud Computing", which allows a ubiquitous access to data and computation in a "cloud" of many servers in a remote place [Sull06]. In the same year, Amazon.com announced one of the most important Cloud Computing services by now: the Elastic Cloud Computing (EC2) as part of the Amazon Web Services (AWS), which made the term "Cloud Computing" into the mainstream then.

Cloud Computing is a new subject at both technological and commercial level, therefore various definitions can be found, focusing on different characteristics of Cloud Computing technology, services, and platform [Geel08]. The term Cloud Computing used in this thesis is defined as: *a parallel and distributed computing environment or service model that enables real-time delivery of products, services and solutions over the Internet or some centralized access points to the clients rather than installed locally on the user's device.*[1] A Cloud environment is a type of distributed system consisting of a collection of interconnected and virtualized

[1] A similar definition of Cloud Computing was given by R. Buyya et al., which described a Cloud as "a type of parallel and distributed system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements (SLA) established through negotiation between the service provider and consumers." Besides this definition, SLA is not yet a bundled part of every Cloud Computing service contract.

computers that are provisioned and presented as one or more unified computing resources and is able to deliver certain Quality of Service (QoS) to service buyers.

Among the researchers, J. Staten [Stat08, 3-4] has provided a "technical" view of some most important features of Cloud Computing, including a prescript and abstracted infrastructure, fully virtualized, equipped with dynamic infrastructure software, application and OS independent, free of software and hardware installation[2]. Compare to that, the definition of Cloud Computing and Cloud environment in this thesis represents clearly the customer's point of view rather than technical or architectural requirements. It is not to say that technical and architectural requirements are not important, but what the customers pay most attention to are the benefits they can get from the technology. For example, a real-time delivery of products and services is more important than whether the products and services are provided via Peer-to-Peer (P2P) network, Virtual Private Network (VPN) network or direct via Internet.

Given the scope of this thesis, it is impossible to study all kinds of products and services "in the Cloud", even though the market is still at a very early stage. A detailed review of the current market situation of Cloud Computing and a layered structure of different service providers (SPs) in this market will be given in Chapter 3.1. In fact, a quite heterogeneous landscape of products and services "in the Cloud" already exists, even for quite a long time: there are services used by normal consumers every day or many times in a day, for example the E-mail services from providers like Yahoo, Google or Microsoft: users do not need to use a specific operation system to get into their mailbox, they do not need to install any specific client software in their local machines to sending or receiving E-mail, and they can log into their E-mail account anytime, anywhere, all they need is a web browser and a Internet connection. The traditional E-mail service is according to this thesis's definition a perfect example of

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[2] He has also mentioned "free of long-term contracts" and "pay by consumption" as features of Cloud Computing, which are inconsistent with the definition of this thesis, and will be explained in more details in Chapter 5.1 and Chapter 5.4.

Cloud Computing, but this thesis is giving particular focus on enterprise customers, which traditionally build and own their data center as a property, and run and maintain each server and PC separately. Increasingly, computing addresses collaboration, data sharing, cycle sharing, and other modes of interaction that involve distributed resources. This trend results in an increasing focus on the interconnection of systems both within and across enterprises. The emerging Cloud Computing can mean a lot for these enterprises because of its potential in cost saving and technological advances [PSFB08, 66].

Like many other emerging technologies, the concept "Cloud Computing" often leads to confusion about its exact *connotation and denotation*, because there is no widely accepted framework to define the concept, and this new technology is still associated with many other already existing technologies and concepts. For Cloud Computing, such technologies and concepts include Virtualization, Grid Computing, and Utility Computing etc.[3]. Chapter 2.1.2, 2.1.3 and 2.1.4 will provide a detailed comparison of Cloud Computing and these computing concepts.

2.1.2 Comparing with Virtualization

Virtualization was a well-known concept firstly in network technology. It meant putting an additional layer between real systems and applications which translates concurrent access to real systems into seemingly exclusive access to the virtual system [McSc08, 1]. Nowadays, it is a technology not only associated with the software layer but the hardware too. The virtualization can be applied on servers,

[3] Another term often used as "comparable concept" to Cloud Computing is "Software as a Service" (SaaS), for which the research institution Gartner has already published a comprehensive comparison in the mid 2008, for more information you can visit: http://www.gartner.com/DisplayDocument?ref=g_search&id=640707. Besides, there are Cloud Computing services providers trying to define their own terms for their specific or general services "in the Cloud", for example Elastra, a start-up providing Cloud Computing platform, software and utility services define their service as "Elastic Computing" [Elas08]. For more information about specific Cloud Computing service providers and general information about the Cloud Computing market, see Chapter 3.1.

networks, storage devices, and even a whole data center. Typical examples for hardware virtualization on the widely used x86 architecture are the Intel VT-x technology and the AMD-V from these two leading chip manufacturers [Fish06, 5-7]. Generally speaking, the resource virtualization is the abstraction of server, storage, network, and operation system by creating a virtual version of them [Fish06]. Virtualization is certainly one of the most underlying technologies enabling Cloud Computing (as well as Grid Computing). As mentioned by Staten [Stat, 3], "nearly every Cloud Computing vendor abstracts the hardware with some sort of server virtualization." System virtualization is not a new technology; it has existed for decades aboard mainframe systems from IBM and other companies. The primary use of virtualization technologies was to support multiple operating systems. Essentially, it uses a virtual machine monitor or host called a "*hypervisor*" to enable multiple operating system instances to run on a single physical server, and based on that, it can enable hardware consolidation in an enterprise or large organization [GHWa06, 5]. At the software platform level, the heterogeneity exists too: Windows NT, Unix, or Java 2 Enterprise Edition are just the most important among them, which usually offer different implementations, semantic behaviors and APIs. For these heterogeneous systems, virtualization is the pivotal technology to realize interoperability [FKNT02, 37].

A good example of how virtualization and Cloud Computing are tightly connected is the Citrix XenDesktop, a desktop virtualization system that centralizes and delivers "*desktop as a service*" to enterprise users anywhere.[4] This virtualization technology avoids installation of all the different office software on the user's local machine and provides ubiquitous access to the software they need, and in the meantime, the system update, backup and other maintenance become much easier and more time-efficient. What the XenDesktop delivers, is a typical Cloud Computing service, although the services are not necessarily provided via Internet[5].

[4] For more information and technical details about the product, you can visit http://www.citrix.com.

[5] See the definition of Cloud Computing in Chapter 2.1.1.

Another commonly-used virtualization technology in Cloud Computing is the 3Tera's *Applogic®*, which can eliminate the binding of software to hardware in a Grid/Cloud Computing system. The Applogic system enables software running in a completely virtualized execution space with virtualized access to storage and networks. According to 3Tera [3Ter08], almost any piece of Linux software can be made into a virtual appliance, which enjoys a great scalability because it consumes no processing resources and only a small amount of storage when it is not running, and the resource used by each appliance in production is only assigned at runtime.

But Cloud Computing is not yet the same as virtualization. Firstly, as described before, virtualization was often used to utilize the usage of a single machine rather than to build a combined network; that kind of "single machine virtualization" is not really within the scope of Cloud Computing. Secondly, although virtualization is a useful tool at the operation system (OS) level to provide hardware portability and OS segregation, but virtualization in-and-of-itself does not provide necessary capabilities of Cloud Computing, like scalability, system continuity and certain level of QoS[6]. To deliver the desired usage of Cloud Computing, virtualization technology should be used alongside other components of s dynamic IT infrastructure. Compared to virtualization, Cloud Computing is more like a kind of "*technology cluster*", which contains more than one distinguishable, but interrelated elements of technology [Roge03, 249-250]. Virtualization is certainly one among these elements, but so do distributed technology, load balancing technology, and web services, to name just a few. This kind of bundled innovation package usually leads to greater flexibility in development process and faster adoption in the market.

2.1.3 Comparing with Grid Computing

The term "Grid Computing" has a longer history than Cloud Computing. Researchers like M. Chetty and R. Buyya [ChBu02, 61-64] have pointed out the development of

6 The features and potential benefits of Cloud Computing will be discussed in more details in Chapter 5.2.

Grid Computing is a natural result from both *demand* and *supply* sides: on one hand, the fast development of distributed and high-performance computing has made the remote delivery and collaboration of computing resources possible, and more importantly, all the basic computing resources like the CPU, disk storage, bandwidth and fiber are growing on exponentials, which greatly improved the ability of computers to complete big and complex projects [FoKe04, 567-575]; on the other hand, many scientists and commercial tasks requiring large-scale, data- and resource-intensive applications have driven the need for scalable computing network beyond a single computer.

According to I. Foster and C. Kesselman [FoKe04, 44-46], Grid Computing is *a technology or a system that enables the sharing, selection, and aggregation of a wide variety of geographically and organizationally distributed resources (like supercomputers, storage systems, data sources, etc.) using standard, open, general-purpose protocols, and delivers the desired QoS via some virtual computing systems*[7]. Therefore, a Grid system enables resource sharing; provides transparent access to remote resources; allows On-Demand aggregation of resources at multiple sites; reduces execution time for large-scale, data-processing applications and provides vast scalability to meet unforeseen emergency demands.

Based on the definition from Foster and Kesselman, the features of Grid computing can be summarized as following: a) it works in distributed systems; b) it is based on a standard, open and general-purpose protocol; c) it needs certain QoS. Therefore, similar to other famous "*Grids*" in our daily life, like Electrical Power Grids or the Railway Systems around the world, the Grid Computing is primarily focusing on the *infrastructure of computing*. Contrarily, Cloud Computing entails the technical infrastructure as well as the *service model and commercial application* upon it.

[7] Similar as for Cloud Computing, a unanimous definition of Grid Computing is hard to find. The definition from Foster and Kesselman is authentic in this relative context because they both are pioneers and main researchers in the "Global Grid Forum" (GGF), a community of users, developers, and vendors leading the global standardization effort for Grid Computing.

There are no global standard architectures of Cloud Computing comparable to the Global Toolkit of Grid Computing [Fost05, 513-514], and Cloud Computing does not necessarily needs a "standard, open, general-purpose protocol" as in the case of Grid Computing [8]. Furthermore, Cloud Computing supports interfaces that are "syntactically simple, semantically restricted and high-level" [JMF008, 1]. These features of interfaces are underlying factors for a rapid adoption of Cloud Computing services in the business world, because they are simple to use, especially compared to the Grid Computing systems. Till now, the Grid systems have a strong scientific orientation, and are mainly supported by research user communities rather than commercial organizations, and most of them are publicly funded, i.e. without clear profit-orientation [CERN08, 6]. Examples for the use of Grid Computing in scientific projects are easy to find, such as the "Virtual Observatory" project in worldwide astronomy communities[9], the "Biomedical Informatics Research Network" (BIRN) for medical research and patient care[10], and the Grid system designed for the "Large Hadron Collider" (LHC)[11]. Compared to that, Cloud Computing has and intends to have a much broader user base, including non-IT companies and individuals seeking commodity-like IT services, e.g. system backups, document management, or file editing. Some researchers may argue that so-called "*Enterprise Grid Systems*" are

[8] Such a protocol is useful for a public Cloud Computing platform or infrastructure, but not necessary for internal use of Cloud Computing technology within an organization.

[9] A project seeking to provide portals, protocols, and standards that unify the world's astronomy archives into a giant database containing all astronomy literature, images, raw data, derived datasets, and simulation data, integrated as a single intelligent telescope. For more information about the project, please visit: http://www.ivoa.net/. For more information about the use of Grid Computing in this project, see [SzGr04, 102-107].

[10] The project aims to share and mine data for both basic and clinic research (in United States). For more information about the project, please visit: http://www.nbirn.net/. For more information about the use of Grid Computing in this project, see [ElPe04, 115-120]

[11] The LHC at the European Center for Nuclear Research (CERN) is designed to record data from the highest-energy proton-proton collisions yet produced. For more information about the LHC, please visit http://lhc.web.cern.ch/lhc/. For more information about the use of Grid Computing in the project, see [GCC+04, 137-145]

getting more and more accepted by the enterprise users, and there are many big IT companies providing Grid Computing solutions, including IBM, Sun, Oracle etc. [NaBu05, 3-4]. But in fact, *none* of these solutions really have a broad customer base after being launched a couple of years ago. For example IBM has only two "Customer Success Stories" on its Grid Computing solution websites (which is quite rare for a big company like IBM), one from a non-profit community (University Health Care System) and another from a university research center (Forschungszentrum Karlsruhe)[12]. On the contrary, Cloud Computing represents a technology by which the research development even lag behind the industrial adoption [MCTs08, 1-2]: leading Cloud Computing services providers like Amazon AWS and Salesforce.com have already attracted thousands of customers, ranging from traditional companies like Allianz Insurance and Washington Post, to small- and middle-sized startups[13]. The Cloud Computing paradigm is currently discussed so much in the business world, that some researchers even regard it as a "marketing buzzword" rather than a real technical trend. To notice is, this process of commercialization is a necessary step of the technology development, and it is by no means less important than the pure technical innovation for the adoption of the technology [Roge03, 152-153]. To put it in another way: Cloud Computing may use a lot of Grid technologies too, but the most substantial difference between Grid and Cloud is not the technology but the business models. The Cloud Computing does support Grid, but can support non-grid environment too; there are ways to implement Grid applications in a Cloud environment [McSc08, 5]. And back to the definition of Cloud Computing in Chapter 2.1.1, it focuses more on *how and what kind of services* users get.

[12] For more information about the IBM Grid Computing, please visit: http://www-03.ibm.com/linux/grid/.

[13] A detailed description of the current market situation for Cloud Computing services will be provided in Chapter 3.1. For more information about the customer base of Amazon AWS and Salesforce.com, please visit: http://aws.amazon.com/solutions/case-studies/ and http://www.salesforce.com/customers/case-studies.jsp.

2.1.4 Comparing with Utility Computing

Compared to other computing paradigms like Grid Computing and Cloud Computing, the term "*Utility Computing*" is much older and already has a history of 40 years. To the best of our knowledge, the first time the concept of using computing resources in a "utility" manner was in 1961, when the computer scientist John McCarthy predicted in a speech given to celebrate MIT's centennial, that "*computing may someday be organized as a public utility*." [Carr08, 59] And a few years later, Leonard Kleinrock, one of the chief scientists of the original Advanced Research Projects Agency Network (ARPANET) project which was the initial form of today's Internet, brought this concept a step further by saying [Klei05, 4]: "As of now, computer networks are still in their infancy. But as they grow up and become more sophisticated, we will probably see the spread of '*computer utilities*' which, like present electric and telephone utilities, will service individual homes and offices across the country." During the last 40 years, the vision of a 24/7-accessible, multi-functional, and "invisible" Internet is becoming a truth. Especially the commercialization of the Internet during 1990s has greatly enabled the Utility Computing because the necessary bandwidth for delivering computing services as a utility via Internet was finally available. Therefore, the Utility Computing concept is becoming a hot topic again.

3Tera[14] has defined Utility Computing as following [3Ter08]: "Utility Computing has sparked imaginations with visions of Pay-as-You-Go (PAYG) billing, and dynamic resources for years. The concept is simple…businesses subscribe to a utility computing service and pay for the resources they actually use." And a similar but more concrete definition can be found by M. A. Rappa from the IBM Global Services [Rapp04, 38-39]: "Utility Computing is the delivery of infrastructure, applications, and business processes in a security-rich, shared, scalable, and standards-based computer environment over the Internet for a fee. Customers will tap into IT

[14] 3Tera is a major Utility Computing and Cloud Computing technology provider. For more information please visit: http://www.3tera.com/.

resources - and pay for them – as easily as they now get their electricity or water". Although the latter definition hasn't literally mentioned "Pay-as-You-Go" (PAYG) model, but the analogy between Utility Computing and electricity or water indicated clearly the inherent price model of Utility Computing.

The vision of Internet and especially of the computing utility mentioned before, based on the *service provisioning model* (like the electric and telephone utilities), anticipates the massive transformation of the entire computing industry in the 21th century whereby computing services will be readily available in today's society. Here we see a major similarity of the concept Utility Computing and Grid Computing: computing service users need to pay providers only when they access computing services, and they no longer need to invest heavily or encounter difficulties in building and maintaining complex IT infrastructure. Cloud Computing shares these features too, but Cloud Computing is not necessarily built on an entire "Pay-As-You-Go" basis, and migration cost as well as other problems of Cloud Computing services do not necessarily lead to an easily built IT infrastructure. All these points will be discussed in more details in Chapter 5.

In this thesis, Utility Computing will be seen as part of the whole Cloud Computing concept. For example, some services provided by Amazon AWS, the current leading Cloud Computing SP, can be regarded as typical "*utility-like*" services[15]. Cloud Computing is a broader concept because it is not just about the basic resources and infrastructure, but about the application design, deployment and operation too.

2.2 Market participants in the Cloud Computing business

In this thesis, the categories of market participants in the Cloud Computing business are simplified as either *service providers* (SPs) or *service buyers/users*. The SPs include organizations which provide computer resources like storage spaces or CPU power, applications and platform for exchange of the resources mentioned above. A

[15] Such as the Elastic Cloud Computing (EC2) service, the Simple Storage Service (S3), this will be discussed in more details in Chapter 3.1.2.

SP in the market is usually responsible for price setting, admission control and resource management. Service buyers/users are their counterparts, and as defined, an organization can be a SP and a service buyer at the same time, e.g. someone uses Amazon's Simple Storage Service (S3) service to provide higher level backup management services. A table of major SPs in the current Cloud Computing market will be provided in Chapter 3.1.2.2.

Another common type of market participants is the *service broker*. Like other markets, Cloud Computing markets also need *intermediates* (brokers) to reduce the transaction cost of services and simplify the transactions for both service buyers and providers. In the definition of this thesis, the role of market broker is mainly covered by *providers of platforms* for Cloud Computing resource exchange, including raw computing power and applications. A typical example of those trading platforms for raw computing power is the "Zimory Marketplace" from Zimory.com, which is described by them as "Public Cloud". Through the Zimory Marketplace, SPs like data center operators can list the unused resources available on their servers and the service users can obtain the desirable data center resources via a Zimory software installed in their local machines [Zimo08, 5]. An example of the trading platforms for Cloud Computing applications would be the AppExchange platform from Salesforce.com, which is building an ecosystem for On-Demand Customer Relationship Management (CRM) software in a community model [Tenw08, 2-3][16].

2.3 Market structure

In terms of market structure of Cloud Computing, this thesis focuses on the forms of transaction, i.e. how transactions of Cloud Computing services are coordinated. Typical forms of market coordination include:

- *The short-term contract*, where service users can buy the desirable service any time they want, from an open and ubiquitous market, without or almost without

[16] More information about Salesforce and the ecosystem of Cloud Computing applications built on the Force.com platform can be found in Chapter 3.1.2.1.

any long-term commitment to the SPs. This indicates the flexibility by decision-making of both sites as well as the instability of the service contracts;

- *The in-house transaction*, which means the buyers prefer not only to receive the services, but also to own the whole products and infrastructure, therefore gain the whole control of the service activity;
- *The long-term contract*, which is a mixture form between short-term contract and in-house transaction. The long-term contracts are usually based on a certain framework between the SP and the service buyer, and provide the buyer a mixture of standard service and specialized facility. The Long-term contracts link sellers and buyers for a long period into a bilateral monopoly in form of a large-scale partnership [NeHi05, 5], which can last as long as many years, and during which the both sides have strictly defined rights and obligations.

A common example of short-term contract is staying in a hotel: the buyers can choose any hotel and stay as long as they want, for one day or a month. There are some terms and conditions between the guest and the hotel, like room cleaning service will be provided every day from the hotel, and the guest should pay for anything he damaged, but the guest does not have any long-term commitment to the hotel, i.e. he can move out of the hotel at any time and simply stop the service. By contrary, an “in-house” solution will be building or buying a property, like a house or an apartment. In that case, one pays the whole construction cost of the property, i.e. “buying the product”; instead of paying for each night he stays in the house. A third way of finding a place to stay will be renting a house or an apartment, which is regarded as a typical example of “long-term contract” here. More discussion about the market structures can be found in Chapter 3.2.1.

2.4 Pricing models

The price model is important because pricing is usually one of the biggest influencing factors for a business decision. Although still at its early stage of development, Cloud Computing is rapidly getting more and more attentions from potential users. For the SPs, an inappropriate price model could either lead to excessive reluctance of potential users to migrate and update to new services, or alternatively, to excess demand that they cannot fulfill profitably or scale to meet reliably. Either scenario could be substantially damaging for the development of Cloud Computing.

This thesis derives the "*purchasing cost*" (i.e. not the transaction cost) of using Cloud Computing services directly from those price models. There are many different price models in the business world, and so far, a detailed comparison of different price models from a market's view was not been drawn. Nonetheless, it may become a critical influencing factor in the consumer's decisions about whether and how they want to use Cloud Computing services, because one of the most discussed feature of Cloud Computing is that the users do not need to install the software or applications in every local machines and can use the software as a service, the so-called "Software as a Service" (SaaS) model.

Naturally, in such business model, users can be charged based on their actual usage of resources, which is described as the "Pay-as-You-Go" (PAYG) price model. Interestingly, not every SP in the market chooses the PAYG model by now; instead of that, the traditional Flat Rate model, as well as a Mixture model, which combines certain monthly or annually basic charge (Flat Rate) with a PAYG price schedule (for usage surpassing certain amount) are still very popular[17]. This phenomenon leads to the discussion in this thesis about what are the influencing factors in choosing different price models for different Cloud Computing services.[18] A comprehensive comparison of all existing price models is beyond the scope of a master thesis. Therefore, the following price models are chosen as researching objects for this

[17] More details about price model used by current service providers in the Cloud Computing market can be found in Chapter 3.1.2.

[18] See Chapter 3.2.1.4.

thesis, simply because they are by now the most popular models for existing Cloud Computing services in the markets[19]:

- *PAYG model*: also known as "*usage-based price model*", by which the users are charged according to their actual usage of resources. Due to the technical obstacles of billing and accounting, PAYG model for IT services (hardware as well as software) was often discussed, but rarely implemented until recently. Another problem about the PAYG model is the matching between price and costs: the software and computing resources are often regarded as typical information goods, for which the traditional *marginal cost pricing method* cannot be applied, since the marginal cost of information goods is zero. However, researchers like K-W. Huang and A. Sandararajan argued that the On-Demand computing services are not really information goods, because their provision involves "non-trivial variable costs that relate to customer service, billing and monitoring" [HuSu05, 2].
- *Flat Rate model*: users are charged a *fixed* amount per time unit, irrespective of actual usage of resources or applications. As the simplest and most convenient price model for both sides of market participants, Flat Rate model requires no accurate measurement for billing and accounting, but provides no incentive of optimizing the resource allocation, because the buyers are insensitive to the actual cost of their service/resource requests. More details about the pros and cons of Flat Rate model can be found in Chapter 3.2.2.2 and 3.2.2.4.
- *Mixture model*: a mixture of PAYG & Flat Rate models. Users are charged a certain fee for resource usage within a certain period, and under a certain cap, e.g. €20 per month for 500 GB online storage space. This fee is fixed no matter the 500 GB storage space is actually used or not. Usage beyond this amount will be

[19] Some researchers believe that PAYG is a solid feature of Cloud Computing [Stat08, 5], as described in Chapter 2.1.4, this thesis regards PAYG as a feature of Utility Computing, which is then a part of the broader Cloud Computing concept.

charged based on the actual usage then. More details about the Mixture model can be found in Chapter 3.2.2.2.

3 Status Quo

3.1 Current market overview

3.1.1 General

Cloud Computing is a booming technology, but in its early age. Compared to other distributed system technologies like Grid Computing, Cloud Computing is especially "market-oriented", and the market situation for Cloud Computing services is yet very complex: in general, the Cloud services for individuals, like the webmail services from Microsoft, Google and Yahoo etc. are already an indispensable part of people's online life. But a market of Cloud Computing services aiming at *enterprise customers* is not yet well developed. These kinds of services include raw computer materials, like CPU power, storage space and memories; software like office software toolkit and Enterprise Resource Planning (ERP) software etc.; as well as IT services like backup service and software change management service. For a long time, companies prefer to keep all the related resources in certain places, either in their own data center or a dedicated data center, and buy or let special IT SPs design software for them, and then own the software as their properties. These consuming patterns of IT services are changing because of the emerging Cloud Computing services for enterprises. As companies seek to consume their IT services in a more cost-effective way, interest is growing in gaining a broad range of services, e.g. computational power, storage and business applications, from Cloud Computing SPs rather than from on-premises equipment.

Facing the ever larger demand of Cloud Computing services, various analysis institutions have mostly made bullish predictions in the market growth of Cloud Computing in the near future (See the table below). IDC [IDC08a] forecasted[20] that the Cloud Computing services will enjoy a growth rate of 27% CAGR in the next 4

[20] This report was based on a customer survey aiming the enterprise end-users of IT products and solutions, through both on-premise and Cloud Computing services.

years and reach a total market volume of $42 billion, accounting for 9% of overall customer spending on IT services. In a more aggressive prediction, Merrill Lynch [Klem08]issued a research note said that the Cloud Computing market will reach a volume of $160 billion in 2011, including $95 billion in "business and productivity applications" like office software and ERP solutions[21], and $65 billion in online advertising. In an enterprise software customer survey conducted by McKinsey and SandHill [DMBR08], 12% of the respondents claimed that they would consider using Cloud Computing services[22]. Gartner Inc., one of the world's leading information technology research company, has predicted the future of Cloud Computing more than one time: once they said in the Gartner's Symposium ITXpo (Las Vegas) in 2008 that by 2012, 80% of Fortune 1000 companies will pay for some Cloud Computing service, and 30% of them will pay for Cloud Computing infrastructure[23] [CERN08, 5]; A more conservative prediction from Gartner Inc. is that Cloud Computing services need at least 7 years to mature, so by 2015, "Cloud Computing will have been commoditized and will be the preferred solution for many application development projects" [Gart09a]. As a leading provider of Cloud Computing service, Amazon AWS has enjoyed a quarterly growth rate of 12% during the period from 2005 to 2008 [Morg08]; another example of how quick the Cloud Computing services from Amazon are expanding is that in mid 2007, the total bandwidth consumption of AWS is already more than the bandwidth consumption of Amazon's Global Websites, the websites providing the traditional eCommerce services. The table below summarizes the predictions about Cloud Computing from various institutions.

Table 1 Various Statements about Cloud Computing Market

Institutions	Statements

[21] This market volume hasn't included the exchange of raw computer materials.

[22] The Cloud Computing services defined in this survey was focusing on the infrastructure level, i.e. computing capacity, like Amazon EC2. Their counterpart is the traditional managed hosting service in a data center.

[23] = the computing resources.

IDC	**27% CAGR[24] during 2008 - 2012, market volume of $42 bn in 2012**
Merrill Lynch	**Market volume of $160 bn in 2011, inc. $65 bn of online advertisements**
McKinsey & SandHill	**Already 12% companies prefer Cloud Computing for their IT services now**
Gartner Inc.	**By 2012, 80% of Fortune 1000 will be using Cloud Computing services, and 30% of them using Cloud Computing infrastructure**
	Cloud Computing will be mature and massively used in 2015

3.1.2 Service provider (including Service intermediate)

3.1.2.1 Pyramid model of Cloud Computing market

Cloud Computing services as a whole are certainly not homogeneous, and the market for Cloud Computing services is not consist of all similar providers, either. In fact, services provided in this market are quite different regarding their inherent characteristics as well as their business models. Figure 1 below demonstrates a layered structure of current Cloud Computing market, based on Blau et al. [BBSt08, 2] and Youseff et al. [YoMa08, 4].

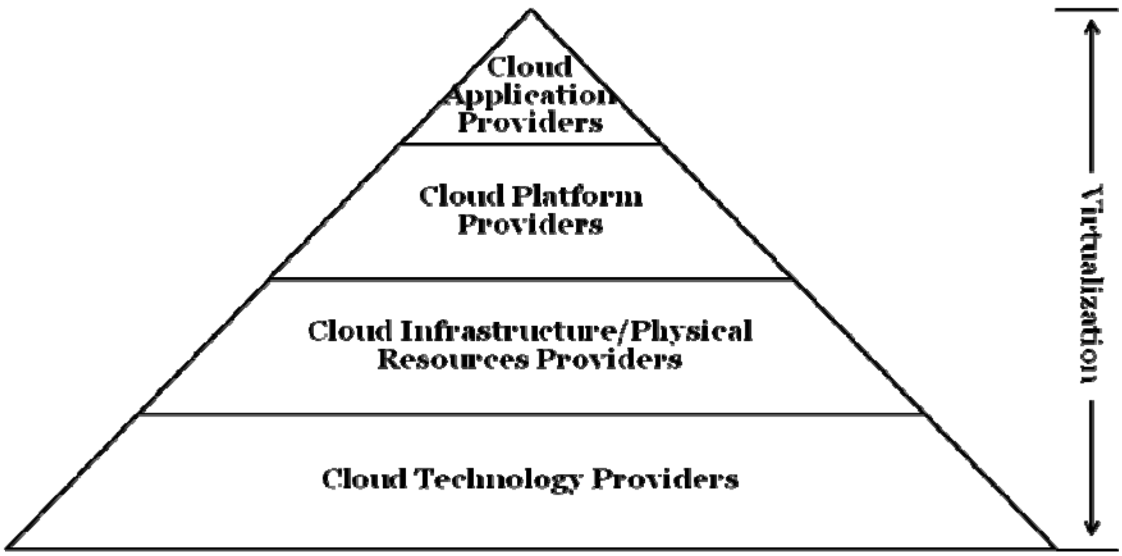

Figure 1 "Cloud Pyramid": Layered Structure of Cloud Computing Services

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[24] CAGR = Compound Annual Growth Rate, which measures the rate of change in a value between two points in time.

- *Cloud Technology Providers*: they are basically the "Cloud enablers", because their technologies are the first step of enabling a Cloud structure. The Technology Providers on the current market can be divided into two types: a) Companies developing and implementing Cloud Computing technology by themselves; and b) Companies focusing purely on technology and delivering the technology to other Cloud SPs. The typical example of the first type is Amazon, which has designed and implemented a whole new, idiosyncratic structure for its ecosystem of Cloud Computing services[25]; and the current leading company of type b is 3Tera. It provides the AppLogic operating system[26], which can be used to transform a normal data center into a "*Grid system*", and therefore enables other companies to provide Cloud Computing services based on that system architecture. The companies providing hosting services based on 3Tera's technology include Gridlayer, Agathongroup, Areti and many other important players in the Cloud Computing market[27].
- *Cloud Infrastructure/Physical Resources Providers*: the physical infrastructure provides fundamental resources to higher-level services such as application services. As suggested by Youseff et al. [YoMa08, 5-6], the physical resources in Cloud Computing market can be categorized into three categories: a) Computational resources, which are commonly calculated in CPU hours. Typical examples are the Amazon EC2 and Google App Engine; b) Data storage; and c) Communication. Among all Cloud Computing services, providing data storage service is relatively easier compared to others, because the physical storage devices are already commodities and the virtualization technology for storage

[25] Currently, the Cloud Computing services provided by Amazon AWS include the file storage system "Simple Storage Services" (S3), the On-Demand computing power service "Elastic Compute Cloud" (EC2), the distributed database service "SimpleDB", the content distribution system "CloudFront", the messaging & queuing service "Simple Queuing Service" (SQS), and the payment processing system "Flexible Payment Services" (FPS). For more information, please visit: http://aws.amazon.com/.

[26] For more information about the AppLogic technology, please visit http://www.3tera.com/ .

[27] See Chapter 3.1.2.2.

system is already mature. Therefore, the number of mid-sized providers of Cloud storage services is growing fast. Typical examples include Areti, Enki, Terremark etc., as well as some traditional data storage/ data center providers like EMC, AT&T etc[28].

- *Cloud Platform Providers*: a platform is a place to exchange certain resources. There are basically two types of Cloud platforms: a) platform for raw computer resources exchange; and b) platform as a software environment for developing, testing, deploying and running Cloud Computing applications. The first type, which can be described as the Ebay for computer resources, can only be built in an environment where exchange of raw computer resources is already a common business, and the widely expected standards for the exchange already exist. As these conditions are not yet reached in the market, the only currently available platform for computer resource exchange is the Zimory Marketplace from Zimory GmbH, a spin-off of Deutsche Telekom Laboratories[29]. The second type of Cloud platform is more common. Typical examples for that include the Force.com from Salesforce, the leading On-Demand CRM software provider, and Google App Engine, which provides raw computer resources in the meantime[30]. As the most successful Cloud Computing application[31] provider, Salesforce currently has more

[28] See Chapter 3.1.2.2

[29] Although Zimory described using their "Public Cloud" as easy as "taking 4 steps and less than 10 minutes", but the actual deployment process can be much more complex [Zim009]. Another interesting thing about Zimory is: currently, the only resource provider in the Zimory platform is the T-Systems, a subsidiary of Deutsche Telekom AG, and therefore tightly connected with Zimory; and during the deployment process, users can see the fix prices for CPU hour, memory, storage, and I/O bandwidth directly in their homepage, independent from which service provider they are going to choose. This raises the question about whether Zimory is really planning to become a kind of "auctioneer for computing resources", by which they prices usually should be determined by the buyers and seller themselves then. For more information about the company Zimory GmbH, please visit http://www.zimory.com/.

[30] See Chapter 3.1.2.2.

[31] It is also named as "Software as a Service" (SaaS) or On-Demand application.

than 50.000 customers, ranging from large-scale enterprises like Toyota (Europe) and Dell, to many other mid- and small-sized companies. The "*AppExchange*" platform, the platform provided by Salesforce for application exchange, currently contains more than 800 different CRM applications, from which the customers can choose freely to use in their Salesforce system and therefore build a fully customized CRM solution for their companies. According to a customer survey from Gartner [MEPD08, 3], nearly 90% of organizations expect to maintain or grow their usage of Cloud Computing applications. This kind of application ecosystem by Salesforce is a typical example of how the Cloud Computing services are evolving and becoming accepted by more and more users.

- *Cloud Application Providers*: this is the most complex, but also indispensable part of a whole Cloud Computing structure. Cloud applications can be categorized into: a) "*elementary applications*"; and b) "*complex applications*". Unlike Blau et al. [BBSt08, 2-3], the difference between elementary and complex applications is mainly characterized by the homogeneity of applications rather than the complexity of their functions. The reason is: homogeneous applications are more like commodities; hence their economic characters share more similarity with the basic services in the Cloud Computing structure, i.e. providing the raw computer resources. And as will be discussed in more details in Chapter 3.2.1 and Chapter 3.2.2, the main purpose of this thesis is to examine the possible connection between service homogeneity, market structure, and price model for Cloud Computing services. Rather than to define which applications are elementary or complex, this thesis will make classifications directly based on the results from the customer survey, which will be presented in Chapter 5.

3.1.2.2 Service providers in Cloud Computing market

The earliest Cloud Computing SPs are typically the Internet service companies with vast amount of computing resources, and in the meantime, a big *volatility of service requests* during peak time and normal time [YoMa08, 7]. These companies, like Amazon and Google, have the natural needs to improve the *utilization rate* of their infrastructure by providing their computing resources during non-peak time. But as more and more companies see the potential of the Cloud Computing markets, both traditional IT companies like IBM, and new technical startups begin to expand in this new market, and Cloud Computing services are becoming more important than just a way to cover expenditures caused by under-utilized infrastructure.

Below is a list of the 38 most active SPs in current Cloud Computing market. Although the market is still at its early age, listing all the SPs in the market will be far beyond the scope of a master thesis. Therefore, this list of selected SPs is mainly based on the company's influence, the kinds of services they provide, as well as their development potential. The works from researchers like J. Staten [Stat08, 6], R. Buyya et al. [BYV+08, 11-12], N. G. Carr [Carr09] and institutions like Information Week [Info08] are taken as reference.

Table 2 The Most Active SPs in Current Cloud Computing Market (Excerpt) [32]

No.	Companies	Active / Beta	A/P/R/T[33]	No.	Companies	Active / Beta	A/P/R/T
1	**10Gen**	**B**	**P, A**	**20**	**Eucalyptus**	**A**	**T**
2	**37signals**	**A**	**A**	**21**	**FlexiScale (Xcalibre)**	**A**	**R**
3	**3Tera**	**A**	**R, T**	**22**	**Fortress ITX**	**A**	**R**
4	**Adobe Acrobat**	**B**	**A**	**23**	**Gh.o.st**	**B**	**A**
5	**Akamai**	**A**	**A, T**	**24**	**GoGrid/ ServePath**	**B**	**R**
6	**Amazon AWS**	**A**	**R**	**25**	**Google**	**B**	**R, P**
7	**Aptana**	**B**	**R, P**	**26**	**IBM**	**A**	**A, T**
8	**Areti (Alentus)**	**A**	**R**	**27**	**Joyent**	**A**	**R, A**
9	**AT&T**	**A**	**R**	**28**	**Microsoft (Azure platform etc.)**	**A**	**R, A, P**
10	**Cassatt**	**A**	**A, T**	**29**	**Mosso**	**A**	**P**

32 The full list in attached in Appendix A. Last update: 10. Feb. 2009.

33 A= Application, P= Platform, R= Physical resource, T= Technology

11	**Cisco Systems**	**A**	**A, T, P**	**30**	**NetSuite**	**A**	**A**
12	**Citrix (inc. XenSource)**	**A**	**A, T**	**31**	**Project Caroline (SUN)**	**B**	**P**
13	**Cloudworks**	**A**	**R, A**	**32**	**QuickBase**	**A**	**P, A**
14	**cohesiveFT**	**A**	**P, T**	**33**	**Right Scale**	**A**	**A, T**
15	**Dell**	**A**	**R, T**	**34**	**Salesforce**	**A**	**P, A**
16	**Elastra**	**A**	**R, P, T**	**35**	**SUN Network.com**	**A**[34]	**R, A**
17	**EMC (inc. VMware & Mozy)**	**A**	**R, T, A**	**36**	**Terremark**	**A**	**R**
18	**Enki**	**A**	**R**	**37**	**Workday**	**A**	**A**
19	**Enomaly**	**B**	**T**	**38**	**Zoho**	**A**	**P, A**

The above table indicates following facts:

- *The Cloud Computing market is expanding quickly*: while many projects or startups are still in beta or preview release, more and more companies, especially the "traditional players" in IT services like Dell, IBM, Microsoft and SUN are providing formal release of their Cloud Computing services. Just during the past two months from end 2008 to Feb. 2009, Amazon AWS has added new services (CloudFront and FPS) into their ecosystem of Cloud Computing; expanded their EC2 services into Europe; and allowed EC2 to support Windows. Many other companies in the Cloud Computing market have experienced the same or even higher speed of expansion.
- *Many companies are trying to open up more than one market segment*: in the early stage of market development, a mature market structure is not yet available, and companies are often forced to provide "*bundle*" of resources and services, because there are no other partners in the market who can provide those resources or services for them. So as Google or Salesforce wanted to build a

[34] The network.com is currently in transition and closed to new customers. But the existing customers and applications using Network.com are still offered continued service.

platform for sale and exchange of On-Demand software, they had to use their own computing resources to deploy them; and as IBM or EMC wanted to sell their new Cloud Computing applications to attract more data center customers, it must develop their own technology to support them. Besides, companies are also not sure about how each market segment will develop, and which segment is the potential best fit for them. An example of companies changing their service catalog is the *Network.com* from SUN. When this service was announced back to 2004, it was highlighted by SUN as a Utility Computing service for enterprise customers, but after being proofed unattractive for the massive business use, SUN is conducting a transition of the Network.com now, preparing to provide a more mature service combining the basic computing resources with useful applications[35]. This example shows that at the infancy stage of a technical trend, the best strategy for the SPs in the market, especially the big ones with more resources, may be "try-and-fail": opening up more market segments parallel, and than focusing on those with the most success.

- *Traditional IT service companies and startups are following different routes of development*: companies like Dell, IBM and EMC are trying to provide Cloud Computing services as "add-on" or additional service. This is because they regard Cloud Computing as a technology in its early age, and thus are not eager to put it into mass use; in the meantime, this also helps them to introduce Cloud Computing services to their existing, but more innovative customers, even makes the research and test of services easier by targeting a small scope of "pioneer" customers. By contrast, startups are usually focusing more on the most innovative services, like Utility Computing and Software as a Service (SaaS). This is partly because the traditional players in these fields, like Seagate, the leading storage device provider, or SAP, the leading ERP system provider, are not yet very active in putting their products or services "into Cloud".

[35] For more information, please visit http://network.com/ and the official website from SUN Microsystems.

- *Open source projects are playing an important role in the Cloud Computing market*[36]: there is no wonder that Cloud Computing services are welcomed by various open source projects, since they have the potential in lowering costs, especially initial investments of the projects, and surpassing the barriers for software development too. In the meantime, open source projects help to enrich the services provided in the Cloud Computing market or a Cloud Computing ecosystem, e.g. the Eucalyptus, imitates the experience of using Amazon EC2, but give the users the possibility of choosing computing resources by themselves, which means they can run the Cloud Computing service internally too.

3.1.3 Service buyer

As mentioned in Chapter 2.1.1, this thesis is focusing on the *enterprise customers* rather than the individuals consumers. Currently, the customers of Cloud Computing are mainly *small companies and startups*. According to Joyent [Boot08], a startup providing Cloud Computing platform for web-based applications, the majority (65%) of their current customers is so-called "Light Engineering Development Team" (LED Team), because they want to avoid the difficulty of going through the whole process of getting approval to run an experimental application inside a legacy data center, or because Cloud Computing services have the potential in cutting costs, compared to the internal transfer cost within the IT departments of many companies. According to J. Staten [Stat08, 9-10], the types of project companies that are willing to use Cloud Computing services are usually: a) R&D[37] projects; b) Low-priority business applications; and c) Web-based collaboration services. And the use of Cloud Computing services is often limited to a department or a short-term project. Here, we can find a certain *mismatch* between the customers' needs and currently provided services: such as Computing resources, as well as ERP or CRM software, are usually the core part of a company's IT activities, rather than "low-priority" applications.

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[36] See Table 14 in Appendix A.

[37] R&D= Research & Development

In the meantime, according to a Gartner survey among *data center executives*, more than half of large enterprise data center executives expect to get some IT services from the cloud within two years [Bitt08], which shows that the growing rate of Cloud Computing market can be very high in the coming years. And companies like Cisco and Citrix[38], which provide web-based collaboration services, are drawing more and more attention from customers, because the Cloud Computing services just seem to be the natural development of their existing solutions.

3.2 Research status

3.2.1 Theoretical groundwork and frameworks for market structure

3.2.1.1 General

While the market structure of Cloud Computing services is rarely discussed in academic literature because Cloud Computing is a new concept and still in its early phase of development, what can be found are papers about market structure and architectures of Cloud-like technology, such as Grid Computing. These concepts share many similar features with the emerging Cloud Computing services. Chetty et al. compared the operational models of Grid Computing and traditional electrical grids [ChBu02, 65-70], and drawn a structure of three types of market participants: a) the *producers* (resource owner); b) the *consumers* (Grid's user); and c) the *resource brokers*. According to them, the whole Grid architecture worked as a global open market then. Yeo et al. created a layered Grid architecture for the so-called Grid economy, including a Grid fabric software layer (basic resources), a core Grid middleware layer, a user-level middleware layer and a Grid application layer; and built a service-oriented architecture for utility-like Grid services based on these layers [YBA+06, 3-17]. AuYoung et al. suggested using contracts to coordinate the SPs and service users in a Grid system [ARWW06]. Eymann et al. differed resource services from application services (including basic and complex services); then drew a

[38] See **Fehler! Verweisquelle konnte nicht gefunden werden.**.

two-tiered market structure for Grid Computing services, in which a resource market involves trading of computational and data resources such as processors, memory, etc; and a service market involves trading of application services [ENR+06, 4]. The separation between two different markets should help to reduce the complexity of analyzing market mechanism, and also allow different market structures to be implemented for different type of resources/services. Neumann et al. developed a similar layered market structure like by Eymann et al., and suggested different market mechanisms for application service markets, such as multi-attribute combinatorial auction, MACE-mechanism [39], augmented proportional share, decentralized local greedy mechanism, the derivative markets, and the bargaining protocol [NSW+08, 70-72].

All these literatures started from a theoretical point of view and tried to design an optimal market mechanism for Grid services[40]. Some suggested mechanisms, such as the multi-attribute combinatorial auction, can be extremely complex and hard to implement in reality. As in reality, market mechanism provided by service providers can often be much simpler. For example Amazon EC2 uses a “take-it-or-leave-it” mechanism, which means the price and terms are all set ex-ante by Amazon, users decide whether or not to purchase the services.

So the situation for Cloud Computing services is a bit different from the theoretical focus: as there are already a number of Cloud Computing services available in the market now, an examination of practically-implemented market mechanisms, as well as the desirable mechanisms from the consumers’ point of view, will shed light on the question about the optimal transaction forms for the market participants. Instead of developing a new theory about how the market participants choose the form of

[39] MACE means “Multi-attribute combinatorial exchange”, a market mechanism allowing multiple buyers and sellers simultaneously the submission of bids on heterogonous services expressing substitutability and complementarities. See [ENR+06, 6-7].

[40] Some latest papers among them also mentioned typical Cloud services like Amazon EC2, although literally called them “Grid services” [NSWe08, 65-66].

transaction[41], this thesis will reexamine one classical theory of market structure: the Transaction Cost Theory from O. E. Williamson.

The Transaction Cost Theory from Williamson will be summarized in the following Chapter, and the hypotheses developed based on it can be found in Chapter 4.1.2.

3.2.1.2 Public Cloud, Private Cloud, and hybrid model

As mentioned in Chapter 2.3, *transaction forms* of Cloud Computing services are categorized into three different types in this thesis: the short-term contract, the long-term contract and the in-house transaction. The short-term contracts of Cloud Computing services are also regarded as "Public Cloud", because they can be directly gained from the open market; the in-house transactions are regarded as "Private Cloud"[42], because they are usually not publicly accessible, and in between of them, the long-term contracts can be seen as a hybrid model sharing characteristics from both sides. These different kinds of market coordination forms are assigned different names from various researchers, i.e. Walter W. Powell [Powe03, 315-316] and many others described the short-term contracts as "markets", in-house transaction as "hierarchies" and the long-term contracts between them as "networks". In this thesis, we also use the term "*market structure*" to describe these transaction forms.

The Public Cloud, such as Amazon EC2, Google App Engine, or Zimory.com, is the broadly accepted form of Cloud Computing, and is usually associated with other terms like Software-as-a-Service (SaaS) and Utility Computing. On the contrary, the term "Private Cloud" can be controversial for people believing that a Cloud Computing service must be delivered via *Internet*, which is not necessarily the case [SFL+08]. The Internet is the largest, truly global-scale "Cloud", but besides that, plenty of smaller "Cloud" can be built at organizational or enterprise level, which enable the sharing of computer resources for members of different projects or departments within the organization. Staten [Stat08, 5] suggested "free of long-term

[41] See Chapter 2.3.

[42] A detailed comparison of Public Cloud and Private Cloud will be provided in Chapter 0.

contracts" as a feature of Cloud Computing services, he said: "most cloud vendors let you come and go as you please. The minimum order through XCalibre's FlexiScale cloud, for example, is one hour, with no sign-up fee. Amazon EC2's policy is equally as lenient. This makes clouds an ideal place to prototype a new service, conduct test and development, or run a limited-time campaign without IT resource commitments." While the description of services provided by FlexiScale and Amazon EC2 is true, there is also a noticeable number of SPs, such as IBM and Dell, which are providing more complex Cloud Computing services in the market. These services can only be delivered in a *customized* manner and therefore bundled with long-term contracts[43]. Back to the definition of Cloud Computing in Chapter 2.1.1, it is clear that this thesis will not restrict Cloud Computing services in a short-term framework.

The following table gives a brief comparison for the three market structures:

Table 3 Comparison of Public Cloud, Private Cloud and Hybrid Model

	Public Cloud	**Hybrid Model**	**Private Cloud**
Deployment location	External	External	Internal
Service delivery via	Internet	Internet	Internal networks (LAN, VPN etc.)
Initial investment	Low	Medium	High
Ex-ante contracting	No	Yes	Yes
Long-term commitment	No	Yes	Yes
SLA guarantees[44]	complex & hard to achieve	Easy to achieve	Easy to achieve

43 A detailed profile of current service providers in the Cloud Computing markets will be provided in Chapter 3.1.2.

44 See Chapter 0.

Service provider (SP)[45]	Startups	Traditional SPs	Both

Choosing between Public or Private Cloud services can be important for users in terms of the different models of service delivery, contracting and pricing. Maxey [Maxe08] summarized several influencing factors of the choice, including a) affordable initial investment; b) amount and longevity of data; c) required performance and Service Level Agreement (SLA); d) access patterns and locations; e) security and data isolation f) confidentiality and destruction of data; and g) in-house technical resources. A report from Gartner [SFL+08] showed that one of the biggest advantages of the Private Cloud over Public Cloud is that users can directly connect to the Cloud services via a VPN network rather than Internet, which greatly increase the speed and stability of applications. As for this thesis, the focus of study is on the cost side, therefore, it is interesting to examine whether the Transaction Cost Theory can provide a useful framework to explain the constellation of those different market structures, i.e. Public Cloud, Private Cloud and Hybrid Model.

The following histogram is based on data from 38 active SPs in the current Cloud Computing market[46]. The chart shows that short-term contracts are adopted by the majority of SPs; where we have less clarity is, whether the short-term contracts are still the dominant transaction form if ranked by *contract volume* instead of the number of SPs, because the traditional IT SPs, like Dell, IBM and EMC, are all in favor of the other two forms, and their contract volumes are usually much bigger than those of the startups. A comparison of these transaction forms by contract volume

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[45] See Chapter 3.1.2.

[46] The full list of these 38 SPs can be found in Appendix A. By the composition of data, 5 Cloud technology providers (3Tera, cohesiveFT, Elastra, Enomaly, and Project Caroline from SUN) are excluded because the thesis is focusing on the application and basic computing resources levels. In the meantime, a few companies (Dell and IBM) are providing more than one type of transaction forms, because they are ready to deliver dedicated services as well as directly build data center for their customers.

may shed more light on the current market constellation, but is beyond the scope of this thesis.

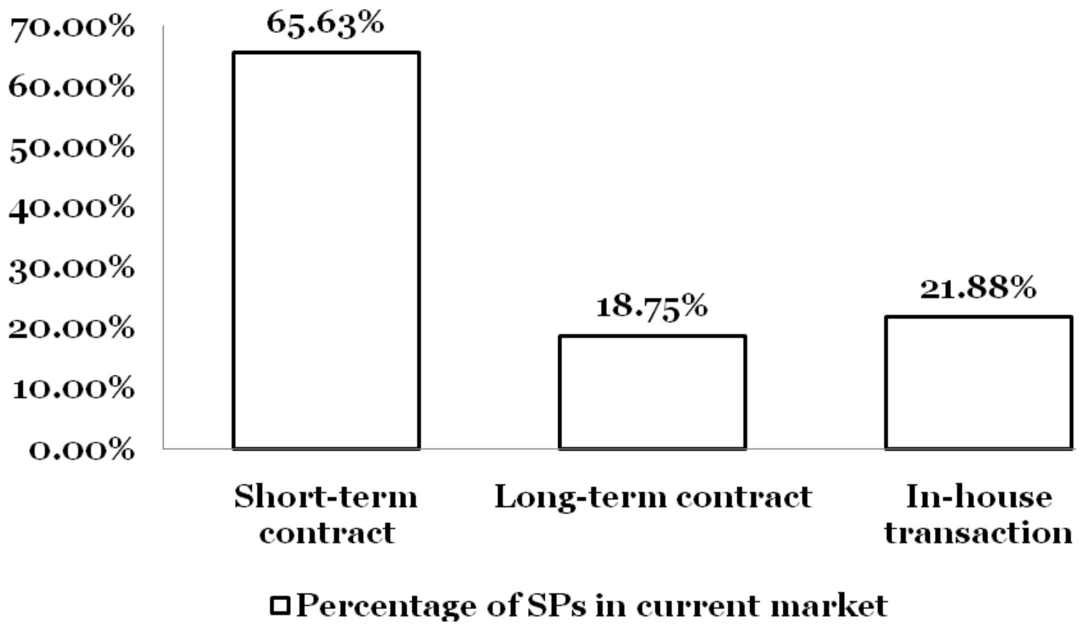

Figure 2 Comparison of Market Structures Employed by the Current SPs in Cloud Computing market

Please note that the Public Cloud, Private Cloud or Hybrid Model discussed here are all transaction-based, not entity-based. A company as an entity can purchase Cloud Computing services in different forms simultaneously, or even use more than one form from these three for a same service.

3.2.1.3 The Transaction Cost Theory

As the example in Chapter 2.3 shows, even for same kind of services, there can be different forms of coordination. In the literature, there are a couple of theories dealing with the issue, why transactions are coordinated in different forms [NeHi05, 5-6]. One of the most influential theories among them is the *Transaction Cost Theory*. The first time the term “transaction cost” became generally known was 1937, when in his classic paper “the nature of the firm”, R. H. Coase tried to use it to explain why firms exist [Coas37, 390ff]. He described transaction cost as “a cost of using the price mechanism”, and “the costs of negotiating and concluding a separate contract for each exchange transaction” [Coas37, 391]. According to Coase, one obvious advantage of arranging a long-term contract, including its ultimate form, i.e. a firm, is saving the cost of making several short-term contracts; and he also mentioned other influencing factors like uncertainty, treatment from the government etc. for building a firm instead of using the pure market mechanism [Coas37, 392-393].

After Coase, O. E. Williamson [Will85] developed a framework to systematically explain the existence of different coordination forms, which he called the "*Transaction Cost Approach*" [Will81, 549ff]. This framework is now serving as the main theoretical groundwork for this thesis to study the market structure of Cloud Computing services. In the Transaction Cost Theory, firms and markets are regarded as different forms of organizations (or "*governance structures*", as formalized by Williamson) and serve as different ways of achieving efficiency under various attributes of transactions [Will85, 68ff.].

According to Williamson's theory, transaction costs are largely influenced by the following three parameters [Will79, 239]:

- *Asset specificity*: a investment conducted by a party of the transaction can either be nonspecific, or idiosyncratic, depending on whether this investment can only be used for the specific transaction or not. The asset specificity defined by Williamson is "the degree to which durable investments that are undertaken in support of particular transaction, the transaction-specific skills and assets that are utilized in the production processes and provision of services for particular customers." [Will85, 55] Williamson classified asset specificity into four types: a) human asset specificity, in those employment relationships which embedded "learning-by-doing" processes; b) physical asset specificity; c) site specificity, by investments with great setup and/or relocation costs; and d) dedicated assets, which are usually purchased or produced on special requirements of certain clients, i.e. expanding existing plant on behalf of a particular buyer [Will85, 95-96][47].

- *Uncertainty*: refers to the cost associated with explaining and understanding products. A higher uncertainty means either that the probability distribution of disturbances remains unchanged but more numerous disturbances occur, or that disturbances become more consequential [Will91, 291].
- *Frequency of transaction*: whether the transactions are occasional or recurrent. One-time transaction belongs to "occasional transactions" too, as suggested by Williamson, because they have little difference in terms of participants' behaviors and economic features [Will79, 247].

The Transaction Cost Theory is the first organizational theory emphasizing the importance of asset specificity [Will85, 17-18]. And among all the influencing factors/dimensions, asset specificity is regarded as the most important for the transaction cost analysis [Will91, 281-282]. According to Williamson, a higher asset-specificity of investments leads to more hierarchical contract structures, as opposed to market exchange. This relationship was already confirmed by many researchers for various industries[48]: Masten and Crocker [MaCr85] explained the "Take-or-Pay" provisions in long-term contracts as a result of the asset specificity in the natural gas industry; Joskow [Josk88] showed the preference for long-term commitments in the coal industry because of the relationship-specific investment of the suppliers.

The Transaction Cost Theory was used by researchers to explain the emergence of electronic markets too [Lian98, 30-31]. It is obvious that electronic markets advance the physical markets in terms of search cost and many other concrete transaction costs, but beyond that, the original purpose of Transaction Cost Theory was trying to explain the difference between organizations, a more fundamental difference than

[47] In his later work, he has also refined the categories and distinguished them into 6 types: a) human-asset specificity; b) physical specificity; c) site specificity; d) brand name capital; e) dedicated assets; and f) temporal specificity. [Will91, 281-282]

[48] Williamson himself has also listed several evidences supporting his theories [Will85, 103-130].

pure cost effect [Will02, 179-182]. That is why it seems interesting to compare the theory from Williamson with the reality in the Cloud Computing market: according to the 3-dimensional model from Williamson, the choice of market structure by the consumers should be strongly influenced by the factor specificity of various Cloud Computing services too. The relationship between asset specificity and choice of market structure is one of the most important hypotheses this thesis is trying to verify for the Cloud Computing services market, based on the customer survey described in more details in Chapter4.

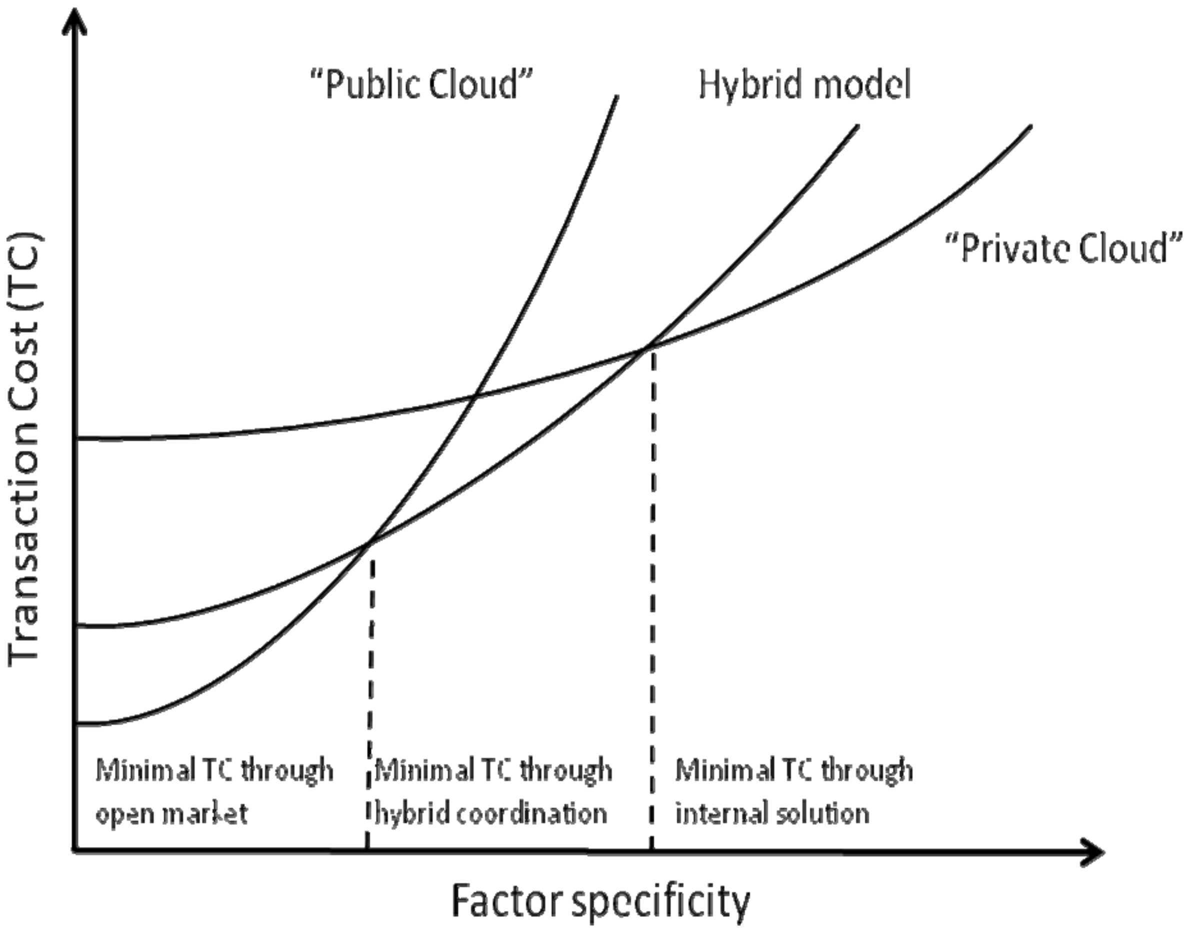

Figure 3 the relationship between transaction cost and factor specificity by different market structures

Figure 3 above was based on an illustration drawn by Williamson about the relationship between asset specificity, transaction cost (governance cost) and different market structures [Will91, 284]. The three lines are the transaction cost functions in each of the three market structures. The transaction costs can be categorized into two types:

- *Ex ante transaction costs*: According to Williamson, the ex ante transaction costs are "the costs of drafting, negotiating, and safeguarding an agreement" [Will85, 20], i.e. the costs such as advertisement, inviting bids from interested parties and so on. For Cloud Computing services/applications, such as a specialized simulation software for a financial institution, these costs by open market transaction can be very high, because the services provided there are usually standardized, not individually customized ("*nonstandard contracting*"); if the users aim to hold the property of the software, the negotiating process will usually become much easier, because the customization cost can be easily covered by the purchasing cost of the users then. For standardized services, the open market is associated with less ex ante transaction costs because the service can easily be defined with a few parameters and structures, and the effect of *economies of scale* can be highly noticeable.
- *Ex post transaction costs*: ex post costs take several forms and mainly caused by contract misalignments [Will85, 21]. For Cloud Computing services such as Amazon EC2, the typical ex post transaction cost is the business loss of service users caused by the Amazon's system outage. Again, for highly special services traded in open market, the chance of finding a substitute service in such situation is very small, hence the potential loss, i.e. the "*switching cost*", is considerably high; but for standardized services, the substitute or compensation methods can be defined in a form of Service Level Agreement (SLA) with little difficulty.

In a *reduced-form analysis* [Will91, 282-286], Williamson concluded that with nonspecific investments, market participants will choose open market as the main form of transaction; with highly idiosyncratic investments, they will choose hierarchy, i.e. the "*firm*"; and with "mixed" investments between nonspecific and idiosyncratic, they will choose a hybrid model between open market an hierarchy, i.e. long-term contracts as the form of transactions. Based on the assertion of Williamson, users should prefer Public Cloud for services with low factor specificity and Private Cloud for services with high factor specificity.

In a more complex analysis considering both asset specificity and frequency as the influencing factors for the optimal market structure [Will79, 247-253], Williamson categorized the market structures into 4 types: a) the "*market governance*", which is equal to short-term contracts in the open market; b) the "*trilateral governance*", which involves no long-term commitment from either sides of transaction, but assistance from a third party[49]; c) the "*bilateral governance*", which is equal to the long-term contracts; and d) the "*unified governance*", i.e. "internal organization", which equals to the in-house transactions. According to the characteristics of these 4 market structures, Williamson drew a matrix with asset specificity and frequency as two dimensions:

Table 4 Matching Market Structures with Asset Specificity and Frequency (Source: [Will79, 253])

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">Asset Specificity</th></tr>
<tr><th>Nonspecific</th><th>Mixed</th><th>Idiosyncratic</th></tr>
<tr><th rowspan="2">Frequency</th><th>Occasional</th><td rowspan="2">Short-term Contracts
(Market Governance)</td><td colspan="2">Short-term Contracts
(Trilateral Governance)</td></tr>
<tr><th>Recurrent</th><td>Long-term Contracts
(Bilateral Governance)</td><td>In-house Transaction
(Unified Governance)</td></tr>
</table>

In other words, we can re-formalize the assertion of Williamson as following:

- For *transactions with high frequency*, the optimal market structure is determined by the degree of asset specificity. And for both mixed and idiosyncratic

[49] Because the transaction cost of bilateral contracting is still high, and the assistance of third party as consultant or intermediate helps to assure the fairness of the contracts [Will79, 249-250].

investments, the ideal transaction form should be "*transaction-specific*" [Will79, 250];

- For *transactions with low frequency*, both parties always prefer the short-term contracts, no matter how specific the involved investments are. As argued by Williamson [Will79, 248-250], for one-time or very infrequent service, the contracting costs involving long-term commitments are always too high for the market participants. Therefore, the short-term contracts are consistently the preferred transaction form; the only question is, whether the both sides conduct the transaction directly, or via some market intermediate ("trilateral governance").

Based on the theoretical framework presented in this Chapter, we have built hypotheses about the relationship between asset specificity, usage frequency, and market structure. The hypotheses are presented in Chapter 4.1, and tested in Chapter 5.3.

3.2.1.4 Physical asset specificity and service homogeneity

As mentioned in the Chapter 3.2.1.3, asset specificity has many different forms and sources. One kind of asset specificity is associated with the physical investments, like a special machine for certain products, or even a plant. This type of asset specificity was described by Williamson as "*physical asset specificity*" [Will91, 281]. The form of asset specificity is an important factor by shaping the bilateral contracting behaviors, and plays, along with other forms of asset specificity, a central role in the Transaction Cost Theory [Will91, 282].

Physical asset specificity in service industry is directly determined by how homogeneous the service is. Illustrating an example, where all applications requiring computing resources are running on a single platform (operating system), either Unix, Linux, or Windows, the providers of computing resources have no need to invest in the development of interoperable environment then; this feature of service reduces the physical asset specificity and the costs, both the service providers and service users (e.g. the application developers) can easily shift their existing investments into other market or market segments because of the inherent interoperability of a single platform.

Based on the explanation above, we see a clear relationship between *physical asset specificity* and *service homogeneity*. The latter is more overt than the former, especially for service users, because they observe directly the services instead of the asset investments behind them. Therefore, we use service homogeneity in our online survey, as well as in later Chapter, as an indicator for the degree of physical asset specificity, and the asset specificity overall.

3.2.2 Theoretical groundwork and frameworks for price model

3.2.2.1 General

A market is where supply meets demand, and in classical economies, price is determined by the interaction between supply and demand, i.e. the equation of supply and demand implies the so-called "*equilibrium price*" [Werd04, 48-49]. As mentioned before, this thesis is focusing on market acceptance of Cloud Computing services by studying the current and potential customers (demand) of these services. One of the most important factors determining whether many customers are willing to use the Cloud Computing services is the price, and it is not only about how high the price is, but also about what the price model is. Williamson was also aware of the fact that although transaction cost is an important tool to explain different behaviors of market participants and coordination forms of transactions, there are other attributes influencing the decisions of market participants, and the study of transaction cost cloud not substitute the attention we should pay to production cost and price [Will81, 552]. The thesis herein uses the term "purchasing cost" for production costs and price, as in the view of service buyers. The most direct way to determine the cost is investigating the pricing mechanism of services, because the purchasing cost of a service is simply determined by the price for each unit of service (which can be measured by use time, connection time, volume, transaction etc.) and the consumed units.

To the best of our knowledge, there are quite few theoretical frameworks explaining the choice between different price models for Cloud or Cloud-like[50] services, which we can refer to as we have done with the Transaction Cost Theory from Williamson for the market structure of Cloud Computing services. A couple of academic concepts for Grid Computing architecture were proposed by different research groups, which include various price models[51], but a framework of explaining the market participants choice of price model in Grid Computing was not given, either.

However, general price models for IT services, such as the Internet access service (i.e. network service), are often discussed in academic papers. But the majority of former research focused on the equilibrium price of the market, i.e. the price resulted from a balance between service/resource supply and demand. These research under so-called "*optimality paradigm*" [SCEH96, 184] was often transformed into more "technical" problems with focus on resource allocation, load balance, and studying of certain pricing functions/models, as what Babad [Baba81] , Greenberg et al. [Gr Mu85] and Ferguson et al. [FNSY96] did. J. Oh [Oh07] showed that PAYG model is in fact superior to Flat Rate model for network access and media content services in regard to the welfare maximization approach. In the meantime, as criticized by Shenker et al. [SCEH96, 184-190], the pricing models under "optimality paradigm" may have great relevance for the goal of maximizing welfare, and therefore may be practical for internal use within an organization, or a non-profit research organization, like many Grid Computing communities, but in a commercial

[50] Such as Grid or Utility Computing services

[51] The major Grid Computing architectures include Bellagio, GRACE, SPAWN, G-Commerce, OCEAN, Mirage, Tycoon, Libra, Aggregate Utility etc. Among them, some are using certain auction mechanisms, while some others are using certain bargaining concepts, or combined [ENR+06, 2-3; BVBu08, 261-266].

environment under the assumption of homo economicus, maximization of welfare is not necessarily the common goal.

Besides the vast number of papers discussing pricing mechanism as a tool for optimal efficiency, many other researchers have studied different price models for use in a real market. Cocchi et al. [CSEZ93] examined customer differentiation ("priority pricing") as alternative option for flat pricing of services in computer networks, and came to the conclusion that under certain conditions, flat pricing may not be the optimal choice for SPs. Gurnani and Karlapalem [GuKa01] compared the traditional software selling strategy with software dissemination via Internet, which includes PAYG option. Similar as Cocchi et al., they found out that under certain conditions[52], the latter option can be more profitable for the software vendors. Zhang and Seidmann [ZhSe03] studied the optimal licensing policy of a monopoly software vendor, including selling and leasing of software. Their conclusion was that software vendors can segment the market and realize effective second-degree price discrimination by using selling and leasing strategies together. Huang and Sundararajan [HuSu05] added "build-your-own" option for corporations purchasing IT infrastructure and studied non-linear pricing models for Cloud Computing or "Cloud-like" services[53], but with a focus on concrete pricing functions instead of choice between different price models. They also concluded that influencing factors for pricing models of Utility Computing (On-Demand Computing) include the purchasing cost, the business value and scale of the infrastructure (initial investment), as well as the variable cost of the Utility Computing service. Jiang et al. [JCMu07] compared fixed-fee and PAYG software licensing in a monopoly market with heterogeneous customers and showed that influencing factors for a SP's optimal choice of licensing model include the potential piracy rate, the "user inconvenience cost" of PAYG licensing, consumer heterogeneity, and the network strength. Choudhary [Chou07] examined the optimal investment in product development for a

52 The premises set by them included monopoly status and certain utility functions.

53 Cloud-like services include On-Demand Computing, Software as a Service and Utility Computing.

software vendor under two different licensing schemes: fixed-fee and subscription-based licensing[54]. His analysis showed that a software vendor will invest more in software development under the subscription-based model relative to the fixed-fee licensing model.

What worth noting is that, although having been studied many times in different literature, the practical price-making decisions in the real business world can often be *intuitive and even arbitrary* [Oxen73, 48]. A typical evidence of inconsistence between academic analysis of pricing and the price model in real business world is: many academic papers have pointed out the inefficiency of fixed price scheme compared to flexible pricing, because under the fixed price scheme, the users have no incentive to shift their usage from high demand periods to low demand periods [BVBu08, 5]; therefore, they have suggested various flexible pricing of computer services [Smidt'68]; however, the majority of computer services available in the markets today are priced with a single fixed price or very little price differentiation. A. Odlyzko [Odly01, 493-501] has investigated various communication services (e.g. mail, telegraph and telephone) and comes to the conclusion that the success of a service was always accompanied by *simple and transparent* pricing model. Although researchers have suggested various pricing mechanisms to achieve an efficient resource allocation and market optimality, but the most of them are simply beyond the scope of any practical algorithm [SCEH96, 187-188]. As it has become clear that a technically (or theoretically) highly efficient (and often complex) price model does not necessarily gain popularity in the real business world, this thesis intends to accomplish a more detailed study on the commonly existing price models including Flat Rate pricing, PAYG pricing and a mixture of these two models, instead of proposing some new price models.

[54] In this thesis, subscription-based licensing is regarded as another form of PAYG price model because the price paid by users is based on the actual usage calculated with subscription number as unit. In Choudhary's model, a higher investment in product development means a higher software quality, and then higher profits and higher social welfare.

3.2.2.2 PAYG, Flat Rate and Mixture Model

Although often being described as two opposite price models, there is no absolute boundary between *Flat Rate* and *PAYG price model* [SCEH96, 198]. Considering a user purchasing a software package, the possible payment structures include a) a one-time selling price, which he pays before using the software and covers all the purchasing cost[55] for the user; b) a fix price for a certain period of use, such as a annually, quarterly, or monthly fee. The user pays so much for the software no matter for how long or how often he uses it during the period; c) a unit price for the usage of the software calculated by the actual user numbers (subscriptions), which can also be combined with a annually, quarterly, or monthly payment structure. Whether type b or even type c payment structure belongs to a PAYG model, depends on the concrete definition of "PAYG". In terms of hardware resources, the situation is similar: the payment structures of certain hardware resources, such as CPU power and storage, include a) a one-time purchase price, which directly transfers the hardware to the user; b) a fix price for a certain period of use; and c) a unit price for the actual usage of resources calculated by CPU hours, used storage space etc.

In this thesis, all kinds of periodical but unlimited payment structures for software and hardware are regarded as Flat Rate model. The following table shows this classification of price models:

Table 5 Classification of different payment structures

	Flat Rate	PAYG	Mixture Model
One-Time Purchase	X		
Periodical Payment	X		
Subscription-based Payment (Software)		X	
Usage-based Payment (Hardware)		X	

55 There may be extra fees for upgrade, consulting, or other customer services. These types of fees are not included here.

Periodical Fee with Payment for Extra Use (Hardware)			X

The last column of the table above shows the third type of price models: the "Mixture Model", which only exists for hardware consumption. Former literature about price models of IT services has mainly focused on either PAYG or Flat Rate model, but very little on the possibility of mixing those two types of price models together [SCEH96, 198]. One approach of developing Mixture model was made by Altmann and Chu [AlCh01] for network access service. They conducted a series of experiments on bandwidth consumption, in which the network service was categorized regarding their quality (bandwidth). They found out that the majority of users prefer to purchase the Flat Rate option for a low bandwidth connection, and they occasionally pay for a higher bandwidth connection in a usage-based way [AlCh01, 528]. For Cloud Computing services, as presented by the histogram below, we observed that a fairly large amount of SPs have chosen a Mixture Model for their Cloud Computing services[56].

[56] The data for this comparison are from 16 of the 38 SPs listed in Appendix A, because for the Cloud technology providers, the companies in beta or preview release, and those open source projects, price models are not applicable.

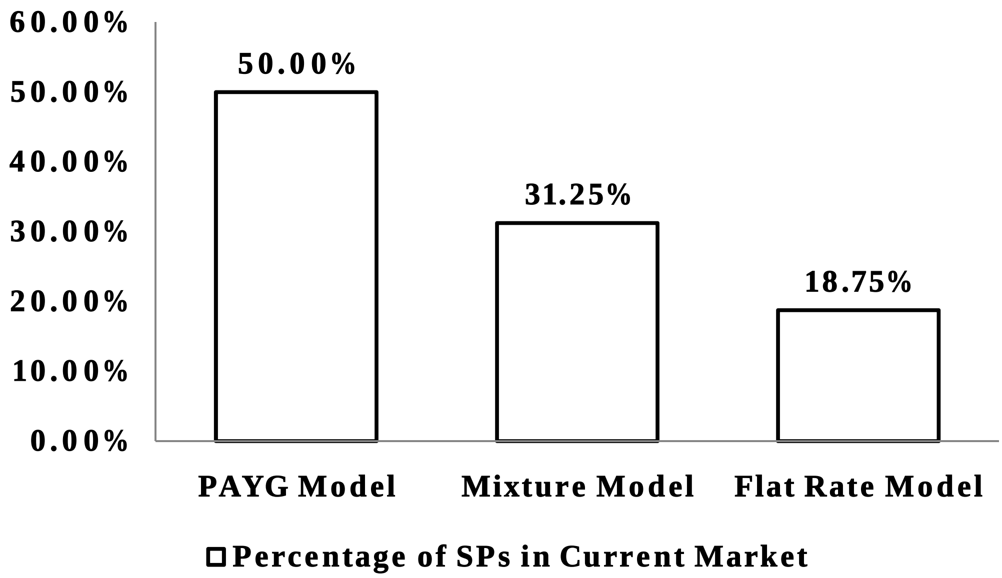

Figure 4 Comparison of Price Models Employed by the Current SPs in the Cloud Computing Market

3.2.2.3 Service homogeneity and price model

Among the research literature of price models of IT services, we have especially studied the papers about price models of *computer utility services*, since utility service is an important part of the Cloud Computing services[57]. 40 years ago, Diamond and Selwyn [DiSe68] compared various price models for computer utility services, including Flat Rate model, resource usage based model (PAYG model), connection time based model[58], and transaction based model[59]. They discussed about the different price models from a market-oriented view, and suggested several criteria for the proper price model, which reflected possible customer preferences. Their criteria included: a) Cost of using the computer utility services should be predictable; b) Users are only willing to pay for services they have actually used; c) Users want to maximize service for given expenditure; d) Users can pay proper share of common

[57] See Chapter 2.1.4.

[58] Charging for the time during which service is to be available.

[59] Service receivers pay a relatively small monthly account maintenance charge (or no charge at all) and have full-time access to the system. Charges are imposed on a transaction basis.

costs; e) Users pay for the "value" of services; and f) Users want to obtain priority service [DiSe68, 193-195]. While these criteria are useful in understanding customer behaviors in the computer utility service market, they do not provide a systematical framework to explain and predict *which price model will be chosen under which circumstances*.

In the paper by Altmann and Chu this thesis has referred to, it was found that users are often willing to pay a certain premium for a basic network access service, i.e. they are willing to pay more for the same bandwidth consumption in a Flat Rate model than in a usage-based model (PAYG model) [AlCh01, 527]. Considering basic network access service as a typical commodity service with nearly no heterogeneity, their findings suggest that *customers prefer a Flat Rate model for Cloud Computing services with high homogeneity*. Another study about the possible relationship between price model and service homogeneity was conducted by Chen and Wu [ChWu04], but from the SPs' point of view. They modeled a seller's choice between fixed-fee and PAYG under different market structures[60] and homogeneity of service. Their suggestions were that when services are homogeneous, SPs are willing to provide services in a PAYG model, *only if* the marginal costs of investments in a PAYG model are significantly lower than that in a Flat Rate model; on the contrary, in a heterogeneous service market, SPs *almost always* prefer the PAYG model, as long as the marginal costs of investments is not significantly higher than that in a Flat Rate model [CheWu04, 3-4]. The implication of this paper is similar as that of the Altmann and Chu's paper mentioned before, i.e. market participants[61] generally prefer Flat Rate model for homogeneous services and PAYG model for heterogeneous services.

[60] The term "market structure" used by Chen and W means the number of service providers in the market and the relationship between them, i.e. monopoly, oligopoly or polypoly.

[61] Although the paper was focused on the SPs, its inference may apply for both sides in the market, since the authors have drawn their conclusions based on the analysis of costs, which can be transferred into price and lead to same decision by the service users.

Yet interesting evidence from the reality is: most utility services, which are regarded as the most homogeneous, including electricity, water, heat, light and gas[62], are all charged in a PAYG model. In fact, PAYG is regarded as "one characteristic that figures prominently in the utility business model and sets it apart from other models [Rapp04, 37]. These partly conflicting research conclusions and realities have aroused our interest in *the actual influence of service homogeneity on the preferred price model in the Cloud Computing markets*. Therefore, we have developed a hypothesis about this in Chapter 4.1.2, and the result of the hypothesis testing can be found in Chapter 5.4.1.

3.2.2.4 Usage frequency and Price model

Besides service homogeneity, we find *usage frequency* to be another potential influencing factor in choosing price model, too. The reason is simple: in a world with no uncertainty, the PAYG model is clearly a superior price model compared to Flat Rate, because no one ever needs the guarantee and flexibility of usage provided by a Flat Rate option. Although Mackie-Mason and Varian [MaVa95] pointed out in as early as 1995 that from a pure cost-efficient point of view, the Flat Rate pricing will lead to a suboptimal solution for the Internet access service, as long as the Internet is not congestion-free, researchers have not been unanimous about why most SPs of Internet access services choose Flat Rate, or a price model containing Flat Rate option. A paper by Lambrecht and Skiera [LaSk06] summarized different explanations of this "Flat Rate bias" and examined them using empirical analysis. According to their analysis, there are three major causes of the Flat Rate bias: a) Insurance effect, which means that "Risk-averse consumers who cannot predict their future demand exactly can choose a flat rate to insure against the risk of high costs in periods of greater-than-average usage"; b) Overestimation effect by the consumers; and c) "Taxi meter effect", which means that consumers may enjoy their usage more on a Flat Rate than on a PAYG price model [LaSk06, 213-214, 221]. We noticed that

[62] One exception may be the telephone service, by which a Flat Rate model or a Mixture model of PAYG and Flat Rate pricing are provided.

the first two causes are tightly associated with the usage uncertainty of services; therefore, the choice of price model should be affected by the degree of uncertainty.

The *uncertainty* is a complex issue: there is uncertainty about the timing, the volume, and the length etc. of service requests. We consider the usage frequency as a good indicator for the service uncertainty, because the need for a recurrently used service is more observable, and therefore more predictable. A similar assumption was made by Sundararajan [Sund04, 1669], which suggested that when the customers in the markets are highly concentrated and mainly low-usage consumers, Flat Rate model is a good strategy, when the markets mature, and the average usage level increases, the service providers should consider either increasing their fixed fee, or shifting into PAYG model. If this assumption is true, high usage frequency should be associated with low uncertainty, and leads to a preference for PAYG price model. A hypothesis based on this assumption is developed in Chapter 4.1.2 and 4.1.1, and the hypothesis test can be found in Chapter 5.

4 Research Methodology

4.1 Survey design

4.1.1 Survey structure

The behaviors of SPs in a market are often more observable than the behaviors of service users, especially potential users. As mentioned in Chapter 3, we have found from the composed market data that the majority of SPs in current Cloud Computing market prefer short-term contracts to other market structures; and that the PAYG model is their favorite price model. Nevertheless, other types of market structures, as well as price models, have been in use among the SPs too. Thus we conclude an optimal choice of market structure and price model is not yet found; or more possibly, that an optimal choice exists only, when certain characteristics of service and other factors are predetermined. These factors can have influence on SPs, customers, or both. We also acknowledge that there is no way we can exhaust all the influencing factors in a thesis. Therefore, as mentioned in Chapter 3.2.1 and 3.2.1.4, this thesis focuses on two possible influencing factors: the service homogeneity and the usage frequency.

Survey is a common tool for the purpose of testing a certain theory or causal relations in reality. To find out the potential influences of these two factors on customer's choice of market structures and price models, the Chair of Information Systems at the University of Bayreuth developed an online survey focusing on the market acceptance of Cloud Computing[63]. Because such kind of empirical study on Cloud Computing customers is still rare in research literature, the survey is also used for discovering more information about the customers' knowledge and preferences about Cloud Computing. The survey is composed of 12 questions, divided into 4 sections as following:

---

[63] Survey address: http://btw6xb.bwl7.uni-bayreuth.de/cloud/index.php?sid=51885. Screenshots of the survey can be found in Appendix C.

- *S1 general information*: general questions about the company (type of company, IT activities and budget).
- *S2 usage and preference of IT service*: questions about the respondents' opinion on the service homogeneity of the IT services they use, i.e. which IT services are regarded as homogeneous; and the reputation mechanism.
- *S3 market structure and price model*: this section contains three questions about the respondents' preferred market structure, price model, and their usage frequency of each IT service. Together with the Q1-4 in the second section, these help to find out the possible correlation between asset specificity with market structure, as well as with price model.
- *S4 knowledge of Cloud Computing*: questions in this section is mainly about the status quo of Cloud Computing market, including how many companies among the respondents are already using or plan to use Cloud Computing services, as well as their opinions on the pros and cons of Cloud Computing services.

4.1.2 Hypotheses on market structure and price model

The core of this survey is the section 3, questions about the market structure and price model. Based on the theoretical frameworks described in Chapter 3.2 for both market structure and price model, we have developed *4 hypotheses* for the relationship between a) service homogeneity and market structure; b) usage frequency and market structure; c) service homogeneity and price model; d) usage frequency and price model. They are presented in the table below, and the test results will be shown in Chapter 5.

Table 6 Hypotheses about Correlations between Homogeneity of Services, Frequency of Use, Market Structure, and Price Model

H1	Customers prefer Public Cloud for homogeneous IT services and Private Cloud for heterogeneous IT services, when the usage frequency is high.
H2	**Customers prefer Public Cloud for all kind of IT services, when the usage frequency is low.**
H3	**Customers prefer PAYG model for homogeneous IT services, and Flat Rate model for heterogeneous IT services**

H4	**Customers prefer PAYG model for frequently-used IT services, and Flat Rate model for infrequently-used IT services**

4.1.3 Types of Cloud Computing services

Although we have noticed that some features of services with great potential of moving into a Cloud Computing environment, e.g. services which are hardly deliverable by a place in a network but need to be ubiquitous, highly available, scalable and manageable; however, it is impossible to list all Cloud Computing services in a thesis.

To summarize Cloud Computing services in a sufficient way, taxonomy of these services is necessary. Many classifications for services can be found in former literature. The commonly-used classification dimensions include tangibility or intangibility; interaction or customer contact; customization; availability of service outlets at single or multiple sites; and product/process [ChPa02, 340]. Unfortunately, the range of Cloud Computing services is so large (from hardware to software, from single product to platform etc.), that none of above mentioned taxonomy fits in the classification of Cloud Computing services. Therefore, the following categories of Cloud Computing services are defined in the survey and this thesis, based on the products and solutions provided by the current Cloud Computing SPs, as well as taxonomy in other similar surveys [Appi08; DMBR08; FCBi08; IDC08b]:

- *Storage, archiving and disaster recovery*
- *Raw computing power (resources)*
- *Dedicated data center or servers*
- *Basic office applications (e.g. Microsoft Office®)*
- *Business applications (e.g. SAP ERP system)*
- *Specialized applications or solutions (e.g. simulation software for financial industry)*
- *Specialized IT services, such as security, management and compliance*
- *Cloud Operating System (e.g. Windows Azure® from Microsoft)*
- *Online Application Exchange Platform (e.g. Salesforce.com)*

4.2 Data collection

Since the Internet is becoming the most widespread communication channel, and the subject of this thesis is an emerging technology tightly associated with the Internet, we decided to use Internet as the channel of survey data collection. In order to provide state-of-the-art information about the Cloud Computing market, all the data used in this and next Chapter for analysis are primary data from the online survey "Market Acceptance of Cloud Computing" conducted by the chair of Information Systems at the University of Bayreuth. No secondary data from other sources are used. The screenshots of the online survey are provided in Appendix C.

One difficulty by the data collection process is to find the right sample pool for the whole Cloud Computing users and potential users. Common statistics and survey technique books recommend *random sampling* [Fowl02, 14-16]. Unfortunately, a simple random sampling is impossible to apply for this survey, because the users and potential users of Cloud Computing services can be any company; even if they aren't yet using any IT services, they can be potential Cloud Computing customers: they can simply use Cloud Computing services from the very beginning and own no legacy system at all. In this case, a simple random sampling means randomly choosing samples from all companies using IT services or going to use IT services which will result in too low "*efficiency*" of the survey, i.e. the sampling pool includes too much units that are not target of the research [Fowl02, 13-14]. Considering that Cloud Computing is still an emerging technology, by which the users and potential users are mainly innovators and early adopters [Roge03, 281], we have chosen a more efficient way of finding these target respondents: we have asked for the help in certain online forums, such as the "Cloud-Computing Group" and "Cloudforum Group" in Google Groups, where the Cloud Computing service providers, researchers, as well as "early adopters" in the market are gathered; and we have sent email invitations for Cloud Computing service providers on the current market, asking them to forward the online survey to their customers or potential customers. The forum post and email invitation are shown in Appendix B.

The survey was activated the end of December 2008; till the end of January 2009, 32 full responses were received; two respondents among them have chosen “Strongly Disagree” for the first question “I am familiar with the idea of Cloud Computing”. Therefore, the effective responses available for analysis are 30[64]. Although the number of responses is not very large, but the efficiency of samples is considerably high, so that we believe this survey does provide some useful information about the Cloud Computing market and the customers.

4.3 Methodology of data analysis

4.3.1 Data preparation

All the raw data obtained from the survey are *nominal* or *ordinal*, or the so-called “nonmetric data” [Blac08, 9]. Typical nominal data are sex, religion, ethnicity, geographic location etc. In our survey, the nominal data are such as the preferred market structure, the preferred price model, and whether a service is regarded as a homogeneous service. In statistics, data in the nominal level are usually used for classification or categorization [Blac08, 8]. Other data set from the survey are ordinal data, e.g. the popular *Likert scale* (Strongly Agree – Agree – Neutral – Disagree – Strongly Disagree), and the *usage frequency of IT services* (Very Frequently – Frequently – Normal – Infrequently – Very Infrequently) employed in this survey[65]. These data can be used to rank or order objects. We usually transfer these data into a reduced form, i.e. a scale of 1-5 or 1-3 before analysis, but they are still “ordinal” data, because the numbers do not really represent the numerical relationship between the options, e.g. if we assign the scale 1-5 for the Likert scale, by which Strongly Agree = 1 and Strongly Disagree = 5, this scale does not mean that intervals between people choosing “Strongly Agree” and “Agree”, and the intervals between people choosing “Disagree” and “Strongly Disagree”, are the same.

[64] See Chapter 5.1.

[65] See Figure 14 in Appendix C.

Nominal and ordinal data are both *very limited* in terms of the types of statistical analysis that can be used with them. There are no parametric methods for purely nominal and ordinal data, so that they fit only for *nonparametric statistics*[66] [Blac08, 10]. In the following sections, we have transferred these data into numerical scales, as described in the last paragraph, then applied independency tests and correlation tests on them to test the hypotheses written in Chapter 4.1.2.

4.3.2 Independency test

As mentioned in Chapter 4.1.2, we have developed 4 hypotheses about the market structure and price model. After converting the data into numerical scales, we begin to test the independency of the factors written in each hypothesis. The simple assumption here is: if the factors in a hypothesis are *independent*, we do not need to test the correlation between them anymore.

As the data we have are nominal and ordinal, we use a *Chi-Square test for R x C contingency tables* to test the independency of the parameters, which is a standard test for deciding whether two variables are statistically independent [Reyn77, 15]. This test uses Chi-Square distribution[67] as an approximation of the real distribution of samples; by a large number of samples, this approximation can be very accurate [Shes04, 495]. In fact, the Chi-Square test for R x C contingency tables is an extension of the *Chi-Square goodness-of-fit test*[68], which can only be applied to test the independency of single sample categorized on a single dimension [Shes04, 493].

The first step of the hypothesis testing is developing a *null hypothesis* [Cono99, 95-96]. The null hypothesis is the hypothesis against the original hypothesis, which is then called the *alternative hypothesis*. For the independency test, we usually write

[66] Nonparametric statistics are also called “distribution free statistics” because they do not require that the data fit into any parameterized distribution. These types of statistics generally require less restrictive assumptions about the data.

[67] More information about mathematical characteristics of Chi-Square distribution can be found at: http://mathworld.wolfram.com/Chi-SquaredDistribution.html.

[68] Also known as *Pearson's Chi-Square test*

the null hypothesis as that “*the two variables are independent*”. Based on sample data, this null hypothesis is either rejected or not rejected. We conduct a hypothesis test using this null hypothesis, setting a certain confidence level, until a preponderance of evidence (i.e. above the confidence level) is gathered, we cannot reject the null hypothesis. Rejection of null hypothesis means acceptation of alternative hypothesis, so that we conclude that the tested parameters are dependent. By hypothesis testing, we can make two types of errors: the *type I error* and *type II error* [Cono99, 98-99]. Type I error refers to the error of rejecting a true null hypothesis, type II error refers to accepting a false null hypothesis. Generally, there is a *trade-off* between type I and type II errors in a test, which means we cannot reduce these two types of errors simultaneously.

The next step is drawing an *R x C contingency table* with two dimensions representing the two variables mentioned in each original hypothesis. R is the number of rows, and C is the number of columns. Using two alphabets indicates that the numbers of rows and columns are not necessarily equal. The data in contingency table represent the times each option was chosen by respondents [Cono99, 179-180]. The contingency tables are a common tool to analyze nominal and ordinal data.

Then we run Chi-Square test based on the contingency table using the SPSS v16.0®, and interpret the test results based on the Chi-Square distribution. According to Sheskin [Shes04, 502], the Chi-Square tests used here employ a continuous distribution to approximate a discrete probability distribution of the nominal or ordinal data, therefore, the *Yates' correction for continuity* can be used based on the results of Chi-Square tests. This correction shows a stricter (i.e. lower) value of significance level by testing the null hypothesis, but it is also recommended to be used only for 2 x 2 contingency tables.

Another commonly used nonparametric independency test is the *Fisher's exact test* [Shes04, 505-506]. Chi-Square test fits only for large sample size and its accuracy increases while the sample size increases. For a sample size smaller than 20, Chi-Square test will be inappropriate since the approximation of actual sample distribution using Chi-Square distribution will be too inaccurate [Reyn77, 20]. Besides this feature, there are two common *assumptions* about the Fisher's exact test:

- Observed data can be summarized into a 2 x 2 contingency table. In fact, Fisher's exact test can be employed for any R x R contingency test, where R does not necessarily equals 2, but a 2 x 2 table was introduced by R. A. Fisher himself and most widely accepted [Shes04, 505-506];
- The Fisher's exact test requires that the totals of both row and column in the contingency table are nonrandom, i.e. predetermined prior to the test. Although this assumption is often neglected since it is too difficult to meet [Shes04, 506].

In our case, the sample size for each test is well beyond 20, and we have employed both 2 x 2 and 3 x 3 contingency tables, where the second assumption of predetermined totals of rows and columns are not met neither. Hence we run the Fisher's exact test simply as an additional reference for the results from the Chi-Square tests.

4.3.3 Correlation test

For the hypotheses by which the null hypothesis of the independency is *rejected*, we are interested how tight the each two variables are connected. Since the Chi-Square tests tell only whether the tested variables are statistically independent, and do not give the *strength or form* of the relationship, we need to use other tests to find out *how the variables are associated*.

In this survey, we define ex ante that the service homogeneity and usage frequency are *independent variables* and market structures and price models are *dependent variables*, so the correlations between these variables are directly interpreted as *dependency*, i.e. *causality relationships*. Given that we do find certain correlations between these variables, it is hard to interpret them as "market structure is an influencing factor for usage frequency" or "price model is an influencing factor for service homogeneity". We think the usage frequency and service homogeneity are both inherent characteristics of either the services or the business themselves, while market structures and price models are formalized by the interaction of market participants, and therefore determined by external factors. Our goal is to find out how much from the preferences for certain market structure and price model can be described by the degree of service homogeneity, or usage frequency.

Since we have used Chi-Square R x C contingency tables and related coefficients for the independency tests, now we employ measures of dependency based on contingency tables too[69], i.e. the correlation coefficients, which depicts how strong two variables are *linearly* related to one another. For minimal and ordinal data, there are 3 commonly-used measure of dependency [Cono99, 227-237]:

- *Contingency coefficient*[70]: the Chi-Square test value depends on both the strength of the relationship and sample size. The contingency coefficient eliminates sample size by dividing Chi-Square value by n, the sample size, plus the Chi-Square value, and taking the square root [Cono99, 231]. So we can use the contingency coefficient as an indicator for the cross-dimensional correlation, excluding the influence of sample size. The value of contingency coefficient is between [0, 1)[71].
- *Phi coefficient*: Phi coefficient is a similar measure to contingency coefficient. It measures the correlation between two nominal variables by calculating the percent of concentration of cases *on the diagonal* in a contingency table: the stronger the observed cases concentrate on the diagonal, the clearer the correlation trend is. Therefore, Phi coefficient is usually used for 2 x 2 contingency tables, i.e. when both variables have a *binomial distribution*; for table larger than 2 x 2, there is no simple intuitive interpretation for the Phi coefficient anymore [Shes04, 534-536];

[69] As stated by W. J. Conover [Cono99, 228]: "If it is good enough to test for dependence, it is good enough to measure dependence."

[70] Also known as "Pearson's contingency coefficient"

[71] One problem about the contingency coefficient is that its value can never equal 1. But this is not a crucial issue for our tests, since we do not expect a perfect correlation between any of the variables we are going to examine anyway.

- *Cramer's V*: similar to the other two measures, Cramer's V interprets the variables' correlation by eliminating the sample size influence from the original Chi-Square values. It divides the Chi-Square value by the sample size, than takes the square root [Con099, 230].

To notice is: an important limitation of the above correlation measures is that a correlation coefficient only gives some rough indication of dependency. For the specific kind of dependency or association, one would design a model and perform a test. Unfortunately, this kind of tests is beyond the scope of this thesis then.

5 Survey Results and Interpretations

5.1 Sample characteristics

One basic characteristic of the survey respondents is a *basic or advanced knowledge* about Cloud Computing, which is guaranteed by the Q1-1 (“I am familiar with the idea of Cloud Computing”). If a respondent chooses the option “Strongly Disagree” for this question, the survey will directly jump to the end page (In all 32 full responses we received, 2 of them have chosen this option).

5.1.1 IT or non-IT company

Since we have made it clear in our email invitations and forum posts, that this survey is designed for Cloud Computing customers, there is no question in the survey about the role respondent’s company plays in the Cloud Computing market. Instead of that, we have categorized the responses into *IT* or *non-IT companies*. As shown by Figure 19 in Appendix E, the majority of respondents (57%) are from the IT companies.

This result shows that, despite the optimistic forecasts from many institutions[72], Cloud Computing is not yet widely used in the mass market: E. M. Rogers has proposed a 5-stages development process of technology innovation regarding the types of main users, or so-called “*user segments*” [Roge03, 281]. According to him, the normal development process of customers of an innovative technology in the market is as following: “innovators” → “early adopters” → “early majority” → “late majority” → “laggards”. At the first two stages of the development, by which the main users of the technology are “*innovators*” and “*early adopters*” respectively, a strong ability to understand and apply complex technical knowledge is needed, and the users are often tightly connected with the source of the innovation in one or another way [Roge03, 282-283]. Therefore, the majority of the survey respondents fit perfectly into the “innovators” and “early adopters” categories of Rogers. Once the Cloud

[72] See Chapter 3.2.2.1.

Computing services are massively adopted by the non-IT companies, we can tell that a new development stage of Cloud Computing is reached.

5.1.2 IT-related investments

Figure 20 in Appendix E shows the percentage of IT-related investments to the overall revenues of corresponding companies. We have surprisingly found out that the percentage of respondents, who confirmed that they spent more than 5% of their total revenues from the previous year on IT-related projects, is considerably high (35%, 16% said their companies have spent more than 20% of their annual revenues on IT-related projects, 19% said this number from last year is between 5% and 20%). One possible reason for the high spending on IT-related projects among the respondents is that the majority of the responses came from IT companies. Their high expenditure on IT-related investments, i.e. their main business, leads to a *bias* in the total sample pool.

Excluding the 17 IT companies from the response pool, we have 27% of the non-IT companies with 1%-5% of their annual revenues from previous year spent on IT-related investments, and 18% of them with 5%-20% spent. Calculating roughly the mean of IT spending from all non-IT companies in the sample pool, we come to an average spending of 3%. These numbers are consistent with the findings from Gartner [Gart09b] that the IT spending from major non-IT sectors was 2%-4% of the company's annual revenue.

5.1.3 Usage frequency of IT services

Since usage frequency is one of the major factors we want to test for its potential influence on market structures and price models, a question about the usage frequency of different IT services was designed in the customer survey (Q3-3: "How frequently does your company use the following IT services?").

To notice is: currently, many companies have not yet used or are just beginning to use a small portion of Cloud Computing services, so a major target group of our survey is the *potential users* of Cloud Computing. By excluding this group of target, the basement of our survey will become much smaller, and more importantly, the potential customers' opinions toward the Cloud Computing services are crucial for the development of the market. But there is no way that we can observe directly the usage frequency of the potential service buyers. So we have employed the usage frequency of current IT services as a *proxy* for the actual usage frequency of Cloud Computing services.

A summary of the usage frequency of various IT services is shown in Figure 21 in Appendix E. Not surprisingly, the most frequently-used IT services are *basic office applications* (e.g. Microsoft Office software), *raw computing resources* (servers, storage discs and bandwidth etc.), and *business applications* (ERP software, CRM software etc.). Although we know that these data cannot fully represent the usage frequency of equivalent Cloud Computing services, we do notice that these services are among the first offered Cloud Computing services in the market. As shown in the Table 14 in Appendix A, companies like Google and Zoho are the pioneers providing online documents editing services, as an equivalent for the traditional Microsoft Office® software. Although these services are not yet widely accepted by large enterprises, it does offer the individuals an alternative for buying the software from Microsoft. As for business applications, we have already described the success of Salesforce.com on the On-Demand CRM application market in Chapter 3.1. And the situation by raw computing resources is even more obvious: the most Cloud Computing service providers on the current market are providing some sort of storage, backup, or synchronization services[73]. So we believe that the Cloud Computing services on the current market match quite well the need of customers and potential customers for general IT services.

Compared to the services mentioned above, much fewer respondents said their companies use *specialized applications* and *special IT services* frequently. This is understandable because these services are "special", which means they are used only

[73] See Table 14 in Appendix A.

for certain proposes, products or customers. We have also observed that even fewer companies are starting to use *Cloud Operating System*. The Cloud Operating Systems are not necessarily an equivalent for Windows or Linux system. The word "Operating" here has a wider range of meaning. These systems work in a distributed system, or between many distributed systems, and are used as a platform for managing applications as well as resources in a network. Currently, there are a couple of start-ups providing Cloud-like Web Operating Systems in the market, such as G.ho.st (see Table 14 in Appendix A) and eyeOS[74], but none of them has experience in developing traditional *on-premises* operating system. Till now, they work more like mash-ups of diverse Web Services [Lawt08, 16-17]. The first major Cloud Operating System is the Windows Azure®, announced by Microsoft at the end of Oct. 2008. It is "less a replacement for the operating system that runs on one's own PC than it is an alternative for developers, intended to let them write programs that live inside Microsoft's data centers as opposed to on the servers of a given business" [Frie08]. Microsoft is clearly the most influential provider on the operating system market, hence its movement means a lot for the whole market, as well as the customers. However, since the service is online for just 4 months, we are not sure whether its influence is already represented in our survey.

5.2 Status Quo of Cloud Computing market

5.2.1 Current market acceptance of Cloud Computing

Figure 22 in Appendix E shows the responses to Q4-1 "the best description of Cloud Computing's current role in your company is". The percentage of companies *already using* certain Cloud Computing services is surprisingly high (36%, 33% of them said they are already using some Cloud Computing services and expect to use more; 3% of them said that they are already using some Cloud Computing services and do not expect to use more). One possible reason for that high ratio of Cloud Computing usage is: as a new concept, Cloud Computing has gained a range of different

74 More Cloud-like Web Operating Systems are introduced by G. Lawton [Lawt08].

definitions[75], even from people familiar with it. For people who consider the services like web email service as Cloud Computing services too, it will be much easier to confirm that their companies have already used certain Cloud Computing services. However, with the majority among the existing users of Cloud Computing choosing "expecting more", their *positive* attitude towards Cloud Computing services is quite clear. Together with another one third of the respondents saying that their companies are planning to use Cloud Computing services, this result provides a solid evidence for the potential growth of Cloud Computing market.

5.2.2 Reason for using Cloud Computing services

Figure 23 in Appendix E shows the reasons why the users and potential users think Cloud Computing services are attractive.

We find out that the *cost reason* is clearly the most influential one for buying Cloud Computing services: nearly all the respondents have chosen "Strongly Agree" or "Agree" for "*less capital lockup*", "*less sunk costs*" and "*less administration & maintenance costs*" as reasons for using Cloud Computing services. We believe this is partly a result due to that *Public Cloud* is regarded by many market participants as the only form of Cloud Computing: in the Software as a Service (SaaS) and Infrastructure as a Service (IaaS) model, users do not need to invest heavily in the applications and infrastructure in advance. However, in the case of a *Private Cloud*, service users should own the infrastructure and applications they use in the Cloud, and there is *no* clear evidence that this will leads to a reduction of capital lockup and sunk costs.

Other important reasons for using Cloud Computing services are performance oriented, such as "*system continuity and availability*" as well as "*high scalability of the system*". To our best knowledge, there is yet no empirical research on how these expectations are met by the SPs. We have tracked the Amazon AWS to obtain a rough picture of the current system continuity of Cloud Computing services, because

75 See Chapter 2.1.1.

Amazon AWS is widely regarded as the most mature (Public) Cloud Computing platform. We have noticed that just in 2008, Amazon AWS has experienced at least three major outages, in the 15th February [Ston08], the 7th April [Gohr08], and the 20th July [AWS08] separately[76]. Each outage has lasted for at least a couple of hours. Various sources show that these outages had a significant impact on many companies or services using Amazon AWS as computing resources or storage host, such as Twitter, 37Signals etc. As for the scalability, a paper from CERN shows that the scalability based on the network performance of Amazon EC2 and S3 is “reasonable and compares well to the performance that can be expected from large data centers like CERN’s”, but they are not sure whether Amazon AWS can afford large scale usage at the level of what large publicly funded centers can offer [CERN08, 16].

About half of the respondents have chosen “Strongly Agree” or “Agree” for “*system interoperability*”, “*less deployment time & complexity*”, “*Green IT*”, and “*less data loss*” as reasons for using Cloud Computing services. The first two are strongly technical oriented subjects, which usually receive more attention in the implementation stage. As for “Green IT”, the main potential contribution of Cloud Computing is improving the *utilization ratio* in data centers and accelerating the data center consolidation. However, as this survey result suggests, the idea of “Green IT” does not yet enjoy a high priority by the IT-related investments at the corresponding companies. It is hard to believe that companies treat security issues like data loss as trivial problem, so the result indicates that many respondents think Cloud Computing is unable to prevent these things from happening. This is also confirmed by the question about customers’ concerns for Cloud Computing[77], by which the “security issue” received most attention from the respondents.

The least chosen reasons for using Cloud Computing services are “*monitoring tools and accountability*”, “*quick integration*” and “*consolidation of legacy systems*”.

[76] Because the “AWS Service Health Dashboard” (http://status.aws.amazon.com/) provides only the service status from the last 35 days, we cannot track the full list of system outages from Amazon itself.

[77] See Chapter 5.2.3.

Despite the inherent monitoring tools of those Cloud Computing platforms, the only third-party monitoring tool we know is provided by Right Scale, for Amazon AWS[78]. As for the latter two reasons, which are in fact associated with each other, more researches are needed to confirm these advantages of Cloud Computing compared to traditional IT services.

5.2.3 Reason against using Cloud Computing services

Figure 24 in Appendix E shows the concerns of users and potential users for Cloud Computing services.

We see the biggest concern among the responses is the "*security issue*". Since the users of Cloud Computing services do not always own the infrastructure and applications (as in the case of Public Cloud and Hybrid Model), they have easily the concern of where their data are stored, and whether they are secure. The security issues are addressed in some SPs' service agreement or description, such as at Amazon AWS. The Amazon AWS uses a range of security measures to mitigate the potential risk, including SOX[79] certification, physical security in data center, and backup services [AWS08]. However, this survey result shows that users and potential users are not yet convinced by the effort made. This finding is also consistent with that from J. Staten, who said that many enterprises are not using Cloud Computing services because they are not secure enough [Stat08, 8].

The nest things bother users of Cloud Computing are the "*technology immaturity*" and "*technology complexity*": more than 60% of the respondents either agree or strongly agree that these are concerns against using Cloud Computing services. Although many of the technologies supporting Cloud Computing are already mature, e.g. the virtualization technology, but the technology immaturity of Cloud Computing

[78] See Table 14 in Appendix A.

[79] SOX = Sarbanes Oxley Act, which establishes new and enhanced standards for all U.S> public company boards, management, and public accounting firms. It contains certain requirements on the IT auditing practices regarding change management, archiving and reporting etc. For more information about SOX, please visit: http://en.wikipedia.org/wiki/Sarbanes-Oxley_Act.

as a whole is partly confirmed by the relatively frequent system outages we mentioned in Chapter 5.2.2, as well as by the characteristics of current users (i.e. mainly “innovators” and “early adopters”). More controversial is the problem about technology complexity: while the unanimous definitions of Cloud Computing, the lack of interoperability between current Cloud Computing platforms, and generally the immature stage of technology development do increase the complexity of Cloud Computing for the users and potential users, Cloud Computing actually promises a lot of *simplicity*: e.g. the users should not care about where exactly the data are hold, have an ubiquitous access to the data and services they need, and enjoy a great usage flexibility because the high scalability of their systems. The survey result shows that the respondents are not yet convinced by the benefits mentioned above. More research efforts are needed, to find out whether they can “simplify” Cloud Computing for the customers *in the long run*.

Nearly 60% of the respondents believe there can be certain “*lock-in*” problem by the Cloud Computing services. The lock-in problem occurs when the customers of a certain SP are unable to change the SP, or can only do that with prohibitively high costs of money or time, so that they are forced to stay in contracting relationship with this SP. The lock-in problem is one form of *ex post transaction cost* in the Transaction Cost Theory [Will79, 239-242]. For Cloud Computing services, this problem is represented by the lack of standards and interoperability between systems. For example Amazon AWS didn’t support Windows OS until the end of 2008; Google App Engine currently supports Python as the only programming language; besides, moving data from Amazon Simple DB to other databases or moving applications from Google App Engine to other platforms can be all very difficult by now [Righ09]. Generally, the standardization of Cloud Computing systems in both interface level and technical level has not yet received much attention [JMFo08, 8].

Besides the concerns mentioned above, most of the other potential problems listed in the survey are regarded as substantial by ca. half of the respondents, including the “*system failure due to hardware*”, which is tightly associated with the “*system* *continuity and availability*" as an important attraction ob Cloud Computing; the "*legacy infrastructure*"; the "hostile software licensing regime", and the "*legal compliance*" problem. To our best knowledge, there are quite few customers of Cloud Computing already replaced their IT systems with the new Cloud Computing services. As mentioned in Chapter 3.1.3, the most current users are using Cloud Computing services for their non-core IT activities. In this case, legacy infrastructure can hardly be a problem, but it does not mean that in the future, when Cloud Computing is becoming a massively adopted IT practices, consolidating the legacy infrastructure will still be a trivial task.

The least concerned problem by the respondents is the potential "*high deployment costs*". The respondents tend to believe that Cloud Computing is not associated with high deployment costs at all. Combined with the results from Chapter 5.2.2, the survey shows that at this time, the biggest attraction of Cloud Computing seems to be the *cost advantages*.

5.3 Market structure of Cloud Computing market

5.3.1 Test results for Hypothesis No.1 (H1)

The H1 is: "*Customers prefer Public Cloud for homogeneous IT services and Private Cloud for heterogeneous IT services, when the usage frequency is high*". As mentioned in Chapter 4.3, we take three steps to test whether this hypothesis is true.

The null hypothesis (H0) to test is: "for Cloud Computing services, market structures and service homogeneity are independent variables." Then, we use the 2 x 2 contingency tables as shown below to test the H0. Responses are categorized with two variables: market structure and service homogeneity. So we are testing the homogeneity of preferred market structures regarding the different service homogeneity here. Since short-term contracts and in-house transaction are the two extreme forms of market structures, we have selected these two options for analysis, leaving the mixture model out, also because a 2 x 2 contingency table fits better for many analyses[80].

Table 7 Relationship between Market Structure and Service Homogeneity

		Market Structure					
		Short-term		In-house		Total	
Service Homogeneity	Homogeneous	17	19%	18	20%	35	39%
	Heterogeneous	11	12%	44	49%	55	61%
	Total	28	31%	62	69%	90	100%

As shown in Table 7 above, for homogeneous services, there are no clear preferences for short-term contracts, as asserted by Williamson. But for heterogeneous services, the majority of respondents clearly prefer in-house transactions. The general difference between respondents choosing short-term contracts and in-house transactions (31% vs. 69%) indicates that service homogeneity is by no means the only influencing factor for the market structure, and this certainly contributes to the bias of the survey results too[81].

Table 8 Chi-Square Tests and Correlation Coefficient for the Relationship between Market Structure and Service Homogeneity[82]

	Value	Df[83]	Asymptotic Sig.[84] (2-sided)
Chi-Square	8.147[85]	1	0.004
Yates' Continuity Correction	6.868	1	0.009
Fisher's Exact Test			0.006

[80] See Chapter 4.3.2 and 4.3.3.

[81] See Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**.

[82] This group of tests, including the Chi-Square test, likelihood test and Fisher's exact test etc. are summarized into one table. Note that when the sample number is not ->∞, the result of Chi-Square may be biased, and the value of Yate's continuity correction (in this case, 0.009) should be used, which is stricter than the original Pearson chi-square value.

[83] Df = Degree of Freedom

[84] Sig.= Significance

[85] Please check the value table of Chi-Square distribution in Appendix F. Here, 0 cells (.0%) have expected count less than 5. The minimum expected count is 10.89.

Contingency Coefficient	**0.288**		**0.004**
Phi Coefficient	**0.301**		**0.004**
Cramer's V	**0.301**		**0.004**
N of Valid Cases	**90**		

The statistical test results are shown in Table 8. The Chi-Square value has a significant level of 0.004, which means that the H0 can be rejected with a confidence level of 99.6% (=1-0,004), and even after correction, the significant level is still as high as 0,009; the Fisher's exact test shows a significant level of 0.006, which means the H0 can be rejected at a 99.4% confidence level. So we can reject the H0 quite confidently. The conclusion here is that the two variables, the market structures and service homogeneity, are *not independent*. Then we calculate the correlation between the two variables (market structures and service homogeneity) using contingency coefficient, Phi coefficient and Cremer's V, to find out how significant the correlation between the two variables is. The Phi coefficient indicates that the correlation between service homogeneity and market structure is 0.301, which shows a *medium correlation* (0.30-0.49)[86].

5.3.2 Test results for Hypothesis No.2 (H2)

The H2 is: "*Customers prefer Public Cloud for all kind of IT services, when the usage frequency is low*". According to the nature of this hypothesis, no contingency table is employed. Instead of that, we try to verify the hypothesis using a *pie chart* summarizing the preferred market structures from all respondents for low-frequency IT services. The pie chart is shown below. We can easily tell whether the hypothesis should be rejected by viewing how much percentages of these responses actually prefer Public Cloud.

[86] Unlike in the physical science, the observed correlations in social science is often much weaker. There are no unanimous definition of what range of correlations should be called "large", "medium" or "small", because it depends on the concrete study subjects or the specific purpose of research. However, we employ here a convention used by J. Cohen, who defined the correlation between 0.10 – 0.30 as *small*, between 0.30 – 0.50 as *medium*, and above 0.50 as *large* [Cohe88, 78-81]

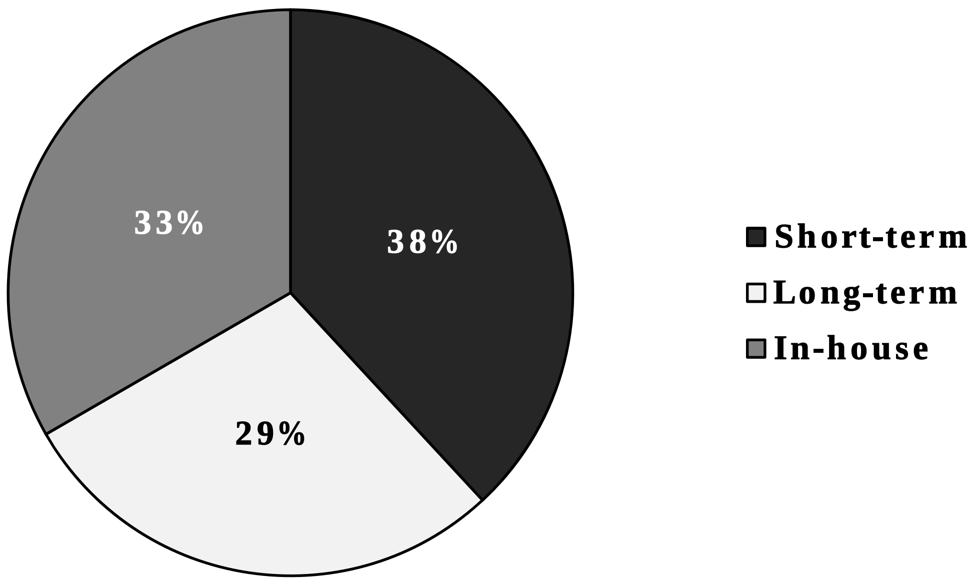

Figure 5 Preferred Market Structures for Infrequent Services[87]

Figure 5 shows that there is no clear preference for short-term contracts, when the services are infrequently consumed. This is clearly against H2, which assumes that customers may prefer short-term contracts for infrequent services, no matter how specific the involved investments are[88].

So the test result for H2 is, that H2 should be rejected, *low usage frequency does not necessarily leads to preference for short-term contracts.*

Since there is no evidence of usage frequency being an influencing factor in the market structure. *An additional test* is made to reexamine the relationship between service homogeneity and market structure, *without* considering the influence of usage frequency, because generally, the service homogeneity should be the major influencing factor on market structure[89]. The major difference between this test and the test conducted in Chapter 5.3.1 is that the survey results here are *grouped* according to each service they belong to, so that the inherent difference between

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[8787] Infrequent services are the services which, as claimed by the respondents in the survey, are "very infrequently (rare)" or "infrequently (monthly)" used in their companies.

[88] See Chapter 4.1.2.

[89] See Chapter 3.2.1.3.

services do not cause bias for the test result[90]. In this case, the service homogeneity is the only independent variable; there is a convenient way to run a *single-variable linear regression* for the test. As shown in the table below: the *standardized coefficient ("R value")* is fairly large (0.546), larger than the results we get from the Chi-Square contingency table before[91]. This indicates that *Service Homogeneity alone can be a good prediction for the preferred market structure*. To notice is though, the significant level of this test is not especially high (0.129), so we mainly use this test result as a reference instead of final conclusion.

Table 9 Single-Variable Linear Regression for Service Homogeneity on Market Structure

	Unstandardized Coefficients		Standardized Coefficients	t-value	Sig.
	Beta	Std. Error	Beta (R value)		
Service Homogeneity	0.531	0.308	0.546	1.723	0.129

5.4 Price models in Cloud Computing market

5.4.1 Test results for Hypothesis No.3 (H3)

The H3 assumes that "*Customers prefer PAYG model for homogeneous IT services and Flat Rate model for heterogeneous IT services*". The test process for this hypothesis is similar to the test for H1.

We have also built a 2 x 2 contingency table. Due to similar reason as for H1[92], we have removed the option "Mixture model" from price models, and focused on the analysis of the two "extreme" options: PAYG model and Flat Rate model. The test results are presented in the table below:

[90] This method does not fit for the first test on H1 in Chapter 5.3.1, because the influence of usage frequency could not be isolated from the grouped results there.

[91] See Table 8.

[92] See Chapter 5.3.1.

Table 10 Relationship between Price Model and Service Homogeneity

		Price Model					
		PAYG		Flat Rate		Total	
Service Homogeneity	Homogeneous	26	19%	34	25%	60	44%
	Heterogeneous	33	24%	44	32%	77	56%
	Total	59	43%	78	57%	137	100%

From the table, we can already see that the service homogeneity seems to have *no influence* on the choice of price model at all, because the proportion of respondents choosing PAYG model and Flat Rate model respectively for homogeneous and heterogeneous services are both 1:1.3 (34/26=1.3, 44/33=1.3). The Chi-Square test is conducted to confirm this finding. The test result is shown in the table below:

Table 11 Chi-Square Tests and Correlation Coefficient for the Relationship between Price Model and Service Homogeneity

	Value	Df.	Asymptotic Sig. (2-sided)
Chi-Square	0.003	1	0.955
Continuity Correction	0.000	1	1.000
Fisher's Exact Test			1.000
Contingency Coefficient	0.005		0.955
Phi Coefficient	0.005		0.955
Cramer’s V	0.005		0.955
N of Valid Cases	137		

From the table, we see that the significant level of all the critical Chi-Square test results are above 0.955, which means the H0 cannot be rejected at all. The correlation coefficients in the table show similar conclusions then: the service homogeneity and price model have a correlation as small as 0.005, which means they can be regarded as independent variables.

So the test result for H3 is: H0 is not rejected, *no correlation between service homogeneity and price models is found*.

5.4.2 Test results for Hypothesis No.4 (H4)

The H4 assumes that "*Customers prefer PAYG model for frequent used IT services and Flat Rate model for heterogeneous IT services*".

The answers for the usage frequency question were given in a Likert scale style[93]. To use a 2 x 2 contingency table, as for the former hypothesis testing, we need remove both the option "Mixture model" from the variable "price model" and the option "normal" from the variable "usage frequency". This will omit too much data and reduce the prediction power of the test. Hence we transfer the Likert scale data for "usage frequency" into a 3 point scale: the category "infrequently" now includes both answers "infrequently and very infrequently" from the original survey results; and the category "frequently" includes both "frequently" and "very frequently" then. In this way, we have created a 3 x 3 contingency table for these two variables: The test process for this hypothesis is similar to the test for H1. Test results are presented below[94]:

Table 12 Relationship between Price Model and Usage frequency

		Price Model			
		PAYG	**Mixture**	**Flat Rate**	**Total**
Usage frequency	**Infrequently**	12	9	20	41
	Normal	4	7	16	27
	Frequently	43	29	30	102
	Total	59	45	66	170

As shown in the table above, the sample size for frequently-used services is considerably larger than that for normally and infrequently-used services. Despite this obvious difference, we can observe a tendency of using more PAYG model for frequently-used services, and Flat Rate model for normally and infrequently-used

93 See Q3-3, Figure 14 in Appendix C.

94 In order to make the table clean, the percentage data are not shown here.

services. We examine this trend using Chi-Square tests as shown below:

Table 13 Chi-Square Tests and Correlation Coefficient for the Relationship between Price Model and Usage frequency[95]

	Value	Df.	Asymptotic Sig. (2-sided)
Chi-Square	11.667	4	0.020
Contingency Coefficient	0.253		0.020
Phi Coefficient	0.262		0.020
Cramer's V	0.185		0.020
N of Valid Cases	170		

The Chi-Square value has a significant level of 0.020, which means we can reject the H0 ("For Cloud Computing services, price models and usage frequency are independent variables.") at a 98% confidence level. After accepting the dependency of price model on usage frequency, we observed the major correlation coefficients with values between 0.185 (Cramer's V) and 0.262 (Phi Coefficient).

This result suggests that usage frequency does have a certain influence on the price model: users prefer PAYG model for frequently-used services and Flat Rate for infrequently-used services, as predicted in Chapter 3.2.2.4 before; however, the correlation between these two variables is not especially high. This indicates that the choice of price models may be determined by other factors than the usage frequency too.

5.5 Evaluation of research methodology

Despite the analyses in this Chapter, we are aware of the limitation of such a single survey, especially at the early stage of market development as well as the academic researches on the certain topic. Alongside with this survey, we think the following points may cause potential biases the readers should pay attention to:

- One basic assumption of Chi-Square independency tests, which are employed in the survey analyses, is that the evaluated data represent a *random sample* from

95 Since both Continuity Correction and Fisher's Exact Test are only applicable for 2x2 cross tabulation, there are no results for these two values in this test.

the target group of survey [Shes04, 494]. However, the responses we get from the survey are not necessarily random, because the main channels of the survey delivering (email invitations, forum posts etc.) involve heavily the SPs and Cloud Computing supporters. Companies with no interest in Cloud Computing, or even negative attitude, may simply not bother to participate in this survey. From the survey result, which indicates that 36% of the corresponding companies are already using Cloud Computing services, we believe there are certain positive biases involved in this survey results.

- As mentioned in Chapter 4.1.1, we acknowledge that the service homogeneity and the usage frequency are not the *only influencing factors* for market structure and price model. For example, security issues may cause general concerns about the implementation of Cloud Computing outside the company, therefore users and potential users may prefer to use in-house Cloud Computing solutions, even when the services are highly homogeneous, and the transaction cost of obtaining the service from open market may be lower. While considering all these potential influencing factors is far beyond the scope of a master thesis, we believe there are certainly other factors worth further research efforts.
- Due to the limitation of available data, "*options in the middle*" for both market structure and price model, i.e. the *Hybrid model* and the *Mixture model* are not sufficiently examined. While they are both popular choices by the current SPs on the Cloud Computing market, we are unable to deliver adequate factor analysis for them based on this survey.

6 Concluding Remarks and Further Research Directions

To our best knowledge, this is the *first* empirical study in the market acceptance of Cloud Computing services regarding the market structures and price models. Based on the customer survey, we have following findings:

- In general, the Cloud Computing market is still *at its early stage of development*. The main users in the market are so-called "innovators" and "early adopters", and users still have many concerns facing the uncertainty of the technology evolvement as well as the business model development. However, the general attitude toward Cloud Computing services among the users and potential users is very positive.
- *Service homogeneity* serves as a good indicator for the preferred *market structure* of certain Cloud Computing service. Generally, the users and potential users tend to choose open market transaction, i.e. Public Cloud for homogeneous services, and in-house transaction, i.e. Private Cloud for heterogeneous services.
- The influence of *usage frequency* on the preferred *market structure* is not observed. The percentages of users and potential users choosing each market structure under the low-frequency services are nearly the same. This finding is against the original assumption from the Transaction Cost Theory, which said that users should always prefer open market transactions against bilateral or unified transactions given the usage frequency is low.
- The *usage frequency* does have certain influence on the preferred *price model*. Users tend to choose PAYG model for high-frequency services, and Flat Rate model for low-frequency services. Since the correlation between the usage frequency and price model is not extremely high, we recommend further investigation of the potential influencing factors on price models of Cloud Computing services.
- Compared to the preferences from users and potential users of Cloud Computing, services provided in the market match well their general need for IT services, but

not the current need for Cloud Computing services. As shown in Chapter 5.1.3, the services mostly promoted by the SPs, are the services with high usage frequency too, such as raw computing resources, basic office applications and business applications, but currently, most companies are not using Cloud Computing services for their core IT activities. While this mismatch can be solved in the market development of Cloud Computing in the future, it does have negative influence on the SPs' profitability by now.

As an evolving technological field, Cloud Computing embeds a mine-field of unanswered questions, to many of which the answers will become obvious possibly only with hindsight. However, we believe there are number of existing theoretical frameworks, such as the Transaction Cost Theory employed in this thesis, which can help us understanding the possible development of Cloud Computing. They may not be designed specific for Cloud Computing, but the general implications from them can be useful. Of course, further verification or empirical studies are necessary before applying an existing theoretical framework. We hope that this thesis can deliver hints for the development of Cloud Computing market as well as for further theoretical analyses in the future.

Appendices

A List of SPs

Table 14 The Full List of 38 SPs in the Current Cloud Computing Market

Companies	Active / Beta	A/P/ R/T [96]	S/ L/I [97]	PAYG/ Mixture/ Flat Rate	Service / Products	Notes
10Gen	B	P, A	I		Hosting service	Open source
37signals	A	A	S		CRM solutions	
3Tera	A	R, T	N/A[98]		Grid Hosting, AppLogic system	
Adobe Acrobat	B	A	S		Collaboration solutions	
Akamai	A	A, T	L		Application Performance Solutions	
Amazon AWS	A	R	S	PAYG	Cloud Computing ecosystem, (EC2, S3, SimpleDB, SQS, and FPS)	Cooperation with Salesforce
Aptana	B	R, P	S	PAYG	Computing service, "Aptana Studio" (platform)	
Areti (Alentus)	A	R	L	Mixture	Grid hosting (Ares), managed hosting, co-location	Using 3Tera's AppLogic
AT&T	A	R	L		Managed hosting	
Cassatt	A	A, T	I		Hosting, Utility Computing ("Cassatt Active Response")	
Cisco Systems	A	A, T, P	I		WebEx Connect platform, Data Center solutions	
Citrix (inc. XenSource)	A	A, T	I		Dynamic Application Delivery System, Citrix Cloud Center	
Cloudworks	A	R, A	S, L	PAYG	Storage service and backups	Supported by Citrix
cohesiveFT	A	P, T	N/A		Development platform, VM[99] Management software	

[96] A= Application, P= Platform, R= Physical resource, T= Technology

[97] S= Short-term Contract, L= Long-term Contract, I= In-house Transaction

[98] N/A= Not Applicable

Dell	A	R	L, I	Flat Rate	Dell Cloud Computing solutions[100]	
Elastra	A	R, P, T	N/A	PAYG	"Elastic computing", system monitoring tools	Supported by Amazon S3
EMC (inc. VMware, Mozy)	A	R, T, A	I		storage & backup service, data center solutions	
Enki	A	R	S	PAYG	“Computing Utility” (Private Data Centers), co-location	Using 3Tera's AppLogic
Enomaly	B	T	N/A		"Enomalism Cloud Computing"	Open source
Eucalyptus	A	T	N/A		“Eucalyptus Public Cloud”	Open source
FlexiScale	A	R	S	PAYG	Server hosting	
Fortress ITX	A	R	L		Managed hosting, co-location	Using 3Tera's AppLogic
Gh.o.st	B	A	S		Virtual desktop	Supported by Amazon S3
GoGrid / ServePath	B	R	S	PAYG	Grid hosting, “Cloud Connect”, storage	
Google	B	R, P	S	PAYG	App Engines (platform), storage	Python environment
IBM	A	A, T	L, I	Flat Rate	"Blue Cloud", "Bluehouse"[101]	
Joyent	A	R, A	S	Mixture	Computing and storage solution, Web application platform	
Microsoft (Azure platform etc.)	A	R, A, P	S		Azure platform, Collaboration solutions, ECM[102], Exchange Hosted Services, CRM	
Mosso	A	P	S	Mixture	Cloud storage, web hosting	
NetSuite	A	A	S		CRM, ERP and eCommerce	

99 VM= Virtual Machines

100 Services provided by Dell include HPCC solution, server/storage consolidation, database solutions, VMware solutions, Citrix solutions etc. For more information, please visit: http://www.dell.com/contentS/topics/global.aspx/sitelets/solutions/main/solutions_center?c=us&cs=555&l=en&s=biz&~ck=mn.

101 “Bluehouse” project is currently in Beta phase.

102 ECM= Enterprise Content Management

Project Caroline (SUN)	B	P	N/A		“Platform as a Service” (PaaS)	Open source
QuickBase	A	P, A	S	Mixture	Online project management, online CRM etc.	
Right Scale	A	A, T	S	Flat Rate	Cloud computing management	Based on Amazon AWS
Salesforce	A	P, A	S	Mixture	"AppExchange" (platform)	
SUN Network.com	A	R, A	S		Utility Computing (Network.com)	
Terremark	A	R	S, L	PAYG	Managed hosting, co-location	Member of "Green Grid"
Workday	A	A	S		HR[103] management, financial management etc.	
Zoho	A	P, A	S		Online document software, CRM software, Zoho Marketplace	

[103] HR= Human Resources

B Email and forum post

B1 Email for SPs:

Dear XXX,

I am writing my master degree thesis on ***Cloud Computing*** *and am here to seek your help for two things:*

1. My main focus will be on ***current/potential customers' requirements and expectations for Cloud Computing****, including pricing models, preferred transaction forms, and SLA. Based on that information, I am trying to figure out the possible development trends in this transforming field. I'd like to know whether your company currently provides any SLA for the customers, and what kind of* ***price model*** *(pay-as-you-go, flat rate etc.) you are using.*

2. Below is an online survey which takes you only ***5-10 mins*** *but can provide us first-hand info about your needs and uses of Cloud Computing. The survey is designed to target* ***USERS of Cloud Computing****, however as a* ***PROVIDER*** *you could help us even more by posting the link to your (potential) customers:* ***http://tinyurl.com/cloud-survey/***

This survey would become the very important start point of my thesis, so your help is much appreciated. My thesis is also part of my faculty's research project at ***Bayreuth University****, Germany (http://www.uni-bayreuth.de)*

I would be more than happy to share the survey results and my completed thesis with you if you leave your email address (optional) at the end of the survey. Hope you will find them useful to you as well.

Thank you and wish you all a very prosperous new year!

Lei Han

B2 Post at Google Groups

From: 韩磊 **<klaushanlei@gmail.com>**

Date: ***Mon, 29 Dec 2008 00:09:25 -0800 (PST)***

Local: ***Mon, Dec 29 2008 9:09 am***

Subject: ***Help needed for CC thesis***

Reply | Reply to author | Forward | Print | Individual message | Show original | Remove | Report this message | Find messages by this author

I am writing my master degree thesis on Cloud Computing and am here to seek your help.

My main focus will be on current/potential customers' requirements and expectations for Cloud Computing, including pricing models, preferred transaction forms, SLA, etc., and eventually try to figure out the possible development trends in this transforming field.

Below is an online survey which takes you only 5-10 mins but can provide us first-hand info about your needs and uses of Cloud Computing. The survey is designed to target USERS of Cloud Computing, however as a PROVIDER you could help us even more by posting the link to your (potential) customers.

http://tinyurl.com/cloud-survey/

This survey would become the very important start point of my thesis, so your help is much appreciated. My thesis is also part of my faculty's research project at Bayreuth University, Germany (http://www.uni-bayreuth.de)

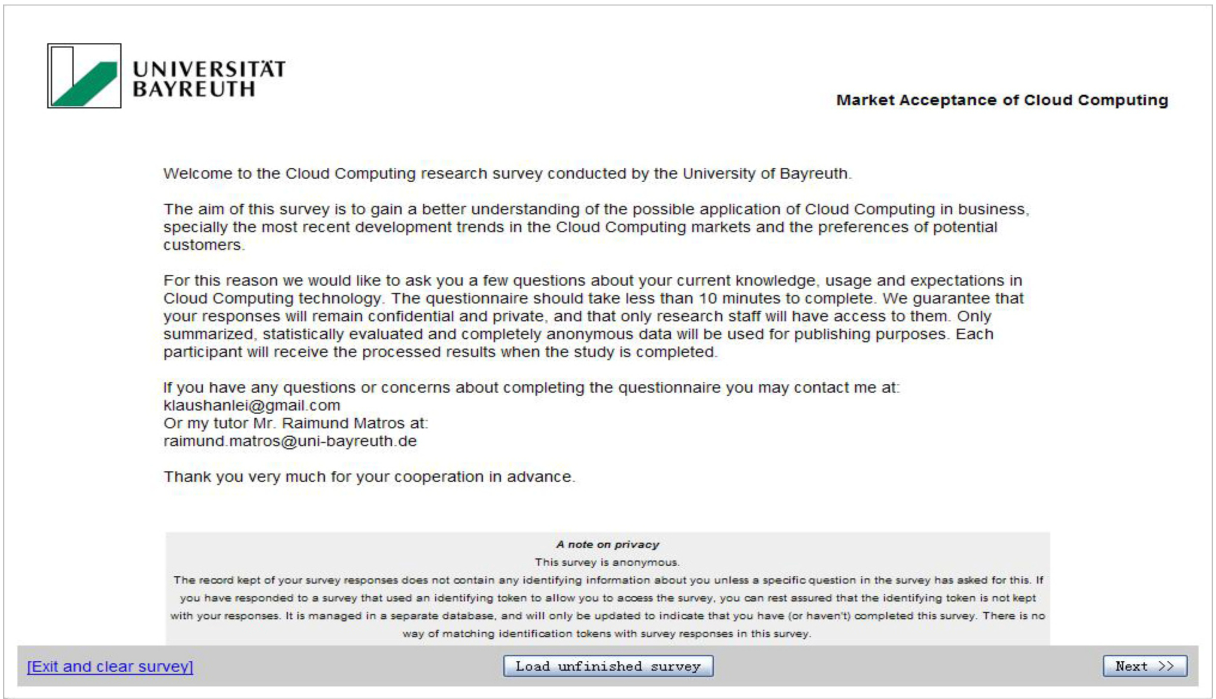
I would be more than happy to share the survey results and my completed thesis with you if you leave your email address (optional) at the end of the survey. Hope you will find them useful to you as well.

Thank you and wish you all a very prosperous new year!

C Survey (screenshots)

The questionnaire was conducted as an online survey, which can be accessed via http://btw6xb.bwl7.uni-bayreuth.de/cloud/index.php?sid=51885. The following figures are the screenshots of the survey:

Figure 6 Front Page of Questionnaire (Page 1 of 13)


UNIVERSITÄT BAYREUTH

Market Acceptance of Cloud Computing

Welcome to the Cloud Computing research survey conducted by the University of Bayreuth.

The aim of this survey is to gain a better understanding of the possible application of Cloud Computing in business, specially the most recent development trends in the Cloud Computing markets and the preferences of potential customers.

For this reason we would like to ask you a few questions about your current knowledge, usage and expectations in Cloud Computing technology. The questionnaire should take less than 10 minutes to complete. We guarantee that your responses will remain confidential and private, and that only research staff will have access to them. Only summarized, statistically evaluated and completely anonymous data will be used for publishing purposes. Each participant will receive the processed results when the study is completed.

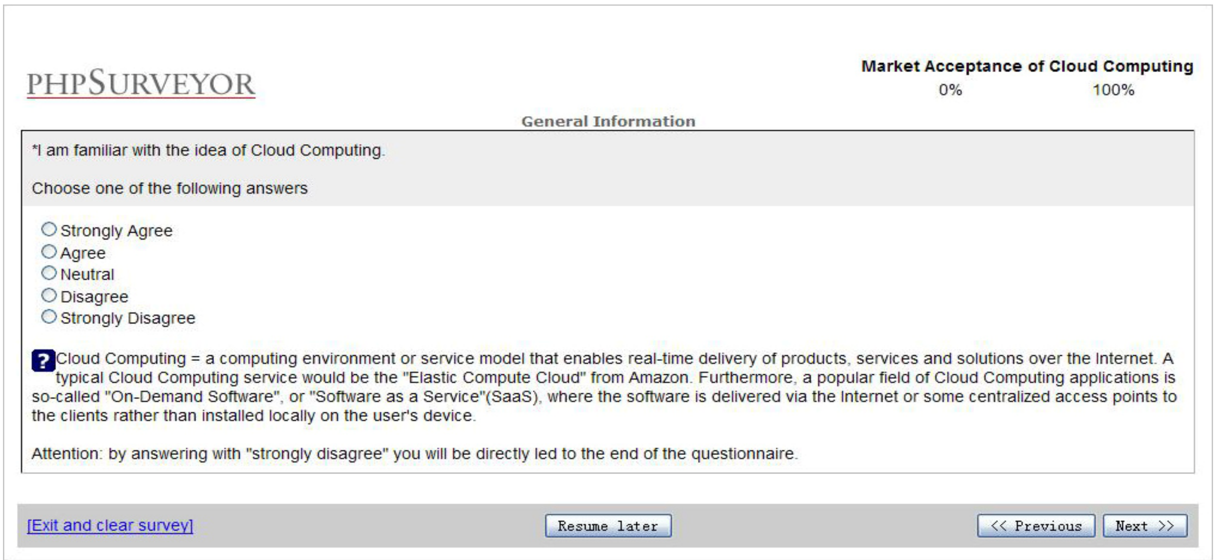
If you have any questions or concerns about completing the questionnaire you may contact me at:
klaushanlei@gmail.com
Or my tutor Mr. Raimund Matros at:
raimund.matros@uni-bayreuth.de

Thank you very much for your cooperation in advance.

A note on privacy
This survey is anonymous.
The record kept of your survey responses does not contain any identifying information about you unless a specific question in the survey has asked for this. If you have responded to a survey that used an identifying token to allow you to access the survey, you can rest assured that the identifying token is not kept with your responses. It is managed in a separate database, and will only be updated to indicate that you have (or haven't) completed this survey. There is no way of matching identification tokens with survey responses in this survey.

[Exit and clear survey] Load unfinished survey Next >>

Figure 7 Question 1-1 (Page 2 of 13)


PHPSURVEYOR

Market Acceptance of Cloud Computing
0% 100%

General Information

*I am familiar with the idea of Cloud Computing.

Choose one of the following answers

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

?Cloud Computing = a computing environment or service model that enables real-time delivery of products, services and solutions over the Internet. A typical Cloud Computing service would be the "Elastic Compute Cloud" from Amazon. Furthermore, a popular field of Cloud Computing applications is so-called "On-Demand Software", or "Software as a Service"(SaaS), where the software is delivered via the Internet or some centralized access points to the clients rather than installed locally on the user's device.

Attention: by answering with "strongly disagree" you will be directly led to the end of the questionnaire.

[Exit and clear survey] Resume later << Previous Next >>

Figure 8 Question 1-2 (Page 3 of 13)

Figure 9 Question 1-3 (Page 4 of 13)

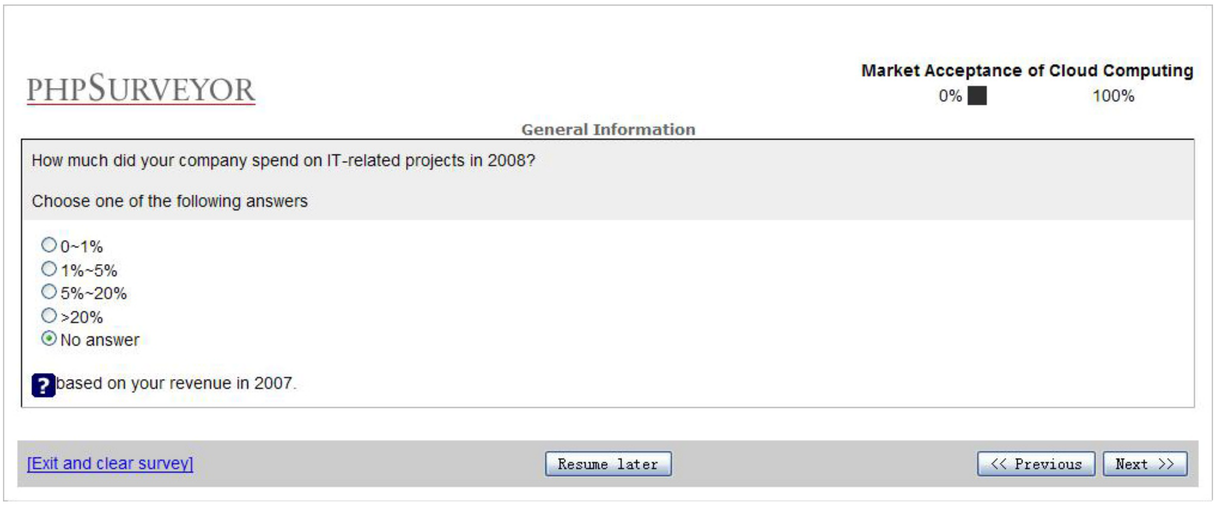


Figure 10 Question 2-1 (Page 5 of 13)

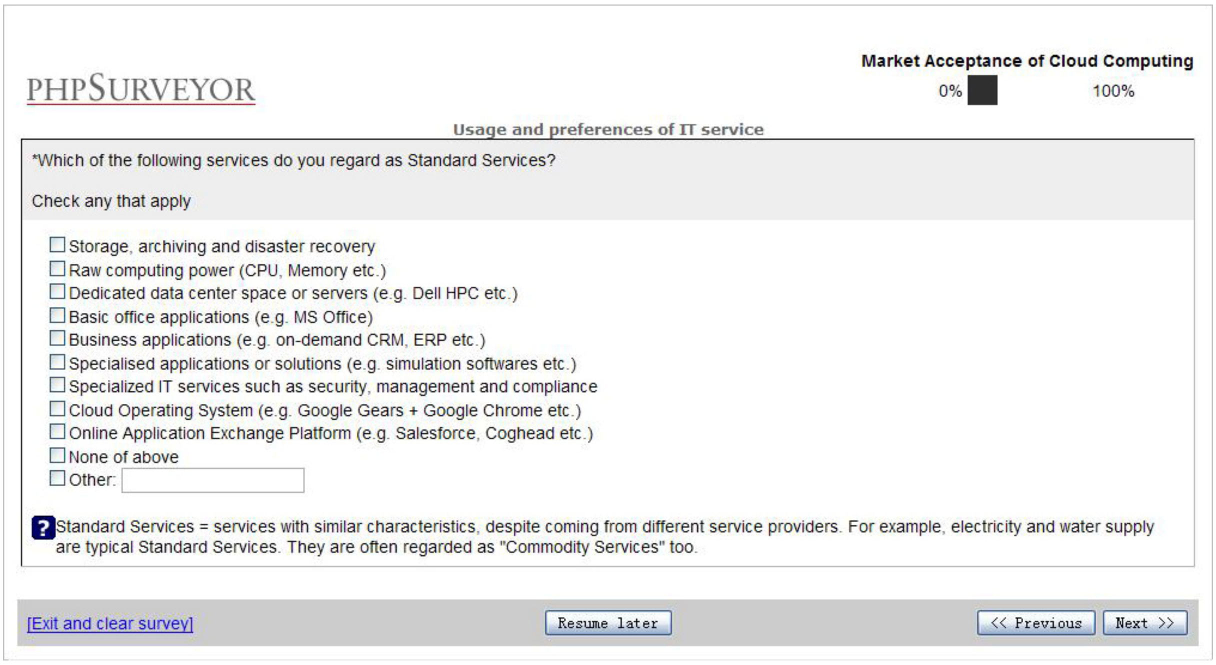


Figure 11 Question 2-2 (Page 6 of 13)

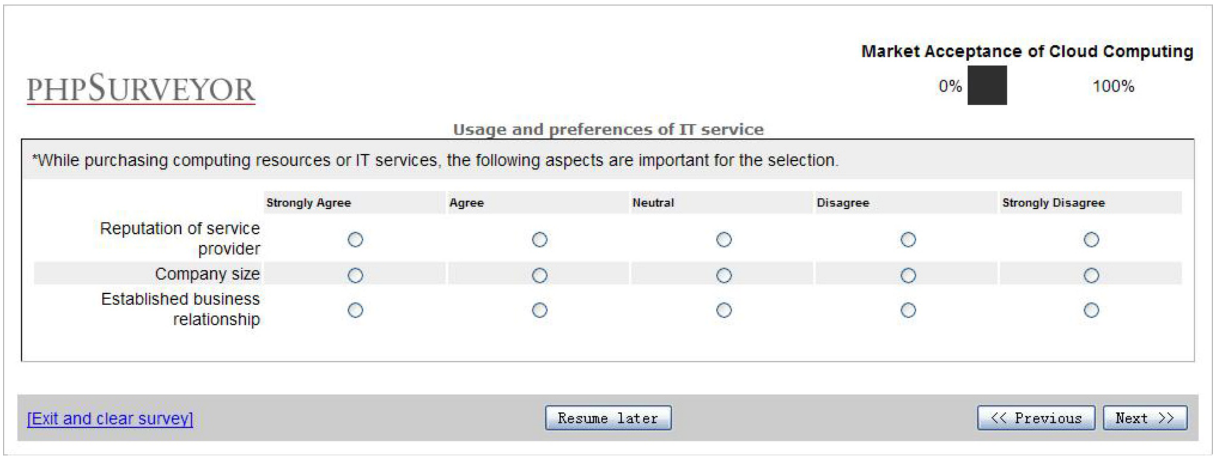


Figure 12 Question 3-1 (Page 7 of 13)

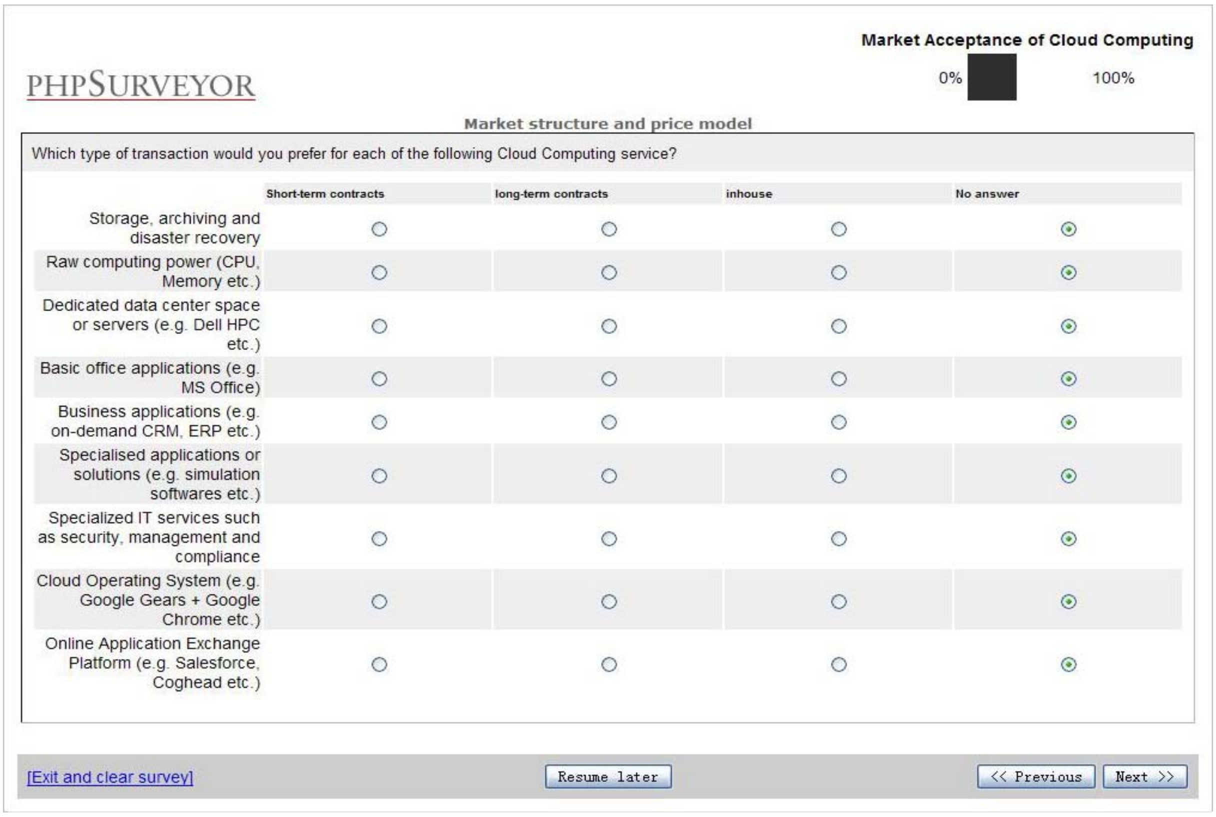
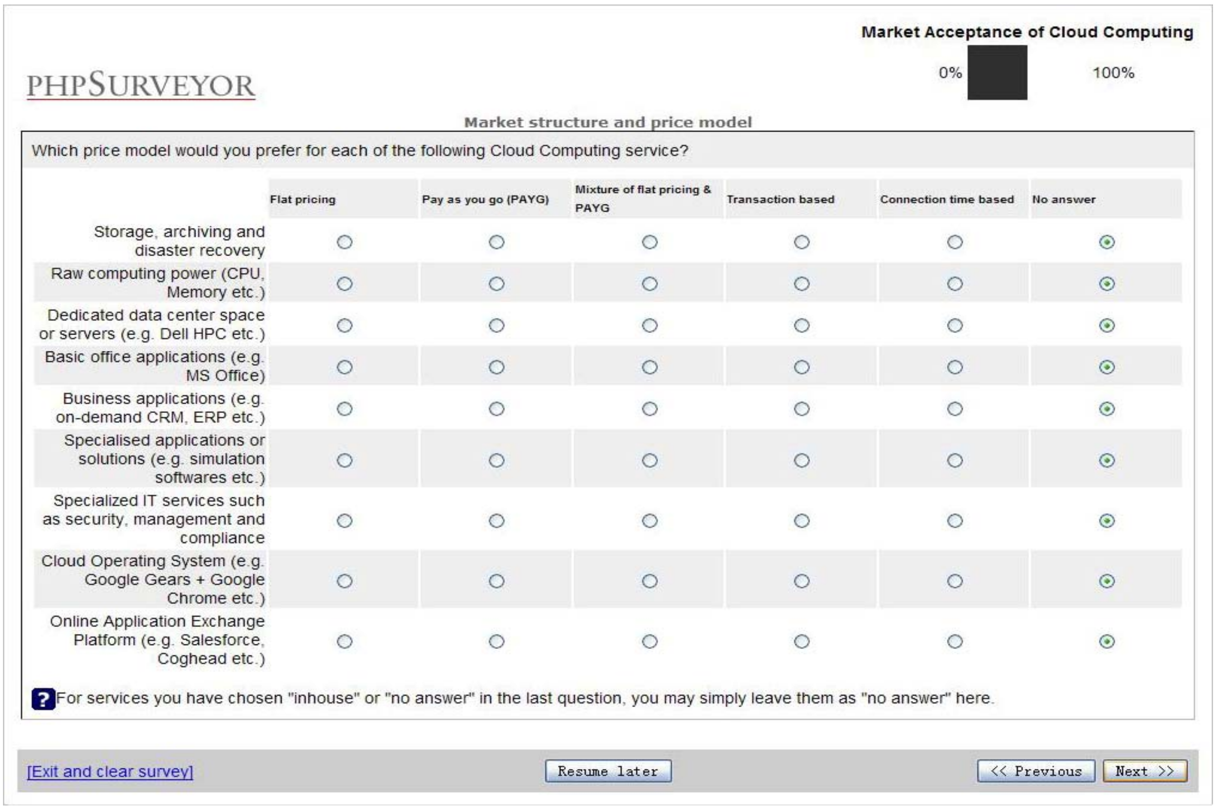


Figure 13 Question 3-2 (Page 8 of 13)



Market Acceptance of Cloud Computing

0% 100%

PHPSURVEYOR

Market structure and price model

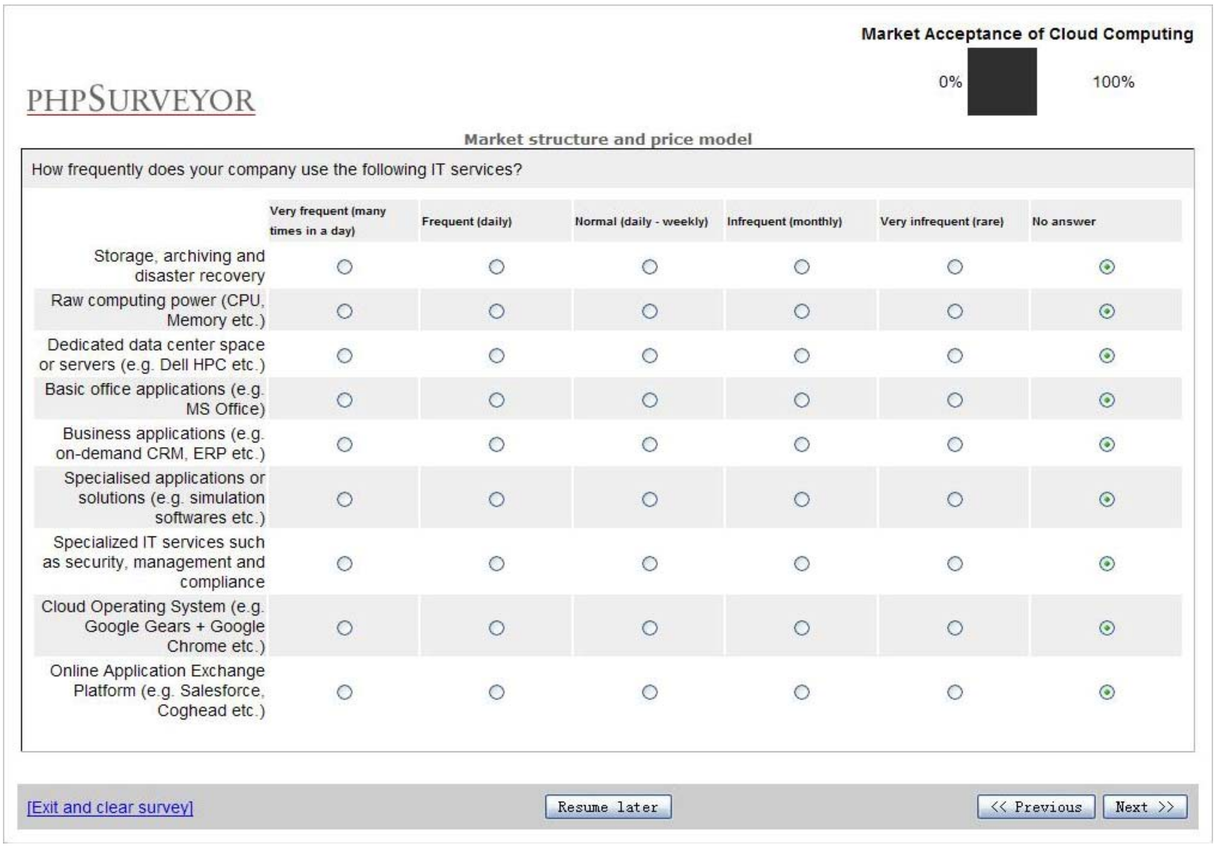
Which price model would you prefer for each of the following Cloud Computing service?

	Flat pricing	Pay as you go (PAYG)	Mixture of flat pricing & PAYG	Transaction based	Connection time based	No answer
Storage, archiving and disaster recovery	○	○	○	○	○	◉
Raw computing power (CPU, Memory etc.)	○	○	○	○	○	◉
Dedicated data center space or servers (e.g. Dell HPC etc.)	○	○	○	○	○	◉
Basic office applications (e.g. MS Office)	○	○	○	○	○	◉
Business applications (e.g. on-demand CRM, ERP etc.)	○	○	○	○	○	◉
Specialised applications or solutions (e.g. simulation softwares etc.)	○	○	○	○	○	◉
Specialized IT services such as security, management and compliance	○	○	○	○	○	◉
Cloud Operating System (e.g. Google Gears + Google Chrome etc.)	○	○	○	○	○	◉
Online Application Exchange Platform (e.g. Salesforce, Coghead etc.)	○	○	○	○	○	◉

?For services you have chosen "inhouse" or "no answer" in the last question, you may simply leave them as "no answer" here.

[Exit and clear survey] Resume later << Previous Next >>

Figure 14 Question 3-3 (Page 9 of 13)



Market Acceptance of Cloud Computing

0% 100%

PHPSURVEYOR

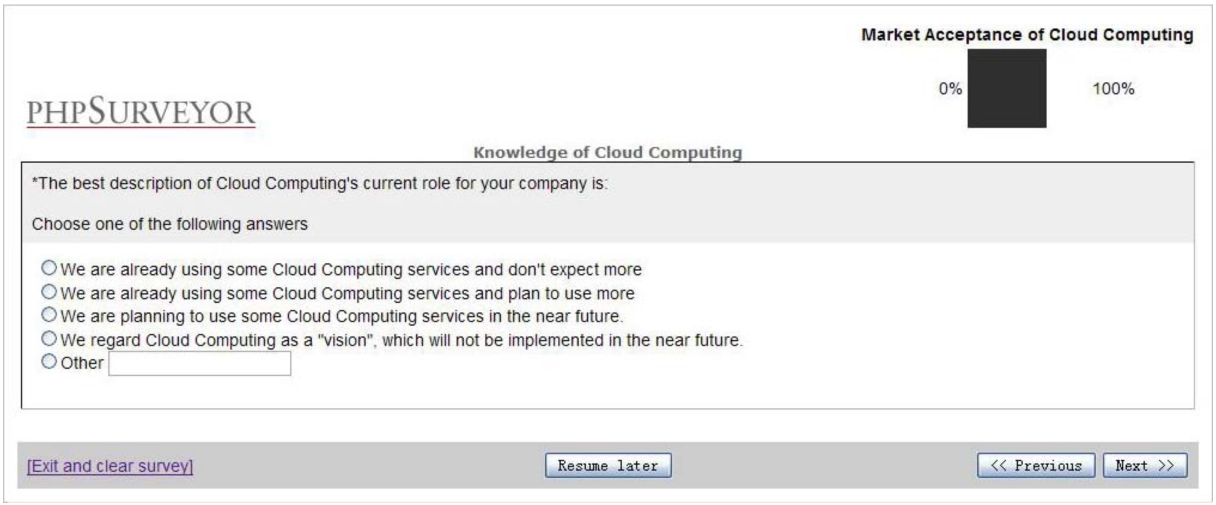
Market structure and price model

How frequently does your company use the following IT services?

	Very frequent (many times in a day)	Frequent (daily)	Normal (daily - weekly)	Infrequent (monthly)	Very infrequent (rare)	No answer
Storage, archiving and disaster recovery	○	○	○	○	○	◉
Raw computing power (CPU, Memory etc.)	○	○	○	○	○	◉
Dedicated data center space or servers (e.g. Dell HPC etc.)	○	○	○	○	○	◉
Basic office applications (e.g. MS Office)	○	○	○	○	○	◉
Business applications (e.g. on-demand CRM, ERP etc.)	○	○	○	○	○	◉
Specialised applications or solutions (e.g. simulation softwares etc.)	○	○	○	○	○	◉
Specialized IT services such as security, management and compliance	○	○	○	○	○	◉
Cloud Operating System (e.g. Google Gears + Google Chrome etc.)	○	○	○	○	○	◉
Online Application Exchange Platform (e.g. Salesforce, Coghead etc.)	○	○	○	○	○	◉

[Exit and clear survey] Resume later << Previous Next >>

Figure 15 Question 4-1 (Page 10 of 13)


Market Acceptance of Cloud Computing

0% 100%

PHPSURVEYOR

Knowledge of Cloud Computing

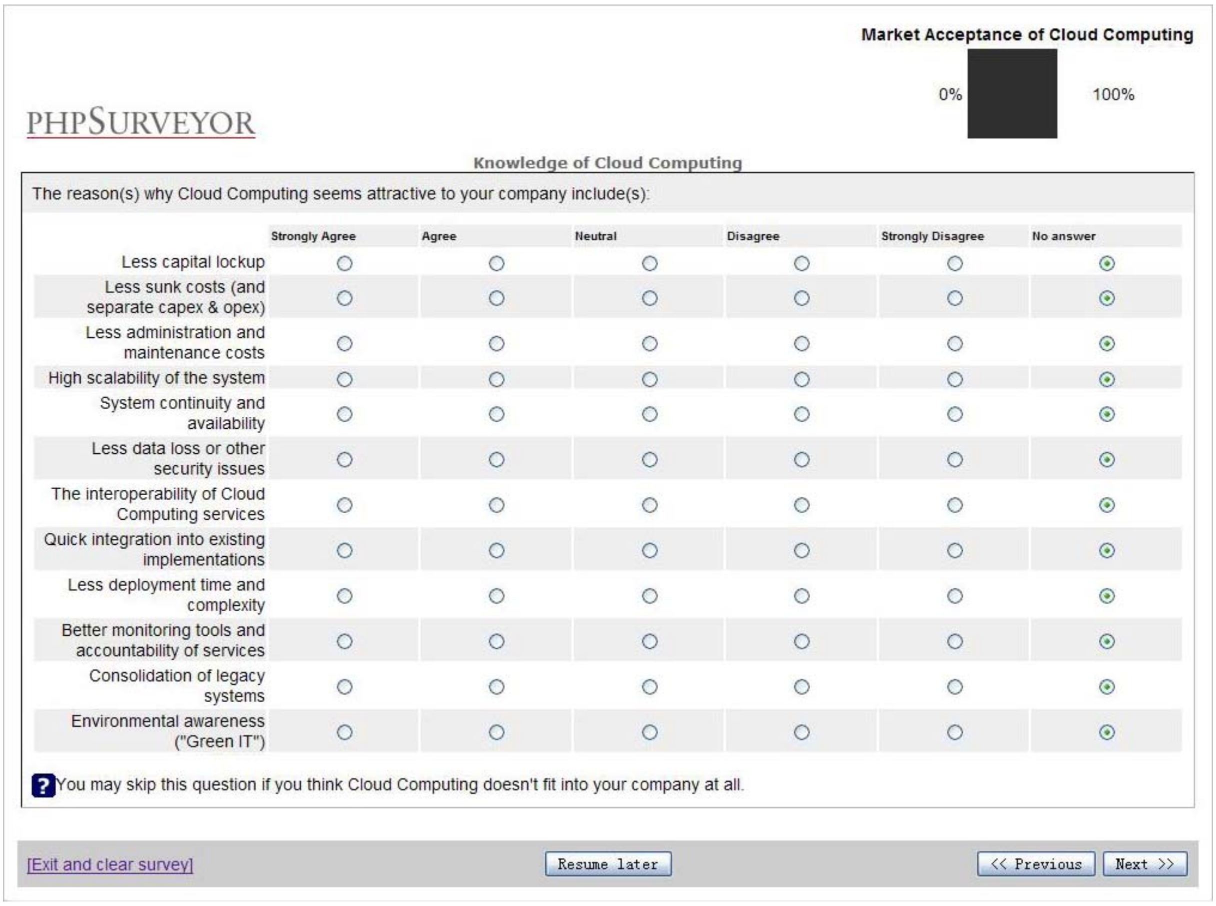
*The best description of Cloud Computing's current role for your company is:

Choose one of the following answers

- We are already using some Cloud Computing services and don't expect more
- We are already using some Cloud Computing services and plan to use more
- We are planning to use some Cloud Computing services in the near future.
- We regard Cloud Computing as a "vision", which will not be implemented in the near future.
- Other

[Exit and clear survey] Resume later << Previous Next >>

Figure 16 Question 4-2 (Page 11 of 13)


Market Acceptance of Cloud Computing

0% 100%

PHPSURVEYOR

Knowledge of Cloud Computing

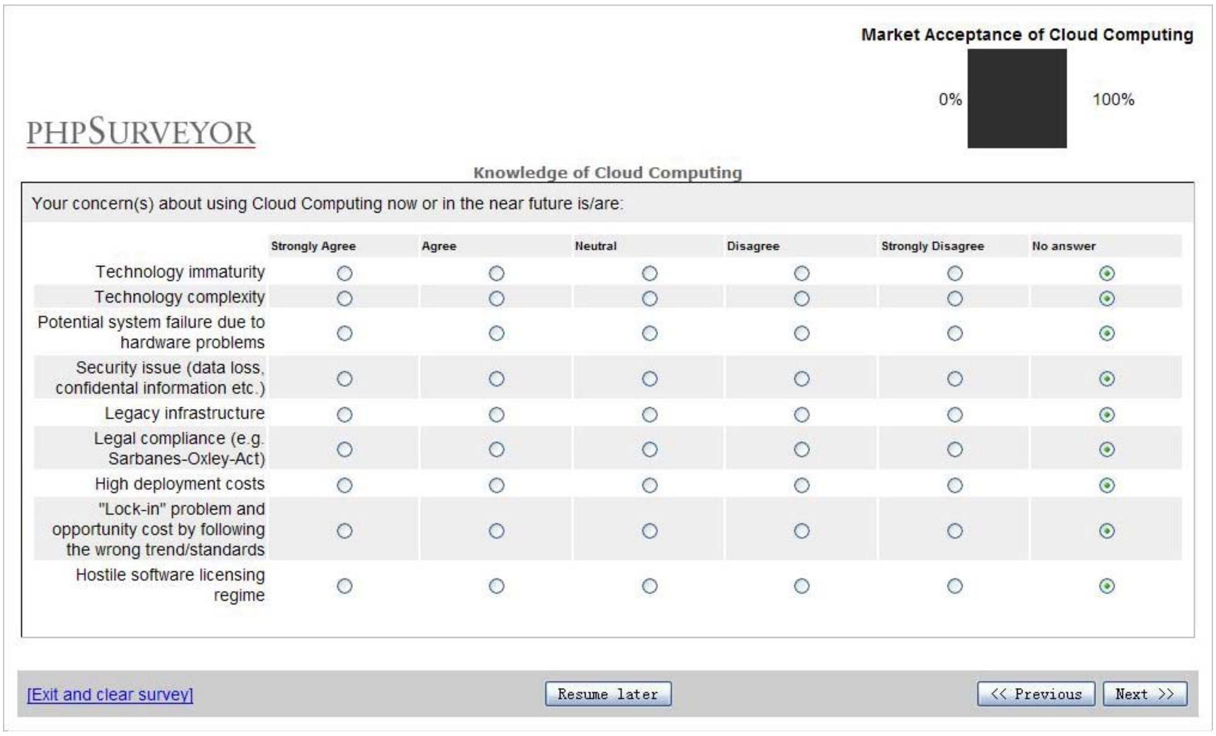
The reason(s) why Cloud Computing seems attractive to your company include(s):

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No answer
Less capital lockup	○	○	○	○	○	◉
Less sunk costs (and separate capex & opex)	○	○	○	○	○	◉
Less administration and maintenance costs	○	○	○	○	○	◉
High scalability of the system	○	○	○	○	○	◉
System continuity and availability	○	○	○	○	○	◉
Less data loss or other security issues	○	○	○	○	○	◉
The interoperability of Cloud Computing services	○	○	○	○	○	◉
Quick integration into existing implementations	○	○	○	○	○	◉
Less deployment time and complexity	○	○	○	○	○	◉
Better monitoring tools and accountability of services	○	○	○	○	○	◉
Consolidation of legacy systems	○	○	○	○	○	◉
Environmental awareness ("Green IT")	○	○	○	○	○	◉

You may skip this question if you think Cloud Computing doesn't fit into your company at all.

[Exit and clear survey] Resume later << Previous Next >>

Figure 17 Question 4-3 (Page 12 of 13)



Market Acceptance of Cloud Computing

0% 100%

PHPSURVEYOR

Knowledge of Cloud Computing

Your concern(s) about using Cloud Computing now or in the near future is/are:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	No answer
Technology immaturity	○	○	○	○	○	◉
Technology complexity	○	○	○	○	○	◉
Potential system failure due to hardware problems	○	○	○	○	○	◉
Security issue (data loss, confidental information etc.)	○	○	○	○	○	◉
Legacy infrastructure	○	○	○	○	○	◉
Legal compliance (e.g. Sarbanes-Oxley-Act)	○	○	○	○	○	◉
High deployment costs	○	○	○	○	○	◉
"Lock-in" problem and opportunity cost by following the wrong trend/standards	○	○	○	○	○	◉
Hostile software licensing regime	○	○	○	○	○	◉

[Exit and clear survey] Resume later << Previous Next >>

Figure 18 Question 4-4 (Page 13 of 13)

Market Acceptance of Cloud Computing

0% 100%

PHPSURVEYOR

Knowledge of Cloud Computing

If you are interested in the results of the survey and my thesis, please leave your email address below:

[Exit and clear survey] Resume later << Previous Submit

D Survey results (raw data)

Glossary:

A	Storage, archiving and disaster recovery
B	Raw computing power (resources)
C	Dedicated data center or servers
D	Basic office applications
E	Business applications
F	Specialized applications or solutions
G	Specialized IT services
H	Cloud Operating System
I	Online Application Exchange Platform
IT	IT Companies
Non-IT	Non-IT Companies
L	Long-term Contracts
S	Short-term Contracts
IN	In-house Transaction
M	Mixture Model
P	PAYG Model
FL	Flat Rate Model
a	Very Frequently
b	Frequently
c	Normal
d	Infrequently
e	Very Infrequently
N	No
Y	Yes
O	Other
SA	Strongly Agree
AG	Agree
NE	Neutral
DI	Disagree
SD	Strongly Disagree

Table 15 Survey Results (Part 1)

ID	Q 1-1	Q 1-2	Q 1-3	Q 2-1									Q 2-2			Q 3-1									Q 3-2								
				A	B	C	D	E	F	G	H	I	x	y	z	A	B	C	D	E	F	G	H	I	A	B	C	D	E	F	G	H	I
1	Ne	O	5%~20%	N	Y	N	N	Y	Y	N	N	Y	AG	NE	AG	L	S	L	IN	L	L	IN	L	L	M	M	M	M	M	M	M	M	M
2	SA	IT	5%~20%	Y	Y	Y	Y	Y	N	Y	Y	Y	SA	NE	NE	IN	S	S	IN	IN	IN	IN	L	L	O	O	O	FL	FL	P	FL	FL	FL
3	A	IT		Y	Y	Y	Y	Y	N	N	Y	Y	SA	DI	DI	L	S	L	S			L	S	S									
4	A	Non-IT	1%~5%	Y	N	N	Y	Y	N	Y	N	N	SA	NE	AG																		
5	SA	IT		Y	Y	Y	Y	Y	N	N	N	Y	SA	DI	NE	L	S	S	IN	S	IN	L	S	S	O	O	O	O	M	M	M	O	M
6	SA	IT	5%~20%	Y	Y	N	Y	Y	N	Y	N	N	SA	AG	AG	L	S	S	L	L	S	L	S	L	FL	P	O	FL	FL	P	M	P	FL
7	SA	IT	>20%	Y	Y	Y	N	N	N	N	Y	Y	SA	NE	NE	S	S	L					S		P	P	FL						
8	SA	IT	0~1%	Y	Y	N	Y	N	N	N	Y	Y	SA	DI	NE	S	S	L	L	S	IN	IN	S	S	M	P	FL	FL	P	P	P	FL	P
9	SA	Non-IT	1%~5%	Y	N	Y	N	N	N	N	N	N	SA	AG	SA	L	S	IN	L	L	L	S	S	L	M	M	FL	O	O	P	M	M	M
10	Ne	Non-IT		Y	Y	N	Y	N	N	N	N	N	AG	NE	SA	S	S	L	S	IN	IN	IN			FL	FL	O	FL	P	P	O		
11	A	Non-IT	5%~20%	Y	N	N	Y	N	Y	N	N	Y	SA	NE	NE	S	L	L	S	S	S	S		L	FL	M	FL	M	M	P	FL	M	M
12	SA	IT	>20%	Y	Y	Y	Y	Y	Y	N	Y	Y	AG	NE	NE	S	S	S	S	S	S	S	S	S	M	O	M	FL	FL	O		O	M
13	SA	IT	1%~5%	Y	Y	Y	Y	Y	Y	Y	N	Y	SA	NE	AG	L	S	L	IN	L	IN	S	S	L	FL	P	M	FL	O	O	FL	O	P
14	SA	IT	>20%	Y	N	Y	N	Y	N	N	N	N	SA	NE	SA	IN	S		S	L	IN	IN	IN	IN	M	P	FL	FL	M	M	FL	FL	FL
15	SA	IT	1%~5%	Y	Y	N	N	N	N	N	N	N	AG	AG	AG	L	S	L	IN	L	IN	S		L	M	P	FL	FL	FL	FL	O		P
16	A	IT		Y	N	Y	N	Y	N	N	Y	Y	SA	NE	NE	S	S	L	S	S	S	S	S	S	P	O		FL	O	O		O	O
17	Ne	Non-IT		Y	Y	Y	Y	N	Y	N	N	N	SA	NE	SA	S	L	L	IN	IN	IN	IN	L		P	P	M	M	M	P	FL	M	O
18	Ne	Non-IT		Y	Y	Y	Y	N	N	N	N	N	NE	NE	AG	S	S	L	L	L	IN	IN			P	M	M	M	FL	P	FL		
19	Ne	Non-IT		Y	Y	N	Y	N	N	N	N	N	AG	NE	NE	S	S	L	L	L	IN	IN			P	P	M	M	M		FL	M	
20	A	O		Y	Y	N	Y	Y	Y	Y	Y	Y	SA	AG	AG	L	S		IN	L	IN	L	L	S	M	P		P	P	M	M	FL	
21	A	IT	5%~20%	Y	Y	Y	N	N	N	Y	N	N	AG	AG	AG										P	P	P	FL	M	P	FL	FL	FL
22	SA	IT	1%~5%	Y	Y	Y	Y	Y	Y	Y	Y	Y	SA	DI	AG	L	S	L	S						P	P	P	P	P	P	P	P	P
23	SA	IT		N	N	Y	Y	Y	Y	Y	N	N	SA	SD	SA	L		L	L	L		L			P		FL	P	P		P		
24	A	Non-IT	5%~20%	N	N	N	N	Y	N	N	N	Y	SA	NE	SA	IN	IN	IN	S	S	S	S	IN	IN									
25	A	IT	>20%	Y	N	Y	N	Y	Y	Y	Y	Y	SA	AG	NE	S	IN	L	IN	L	L	S	L	L	O		FL		FL	FL	P	P	P
26	Ne	Non-IT		N	N	N	Y	Y	N	Y	Y	N	SA	NE	AG	S	L	L	L	L	IN				P	P	M	FL	FL	FL	FL	M	O
27	A	Non-IT		Y	Y	Y	Y	Y	N	N	N	N	AG	NE	AG	S	S	L	S	L	IN	L	L	S	P	P	M	FL	M	P	FL		FL
28	A	IT	>20%	N	N	N	N	Y	N	N	N	N	NE	NE	NE	S	S	S	L	L	L	L	L	L	P	P	P	P	P	P	P	P	P
29	A	Non-IT	1%~5%	Y	Y	N	Y	N	N	N	N	N	NE	DI	AG	S	S	L	IN	IN	IN	IN			P	P	FL	FL	O	FL	FL	P	P
30	A	IT		Y	Y	N	N	Y	N	N	Y	Y	AG	AG	AG	S	S	S	S	S	S	S	S	S	P	P	P	P	P	P	P	P	P

Table 16 Survey Results (Part 2)

ID	Q 3-3									Q 4-1	ID	Q 4-2												Q 4-3								
	A	B	C	D	E	F	G	H	I			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	c	a	c	a	b	a		b		Planning	5	AG	AG	AG	NE	AG	AG	NE	DI	NE	NE	DI	AG	AG	NE	DI	AG	AG	AG	NE	AG	AG
2	c	c	e	b	c	e	b	c	d	Using and need more	6	SA	SA	AG	SA	SA	NE	AG	NE	DI	DI	SD	AG	SA	SA	AG	SA	DI	DI	SD	SA	DI
3										Using and need more	7																					
4	b	b	b	b	b	b	b	d	e	Planning	9	SA	SA	AG	AG	NE	NE	DI	NE	NE	DI	NE	NE	AG	AG	AG	AG	DI	NE	DI	AG	NE
5	b	a	c	a	a	a	a	a	a	Using and need more	10	SA	SA	SA	SA	SA	AG	SA	SA	SA	NE	DI	SA	DI	DI	DI	AG	AG	AG	SD	AG	DI
6	c	e	e	a	a	e	b	e	e	Planning	11	NE	AG	AG	NE	NE	NE	DI	DI	DI	NE	NE	DI	DI	DI	DI	AG	AG	SA	NE	NE	NE
7	a	a	a							Using and need more	13	SA	SA	SA	SA	SA	SA	SA	SA	SA	NE	SA	NE	SA	SA	NE	NE	NE	NE	SA	SA	SA
8	a	d	e	c	b	c	d	a	a	Other	15	SA	AG	SA	AG	SA	AG	NE	DI	AG	NE	NE	AG	AG	DI	AG	AG	AG	DI	NE	AG	NE
9	a	a	a	a	a	a	a	e	d	Vision	16	SA	SA	SD	NE	SA	NE	DI	DI	DI	NE	NE	NE	AG	AG	NE	AG	DI	AG	SD	NE	AG
10	c	c	d	a	b	e	d			Planning	21		SA	AG		SA	AG		DI	NE		DI	AG	NE	AG	DI	AG	SA	AG	DI	NE	NE
11	c	d	e	c	e	c	c	d	c	Using and need more	24	NE	AG	AG	AG	NE	AG	AG	AG	SA	AG	AG	NE	AG	NE	AG	AG	NE	AG	NE	AG	AG
12	d	a	c	a	a	b	d	b	a	Using and need more	26	SA	SA	SA	SA	SA	SA	SA	SA	AG	AG	NE	SA	SA	SA	NE	NE	SA	AG	NE	AG	AG
13	b	a	a	a	a	a	e	e	a	Using and need more	27	SA	SA	AG	AG	NE	NE	NE	NE	AG	DI	SD	NE	DI	DI	DI	AG	DI	NE	DI	NE	NE
14	c	b	b	b	b	b	b	b	b	Planning	28	SA	SA	SA	SA	SA	DI	SD	AG	SA	SA	SA	SA	SD	SD	SD	SD	SD	SD	SD	SD	AG
15	e	c	b	e	e	e	e	e	b	Using and need more	29	SA	SA	NE	AG	NE	AG	SD	NE	NE	NE	AG	DI	NE	NE	AG	AG	DI	DI	DI	AG	AG
16	a	a	a	a	a		b	b		Using and enough	30	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	AG	AG	AG	SA	AG	AG	DI	DI	
17	b	a	b	a	a	d	b			Planning	33	AG	AG	AG		AG	AG		AG	AG				AG	AG	NE	AG	AG	NE	NE	DI	
18	b	b	b	b	c	d	b			Vision	35	AG	AG	NE	SA	SA	NE	AG	AG	AG	NE	NE		AG	AG		AG	NE		NE	AG	
19	a	a	b	a	c	c	c			Vision	36	SA	SA		SA	AG	NE	AG	AG	AG	AG	NE	AG	NE	AG		NE	NE		NE	AG	
20										Other	39	SA	AG	AG	SA	AG	NE	AG	AG	AG	AG	AG	NE	AG	SA	SA	SA	AG	NE	NE	AG	NE
21	c	b	b	c	d	d	d	c	c	Using and need more	40	AG	AG	AG	AG	AG	NE	DI	SD	NE	NE	NE	NE	AG	AG	NE	NE	NE	DI	AG	AG	NE
22	e	e	e	e	e	e	e	e	e	Vision	41	AG	AG	AG	AG	AG	AG	DI	NE	AG	NE	NE	NE	AG	AG	DI	NE	NE	NE	DI	NE	AG
23	a		a	a	a		a			Other	42	SA		SA	SA	SA	SA	SA			SA		SA									
24	c	c	d	a	b	b	b	d	d	Planning	47													AG	AG	AG	AG	NE	NE	DI	AG	AG
25	b		b		a	b	b	a	a	Using and need more	48	SA	AG	AG	AG	SA	AG	AG	AG	SA	SA	AG	AG	SA	SA	SA	SA	AG	AG	DI	NE	NE
26	b	a	b	a	c	d	c	d	d	Planning	51	AG	AG	AG	SA	SA	SA	NE	AG	NE	NE	NE	AG	SA	AG	SA	SA	NE	NE	NE	NE	AG
27	a	a	b	a	a	e	b	e	e	Planning	52	AG	AG	NE	SA	SA	NE	AG	NE	NE	NE	NE	AG	AG	AG	AG	SA	AG	NE	NE	AG	NE
28	b	b	b	b	b	b	b	b	b	Vision	58																					
29	a	a	c	a	a	d	a			Planning	59	AG	SA	AG	SA	SA	DI	SA	DI	NE	NE	NE	AG	AG	NE	NE	AG	AG	NE	NE	AG	NE
30	a	a	a							Using and need more	61	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	NE	NE	NE	NE	NE	NE	NE	NE	NE

E Analysis of survey results

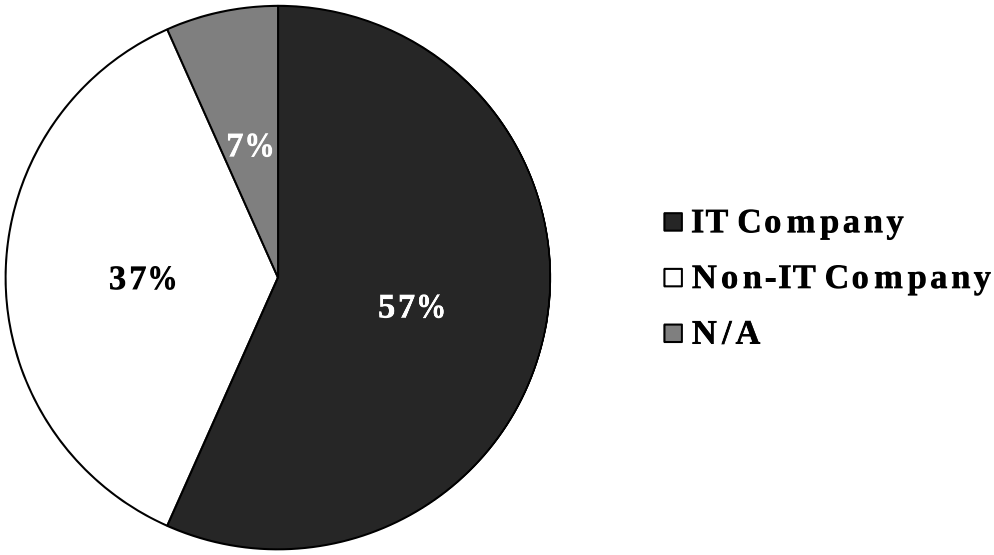


Figure 19 Characteristics of the Respondents' Companies

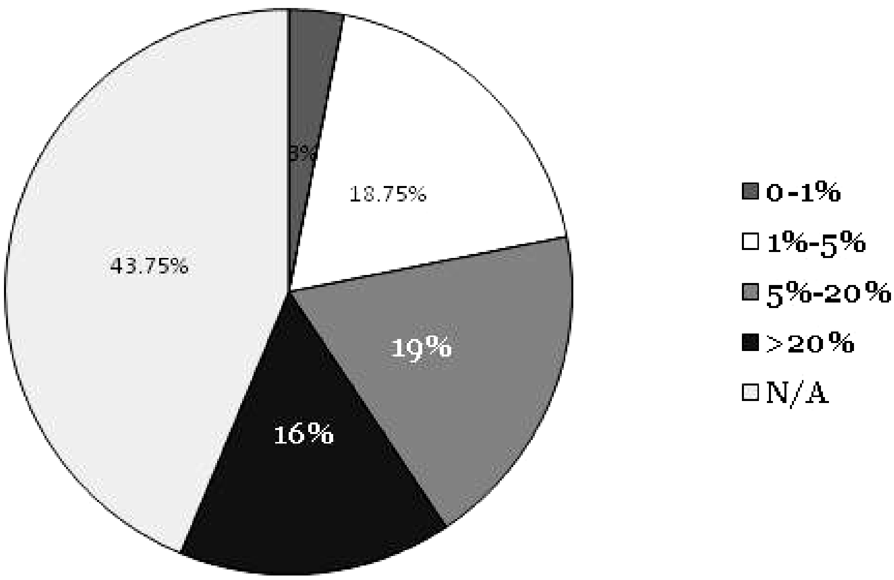


Figure 20 Corresponding Companies' IT budgets in Percentage of Total Revenue from Previous Year (2008)

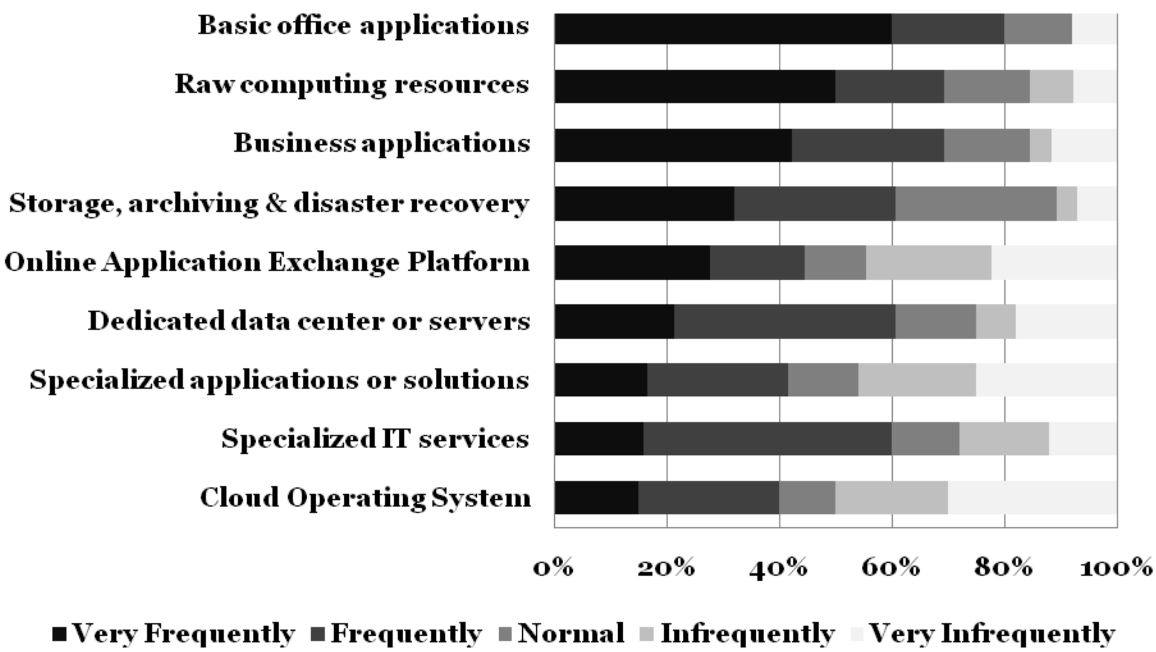


Figure 21 Usage Frequency of IT Services

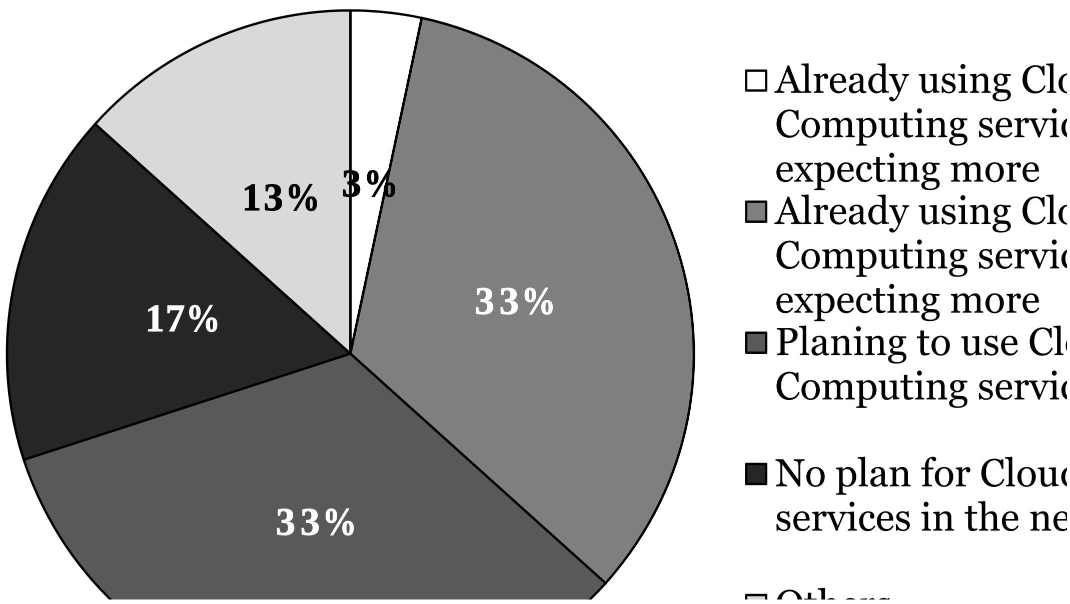


Figure 22 The Current Acceptance of Cloud Computing Services

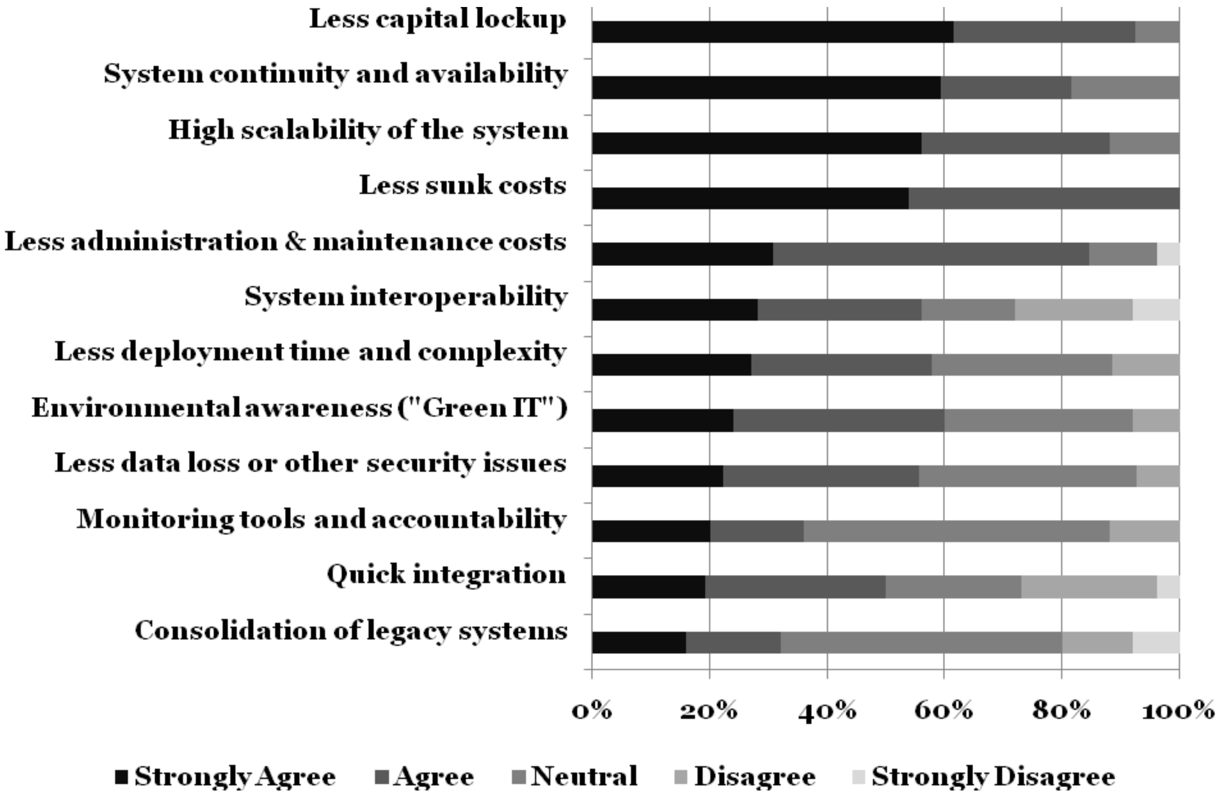


Figure 23 Reasons of Using Cloud Computing Services

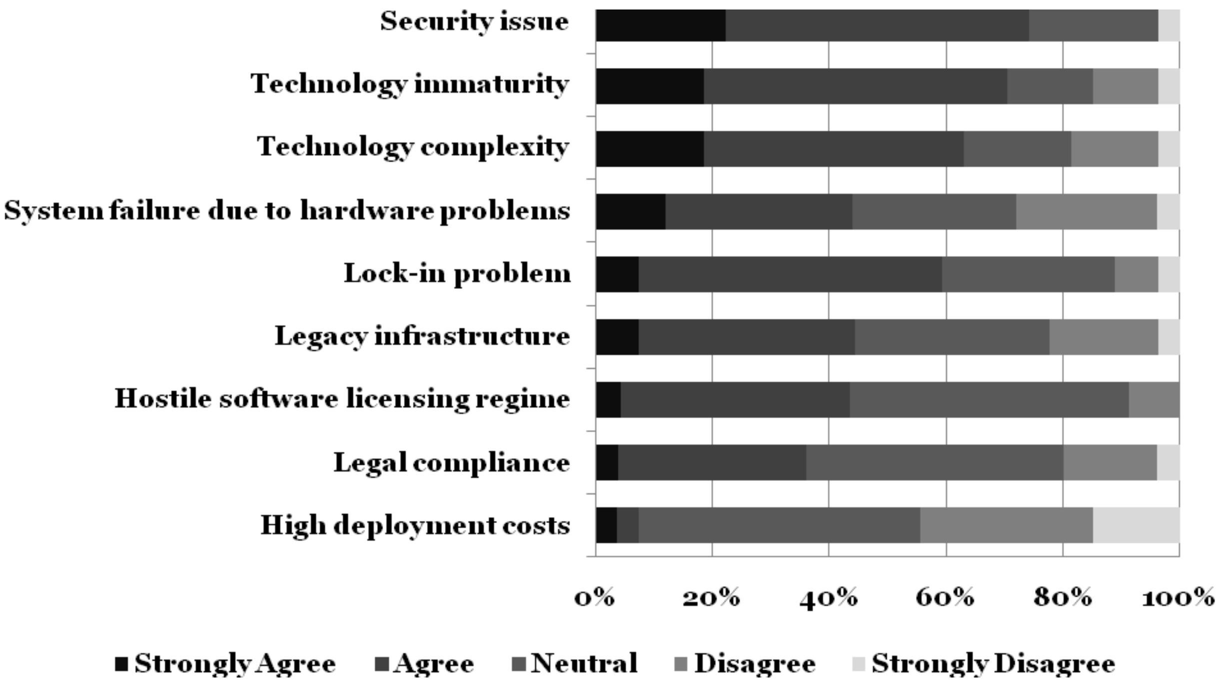


Figure 24 Concerns of Using Cloud Computing Services

F Chi-Square Distribution

Table 17 Critical Values of Chi-Square Distribution

Sig.	0.10	0.05	0.025	0.01	0.001
Df.					
1	2.706	3.841	5.024	6.635	10.828
2	4.605	5.991	7.378	9.210	13.816
3	6.251	7.815	9.348	11.345	16.266
4	7.779	9.488	11.143	13.277	18.467
5	9.236	11.070	12.833	15.086	20.515
6	10.645	12.592	14.449	16.812	22.458
7	12.017	14.067	16.013	18.475	24.322
8	13.362	15.507	17.535	20.090	26.125
9	14.684	16.919	19.023	21.666	27.877
10	15.987	18.307	20.483	23.209	29.588
11	17.275	19.675	21.920	24.725	31.264
12	18.549	21.026	23.337	26.217	32.910
13	19.812	22.362	24.736	27.688	34.528
14	21.064	23.685	26.119	29.141	36.123
15	22.307	24.996	27.488	30.578	37.697
16	23.542	26.296	28.845	32.000	39.252
17	24.769	27.587	30.191	33.409	40.790
18	25.989	28.869	31.526	34.805	42.312
19	27.204	30.144	32.852	36.191	43.820
20	28.412	31.410	34.170	37.566	45.315
21	29.615	32.671	35.479	38.932	46.797
22	30.813	33.924	36.781	40.289	48.268
23	32.007	35.172	38.076	41.638	49.728
24	33.196	36.415	39.364	42.980	51.179
25	34.382	37.652	40.646	44.314	52.620
26	35.563	38.885	41.923	45.642	54.052
27	36.741	40.113	43.195	46.963	55.476
28	37.916	41.337	44.461	48.278	56.892
29	39.087	42.557	45.722	49.588	58.301
30	40.256	43.773	46.979	50.892	59.703
31	41.422	44.985	48.232	52.191	61.098

Honor Code

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbständig und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten Schriften entnommen wurden, sind als solche gekennzeichnet.

Die Arbeit hat in gleicher oder ähnlicher Form noch keiner anderen Prüfungsbehörde vorgelegen.

Bayreuth, 2009-02-23

Lei HAN

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As an emerging technology and business paradigm, Cloud Computing embeds fairly large amount of unexplored fields, from technological definition to business models. While the market of Cloud Computing is expected to expand in the near future, few studies of the actual market acceptance of the Cloud Computing services are done. It may be interesting, especially for the Cloud Computing service providers, to know more about the preferences of transaction forms and price models from the users and potential users. From an academic research's point of view, we want to know whether the development of Cloud Computing market can be explained or even predicted by certain theoretical frameworks.

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