Cloud Computing and Decision-Making : Determinants, Modelling and Impacts

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PARIS-SACLAY

NNT : 2017SACLS382

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Thèse de doctorat de l'Université Paris-Saclay
préparée à Université Paris-Sud

École doctorale n°578 sciences de l'homme et de la société (SHS)
Spécialité de doctorat : Sciences de Gestion

Thèse présentée et soutenue à Sceaux, 20 Novembre, 2017 par

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Acknowledgements

My deepest and foremost gratitude goes first to my supervisor Professor Ahmed Bounfour for his valuable advices and constant encouragement during all the time of my Ph.D studies, who has encouraged and challenged me to be faithful to Scripture. Without his support and guidance, this thesis would not have been possible. His enthusiasm, optimism, patience, expert remark and unwavering support are invaluable to me. I appreciate all of these very much.

I would like to express my gratitude to all the members of the jury. I am thankful to Professor Rolande Marciniak and Professor Thomas J. Housel for taking time to carefully review this thesis. I am grateful to Professor Aurélie Dudezert for accepting to evaluate my work and participating in this jury as examiner.

I also owe a special debt of gratitude to Université Paris-Sud for kindly opening the door and accepting me as a Ph.D student. In particular, my sincere gratitude is reserved for Institut de la Société Numérique for funding my research with a doctoral contract. I am also thankful to the members of the École Doctorale SHS and RITM laboratory for their welcome. I am particularly thankful to Professor José de Sousa, the head of labotory RITM, for his mentoring and funding support. I should also mention Mariele Rosine, Maryse Chomette, Sandra Lagarde and Philippe Martins for their kind assistance.

I greatly appreciate the contribution of my parterners in my papers: Jean-Michel Etienne, Alessandro Solimando, Emmanuel Waller and my colleagues who were a precious source of companionship : Thierry Nabeth, Liang Guo, Arielle Santé, Noelle Lahouij, Estelle Gandillot Nicolas, Sarah Serval, Alexis Pokrovsky, Philippe Gillet, Florent Pestre, Serge Pajak, Nicolas Soulié, Fabrice Le Guel, Felipe Starosta de Waldemar, Matthieu Manant, Grazia Cecere.

Last but definitely not least, I would like to gratefully acknowledge various people who have been journeyed with me in recent years as I have worked on this thesis. I would like to give my most sincere gratitute to my family, my parents Haijun Cheng and Shuzhen Ma. They are my dynamic source. There is an inexhaustible power on the road of my life.

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Synthèse en Français

Cette thèse cherche à traiter des sujets de l'adoption de cloud et la décision de cloud. Elle analyse des déterminants de l'adoption, discute des services de cloud et compare des fournisseurs de cloud. Cloud computing a des dimensions à la fois techniques et organisationnelles. Jusqu'à présent, la dimension organisationnelle a reçu peu d'attention, et cloud computing a été essentiellement considéré d'un point de vue technique. Cependant, la "cloudification" des systèms d'information pose de nombreuses questions économiques et managériales qui doivent être évaluées. Il est donc important d'enrichir notre compréhension des phénomènes liés à la "virtualization" de l'information, à travers un examen de leurs caractéristiques multidimensionnelles.

Le champ de recherche en Systèmes d'Information (SI) sur le cloud computing est relativement émergent. En effet, les premières études sur la thématique du 'cloud computing' datent des années 2006 suivant la prolifération de ce phénomène lancé par les géants Amazon et Google. Avant l'académie, la presse s'est emparée de la thématique vue la nouveauté du service et les promesses d'une capacité de computing à la demande avec une rapidité dans l'implémentation, moins maintenance, moins d'effectifs et par conséquent de moindres coûts. Le cloud computing a été régulièrement classé parmi les 10 premières thématiques d'actualité par les CIO (Chief Information officers). On a même qualifié le cloud computing de la cinquième élément après l'eau, le gaz, l'électricité et le téléphone.

Par définition, le cloud computing est un service informatique sur Internet. Le NIST (National Institute of Standards and Technology) définit le service cloud par les cinq caractéristiques suivantes :

1. Un service à la demande du client. Le client peut s'approvisionner, avoir accès à ce service directement sans obligation d'interaction physique avec le fournisseur du service.
2. Accès étendu au réseau. Le service cloud ou la capabilités cloud sont disponibles sur le réseau à travers des mécanismes standards pour promouvoir l'usage
3. Mise en commun des ressources. Le fournisseur du service cloud met à disposition des clients un éventail de ressources (stockage, traitement, mémoire, machines virtuelles…)
4. Elasticité rapide. Le client devrait être capable d'étendre ou restreindre sa demande sans obstacles majeurs et parfois automatiquement
5. Un service mesuré et contrôlé. Les systèmes cloud sont continuellement et automatiquement contrôlés et optimisés.

Suivant la relation entre le client et le fournisseur du service cloud, le cloud peut être :

- Public : c'est le cas le plus répandu, le service appartient et est opéré par un fournisseur indépendant et accessible au public.
- Privé : l'usage de la technologie cloud est interne à l'entreprise. Le service est uniquement accessible aux usagers appartenant à l'entreprise.
- De communauté : nn service partagé par des organisations qui soutiennent les mêmes causes.
- Hybride : un service qui combine deux ou plus des types précédents.

Les service cloud peuvent être classés en trois niveaux :

1. IaaS (Infrastructure as a Service) : le service inclut des capabilités basiques de stockage et de traitement et autres formes de services basiques de réseau et de hardware, à la demande et via internet.
2. PaaS : le service présente un niveau de complexité plus élevé que le IaaS. Le service inclut des environnements de programmation et d'exécution. Il prend la forme de 'design intégré' où le client peut développer, tester et déployer des plateformes
3. SaaS : le service inclut des applications 'clé en main' prêtes à être utilisées via internet.

La recherche actuelle de l'adoption de cloud computing est sur l'identification des facteurs. Notre recherche couvre les facteurs techniques et économiques, et trois dimensions identifiées : dimension stable, dimension relativement stable et dimension variable pour positionner des entreprises par rapport à leur prétention de l'adoption de cloud computing et choisir des services appropriés. Des résultats révèlent que notre modèle de l'adoption est très efficace ; L'adoption de cloud computing n'est pas influencée par la taille de l'entreprise ; L'adoption de CaaS et IaaS correspondent au savoir-faire informatique; SaaS est le service le plus couramment utilisé et le modèle interne privé est le modèle le plus utilisé. Ce papier contribue à désigner un ensemble de dimensions fondamentales de l'adoption de cloud computing pour la recherche de la future et le développement de la théorie de l'adoption.

Du fait d'un nombre de plus en plus grand d'utilisateurs de services de cloud, la question cruciale qui se pose est celle de la sélection d'un fournisseur de services de cloud approprié qui réponde à toutes les stratégies commerciales et les objectifs de l'entreprise. Par la revue da la littérature, nous avons trouvé un manque de travaux de recherche portant t sur l'interdépendance entre les critères de décision. Dans cette étude, nous abordons cette lacune de recherche essentielle en développant un modèle de recherche intégrée qui combine la théorie de la logique floue et processus d'analyse hiérarchique. Nous utilisons ce modèle pour évaluer globalement les fournisseurs de cloud PaaS et IaaS axés sur des critères prédéterminés. Des résultats de la simulation ont souligné qu'il existe une corrélation entre certain critères de décision et que les performances des fournisseurs de cloud sont très différentes.

En général, cette thèse démontre que l'utilité perçue, la facilité d'utilisation perçue, la complexité et la compatibilité sont des facteurs clés de l'adoption de cloud, le savoir-faire informatique joue également un rôle important dans le processus de la décision ; La plupart des petits fournisseurs de cloud ont des performances plus stables et plus efficaces que les grands fournisseurs de cloud, la performance du processeur ayant un impact significatif sur le prix. Cette thèse contribue beaucoup aux dimensions théoriques et managériales de la recherche sur cloud, mais il y a plus de travail de recherche à faire du point de vue de l'adoption de cloud et de la prise de décision dans le cloud. La recherche future se concentrera sur ces points.

Chapter 1

Introduction: Framing Cloud Computing Research

Due to the agility and the variety of cloud computing, it has drawn significant attention from enterprises and academic researchers. Cloud computing is no longer a buzzword, it's a strategy, a business model, and a set of technologies. Cloud computing addresses both technical and organizational aspects, ranging from resource provisioning to systems interoperability, from the level of IT-related outsourcing of an enterprise to the capability of effortless keeping the pace of hardware and software innovation. Cloud computing is growing rapidly, Forrester reported that cloud computing market will reach 240 billion dollars by 2020. The drivers behind cloud computing growth are principally reduced cost, pay-as-you-go and easy access. The involvement of cloud computing will change not only the way of business models but also the way of people's life.

During the last decade, IS researchers have progressively placed cloud computing at the core of management literature. From the perspective of management, this thesis aims to increase our understanding on the adoption and the decision-making of cloud computing. Ang Li has identified common services of cloud computing: elastic computing cluster, persistent storage, intra-cloud network and wide-area network (Li et al., 2010). Cluster runs application's codes using numerous virtual instances. Persistent storage is used to keep data of application and accessed through API calls. Intra-cloud network provides connection between application instances, wide-area network connects different data centers where the applications are hosted.

Early studies on cloud computing adoption tend to be skewed toward benefits and challenges, yet in spite of some segmentation efforts, actually there is a lack of research framework focusing on the adoption of cloud services and cloud deployment models. The strategies of cloud computing is very different from traditional IT strategies. There is a need to discuss how to select cloud services and cloud deployment models. Cloud computing is a transformative technology changing the way of IT information system, however, the transformative and value-creating capacity of cloud computing has attracted less attention, we need further research to contribute to the themes.

The objective of the first chapter is to provide an overview of the current state of cloud computing research in order to structure a theoretical background for this dissertation. Section 1.1 introduces some necessary background notions and cloud computing related definitions. Section 1.2 proposes a research problem by identifying research gaps and opportunities. Section 1.3 summarizes the following chapters and indicates their relationships.

1.1 Main theoretical background

This section contributes to give a comprehensive analysis of cloud computing related notions and its development process. It starts with the introduction of related background notion for understanding the reminder of this dissertation. It continues with the description of the process of cloud computing development. Finally, it outlines the main definitions of cloud computing and its components.

1.1.1 Cloud computing background notions

- **Virtualization**

The term refers to the creation of a virtual version of a device or resource. The aims of virtualization are multiple, and include an abstraction of hardware for interoperability purposes, the sharing of a single resource by different consumers, the aggregation of different physical devices allowing to use it as a single one, security (by means of a technique called sandboxing), portability, for reducing the downtime in case of faults, etc.

In the context of cloud computing, the generic term virtualization is often used as a synonym for a specific kind of virtualization called full virtualization, based on the notion of (system) virtual machine (VM), which is the emulation of a specific computer system, whose virtual resources can be obtained by means of virtualization of physical ones, having different characteristics (e.g., architecture, size etc.). A single virtual machine is capable of running an operating system (OS), and to provide all the capabilities of a physical computing system. VMs are management by the so-called hypervisor softwares, which can be in turn programs running on a specific OS, or native programs in assembly language (Popek and Goldberg, 1974). Hypervisor is in charge of allocating the necessary resources for each VM, create and run them in isolation.

- **Outsourcing**

Cloud computing represents a new means of outsourcing IT resources. For SaaS products, outsourced resources are application software; for IaaS products, outsourced resources are computing hardware (e.g., servers, storage devices); and for PaaS products, outsourced resources include hardware, development and software hosting platforms. Through a literature review, Stefanie Leimeister found that cloud computing is primarily described as an IT outsourcing model on the basis of virtualization technologies (Leimeister et al., 2010). Benedikt Martens and Frank Teuteberg described cloud computing and IT outsourcing using the same decision model and showed that both provide similar benefits to their users; methods developed for IT outsourcing can also be applied to analyses of cloud computing (Martens, Walterbusch and Teuteberg, 2012).

- **Service oriented architecture**

Service-oriented architecture (SOA) is one of the technologies which contributed to make cloud computing viable (Toosi et al. 2014). SOA is an architectural pattern in computer software design in which application components provide services to other components via a communications protocol, typically over a network. A service is a self-contained unit of functionality, such as retrieving an online bank statement (Cavalcanti 2014). Services can be combined with other systems in order to provide the functionalities of a software application (Valipour et al. 2009).

SOA favors the cooperation and communication of software components, connected over a network. Every machine can run different services, which are designed in a way that ensures the exchange of information, among services, without user intervention, by means of standard interfaces, protocols and data representation format such as XML (W3C 2008). The use of open standard contributes to the loose coupling among provider and consumer services.

By analyzing the definition of SOA and its ingredients and characteristics, we find several commonalities with cloud computing, that is an evolution of SOA which applies some of its key concepts to components other than software. There are obviously also differences between cloud computing and SOA, ranging from the already mentioned level of abstraction, to the different coordination efforts required by the two technologies. Another core aspect of SOA, that is not as central in cloud computing, is the notion of semiautomatic or automatic discovery of services, involving not only technical interoperability but also the semantics of the offered service.

- **Software-based storage**

Software-based storage (SBS) is a broad categorization of software solutions for decoupling the storage management and virtualization logics from the underlying hardware. The reasons behind SBS are an increase of flexibility in terms of hardware choice to build datacenter storage services. In addition, this allows to lower the cost by combining low-cost hardware at the logical level, enabling also scalability and improved efficiency if suitable techniques are employed. Global policies and additional services can be easily provided, such as deduplication, replication, thin provisioning, snapshots and backup. Storage virtualization aggregates storage components in a coordinated way into a pool of resources, in order to maximize efficiency in serving the client applications.

SBS can run on top of the software layer provided by a distributed file system, such as *Google File System* (GFS) (Ghemawat et al. 2003). GFS splits files in chunks, identified by unique immutable identifier called *bit chunk handle.* Chunks are then stored in the so-called *chunk-servers*, as regular files, with usually 3 replicas. A machine called *master* maintains the metadata and the association between each bit chunk handle and the corresponding chunk servers storing the physical data. Clients refer to the master for metadata-related operations, but for all the data-related operations they directly connect to chunk-servers. Hadoop File System (HDFS), is an open-source implementation of GFS.

Another well-known example is the General Parallel File System (GPFS) from IBM, a distributed and parallel file system tailored for concurrent accesses to shared volumes. Data coherency and locking at the file level are handled through daemons which are running both on the disk-servers and on the different clients; these daemons are connected and communicate with each other, and they are able to synchronize their information about data, metadata, lock status over the different portions of the file system, in order to guarantee the consistency of the file system, even upon concurrent access.

- **Grid computing**

Grid computing is a distributed computing paradigm, based on the use of different resources which are loosely-coupled and accessible through a network, with the aim of completing a single computational task. The nodes composing the grid, differently from general high performance computing, can be geographically distributed, and are usually heterogeneous machines. A grid can be composed by smaller grids, usually provided by different institutions, thus allowing a hierarchical organization. In addition, differently from supercomputers, the constituents of the grid are connected through standard network interfaces, and are not connected through a single local high-speed computer bus.

Cloud computing is similarly to grid computing, there is an intermediate middleware for the coordination of the different nodes that usually receive a portion of the data to elaborate. Again similarly to grid computing, the middleware needs to handle nodes' failure, and possible reassign resources in order to complete the global task. An important difference between grid computing and cloud computing, is that the former is strongly based on open standards, while the latter is mainly based on proprietary formats and platforms, and interoperability issues are still a concern.

1.1.2 History of cloud computing

Cloud computing is not a new technology, it is a developed model that combines different technologies and different business models. Such as distributed computing, virtualization, pay-per-use model which are existed notions for several years. Cloud computing has developed through a number of phases which comprises public utility computing, virtualization, Application Service Provision, and Software as a Service etc. In the sixties, delivering computing resources through website is started. The actual history of cloud computing is not that old, the first cloud computing definition seems to be given by Professor Ramnath Chellappa in Dallas in 1997. The first milestone of cloud computing development arrived in 1999, Salesforce launched its delivered enterprise applications via website. It's the first cloud computing services delivered to business. Another important step for cloud computing development is the emergence of Amazon web services in 2002, Amazon cloud services' prevalence leads to a quickly development of cloud computing for the next decade.

1st phrase-1960s	John McCarthy, a scientist and a Turing Award winner in 1971, proposed timesharing mainframe notions and predicted that computing would be organized as a public utility in his speech at MIT (Wheeler and Waggener, 2009). This step is described as a significant contribution to the development of cloud computing.
2nd phrase-1970s	Virtualization is an important technology to make cloud computing realized. Alone with the emergence of virtualization in 1970s, it became possible to run a virtual machine inside a different operating system and to run more than one operating system simultaneously.
3rd phrase-1997	The first definition of cloud computing was considered given by Prof. Ramnath Chellappa in Dallas in 1997 "A computing paradigm where the boundaries of computing will be determined by economic rationale rather than technical limits alone."
4th phrase-1999	The first milestone of cloud computing development was recognized as the arrival of Salesforce in 1999. It realized delivering enterprise applications via simple website and it was considered as one of most highly valued cloud computing companies in US.

5th phrase-2002	Amazon launched its Web Services in 2002, it is a suite of cloud-based services that composed of computing services, storage services and human intelligence. They are the first widely used cloud services.
6th phrase-2006	Elastic Compute Cloud (EC2) and Simple Storage Service (S3) were launched in 2006 by Amazon. They are commercial web services that allows small enterprise and personals to run their own applications all on the cloud. They are the first accessible cloud computing infrastructure service.

Table 1. Cloud Computing History

1.1.3 Cloud computing related definitions

There are numerous definitions from industry as well as academia. This section contributes to present a comprehensive overview of cloud computing definition. (Youseff et al. 2008) was considered as one of the first who tried to provide an accurate definition of cloud computing. They defined cloud computing as "a collection of many old and few new concepts in several research fields like Service-Oriented Architectures (SOA), distributed and grid computing as well as Virtualization" According to the above mentioned definition, cloud computing can be considered as a new computing paradigm such as distributed computing, parallel computing and utility computing.

(Armbrust et al. 2009) defined "Cloud computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the datacenters that provide those services. The services themselves have long been referred to as Software as a service (SaaS), so we use that term. The datacenter hardware and software is what we will call a cloud". In this definition, cloud refers to data centers that provide virtualized computing resources.

(Buyya et al. 2009) defined cloud computing as follows: "Cloud is a parallel and distributed computing 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" It appears that cloud computing is a combination of distributed computing and cluster computing, but it is not true. Cloud is a new term based on hardware and software datacenters.

(McKinsey & Co. 2009) report that "Clouds are hardware based services offering compute, network, and storage capacity where: hardware management is highly abstracted from the buyer, buyers incur infrastructure costs as variable OPEX, and infrastructure capacity is highly elastic" (Leimeister et al. 2010) described cloud computing as an IT outsourcing model on the basis of virtualization technology and pay-per-use pricing models. (Foster et al. 2008) defined cloud computing as a large-scale distributed computing paradigm in which a pool of virtualized computing power, storage, platforms, and services are delivered on demand to external customers over the Internet. (Vaquero et al. 2009) mentioned that "clouds are a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically reconfigured to adjust to a variable load (scale), allowing also for an optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the Infrastructure Provider by means of customized Service Level Agreements"

From a comprehensive review of the literature, we found that many cloud computing definitions exist. However, there is currently no common, universally accepted definition of cloud computing. (Zhang et al. 2010) indicated that the main reason of different existed cloud computing definitions is that cloud computing is not a new technology, it is just a combination of different old technologies to meet today's business strategy, To facilitate the following discussion, we use the most cited and viewed definition of the US National Institute of Standards and Technology (NIST) (Mell and Grance, 2001): "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models." The NIST definition covered the commonly essential aspects of cloud computing.

Based on the NIST definition, cloud computing composed of

i) *Four deployment models*: Private cloud, Community cloud, Public cloud, and Hybrid cloud.
ii) *Three service models*: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS).
iii) *Five characteristics*: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. In the following the essential elements are described.

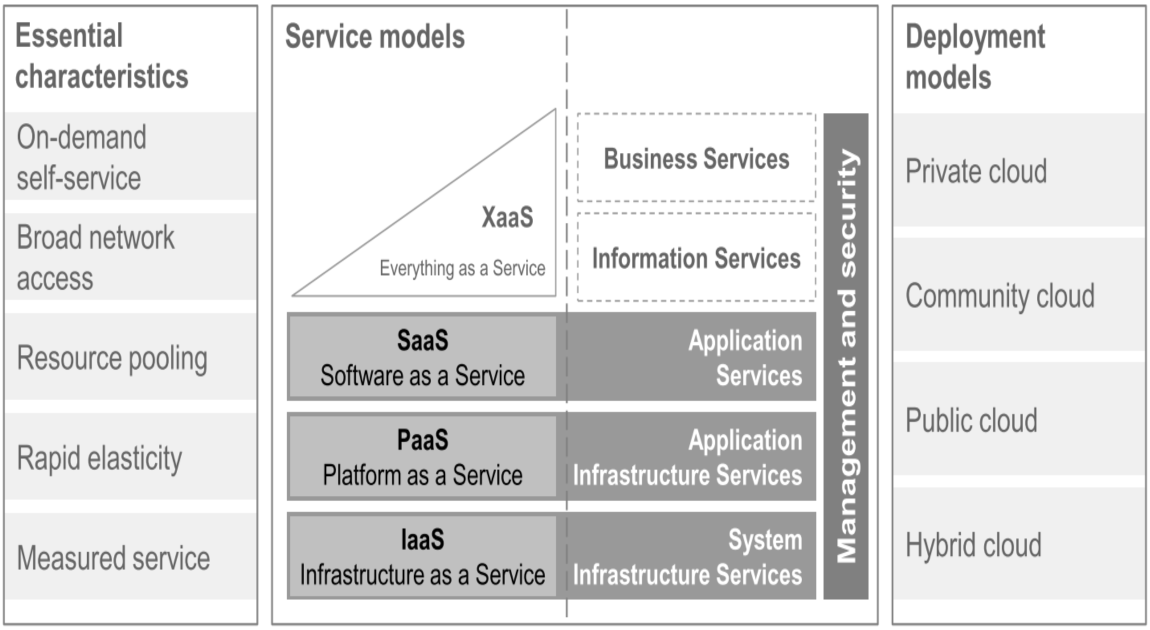


Table 2. NIST Cloud Computing Definition
(Source: Peter Kits and Thomas Loczewski (2013))

- **Deployment models**

Deployment models define the types in which cloud services can be accessed: public, private, hybrid and community. *Public cloud* is open for the general public, it can be managed and operated by any organizations, so there will be an issue of data privacy. However, *private cloud* is used just by a single organization which can be provided private spaces for critical data. *Community cloud* provides services for a specific community of organizations. They share the common network, storage and computing services that can be operated and managed by one or more of the community members. *Hybrid cloud* is a combination of different deployment cloud models (public, private and community), it provides more agility and stability compared to other mentioned models.

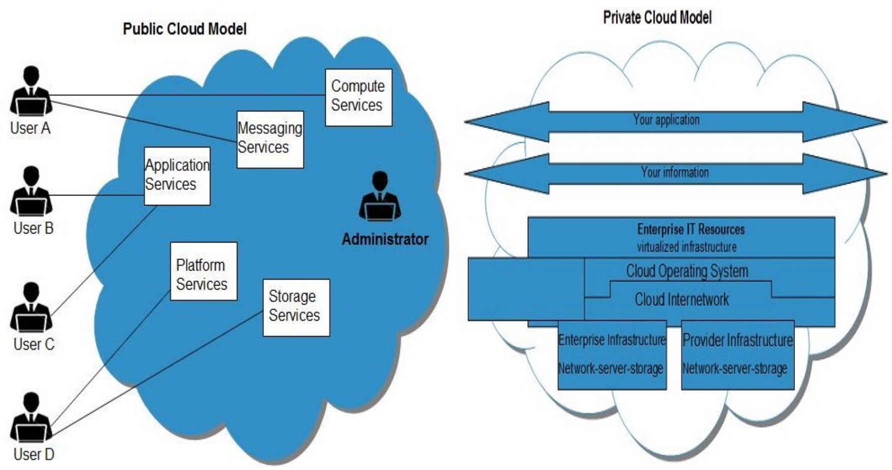
- **Service models**

Software as a Service (SaaS) provides the supplier's applications running on a cloud infrastructure; *Platform as a Service (PaaS)* provides a plateform to deploy infrastructure or to create acquired applications using programming languages; *Infrastructure as a Service (IaaS)* provides storage, networks and fundamental computing resources to deploy and run arbitrary software. SaaS is the most popularly used cloud service due to its ease of use. On the contratry, PaaS and IaaS need relatively IT knowledge to operate and manage platform and infrastructure. Besides SaaS, PaaS and IaaS, *Container* *as a Service (CaaS)* has become the fourth important cloud service. CaaS is a type of container–based cloud service in which provides engines and compute resources.

- **Essential characteristics**

There are four essential characteristics of cloud computing. They are described as on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. *On-demand self-service* allows customers to provision cloud services without the human interaction of cloud providers, they can access to the services at any time. *Broad network access* implies that cloud computing is web based services, it can be accessed in different platforms from anywhere. *Resource pooling* indicates that multiple tenants share a common pool of resources such as storage, processing, memory, and network bandwidth. *Rapid elasticity* describes that cloud computing resources can be provisioned and released in any quantity at any time. *Measured service* means that the resources used by the consumers can be managed and monitored automatically by the consumers and providers.

NIST definition makes an appropriate background for our research, since it defined a framework of different cloud services and deployment models. The different deployment models are defined from the perspective of cloud users, it depends if it is open for the public personals or organizations. If we define them from the perspective of manager of cloud resources, cloud computing will be divided into internal cloud and external cloud. One firm is fully in charge of used cloud resources, it is internal cloud. The cloud resources is ensured by a cloud service provider, it is external cloud. The combination of the aforementioned deployment models: internal private cloud, external private cloud, internal public cloud and external public cloud is one of our research objectives.



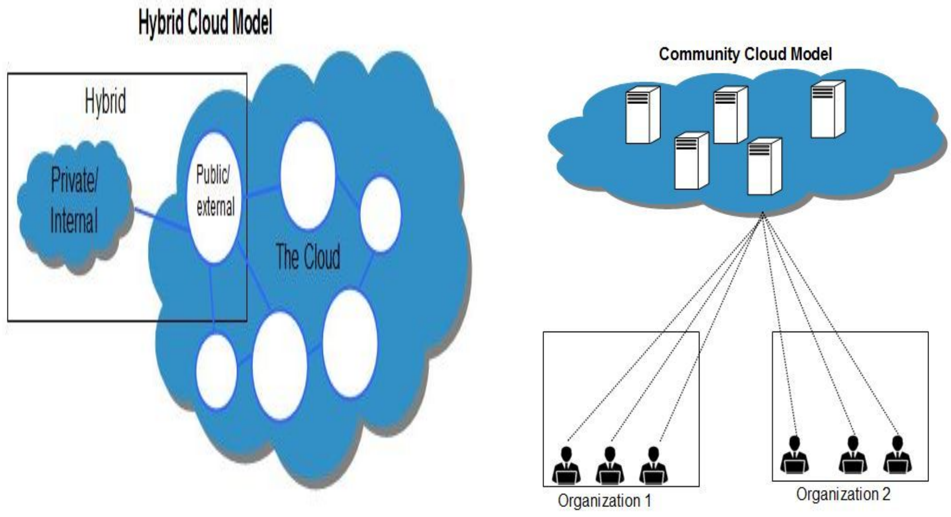


Figure 1. Cloud Computing Deployment Models (Source: Manesh T, Thankappan)

1.1.4 Cloud computing issues

Cloud computing has brought numerous advantages for individuals and organizations, such as the agility and the economic attractions, however, there are still many issues. Sultan & Sultan, (2012) indicates that security, vendor lock-in, and availability are the most important challenges for the adoption of cloud computing. Like any other modern technologies, security is considered as a major concern in the adoption of cloud computing services (Brender & markov, 2013). Susanto et al. (2012) describes security as a common issue of cloud computing. Availability is a serious problem for cloud users (sultan 2013), especially for critical business. Another main concern is vendor lock-in, it relates to interoperability and portability, because most of cloud services are offered by proprietary Application Programming Interface (API). That means that it's very difficult for organizations to change cloud providers from one to another. Availability is considered as another important issue of cloud computing service because of failure of cloud provider.

- **Privacy and security**

Privacy and security are the main concerns about cloud computing since data is held on the cloud. It increases the risk to handover the sensitive data to cloud computing services. Therefore, cloud computing providers should offer a well-built security environment to ensure customers' data are secured. Due to the distribution of data centers will limit potential attacks, many cloud providers established their cloud data centers in different locations of all the world in order to make their customers can choose their adequate data stored locations. In addition, there will be more and more private sectors with their confidential data migrating to cloud computing services, a strict security will be needed.

Hybrid cloud computing services will be another solution giving relative level of control over the security of private data will be a solution to this issue.

- **Vendor Lock-in**

Vendor lock-in leads to the difficulty for cloud customers switching from one cloud provider to another one for the data transformation and entire applications transformation. It makes cloud users tie to a particular cloud provider all the time. Especially, PaaS faces the biggest problem with this type of issue. For example, a system written in Python is not coherent with Google's App Engine, it's the platform lock-in. Interoperability and portability challenges will become greater because of the increasing of cloud provider numbers. With regards to this problem, the basis of the APIs on open source message communication standards is adequate solution. Cloud providers such as Amazon Web services and Microsoft's Azure offer Simple object Access Protocol (SOAP) and Representational State Transfer (REST) accesses.

- **Availability**

The rate of availability is not hundred percent, failure of a cloud provider can have serious problems. Amazon's EC2 was unavailable for multi-day in April 2011 because it experienced an outage when its northern Virginia data center site was affected. The connectivity of Amazon's EC2 service was failure. Focusing on this issue, any enterprise intending to migrate their critical business to the cloud should define a Service Level Agreement (SLA) for the availability with their cloud provider and inspect providers by checking their technology, revenue and experience.

1.2 Research framework

Cloud computing research is still in its early days. Much of the current literature focuses on its benefits and risks, or examines case studies of cloud adoption and cloud computing architectures (Bhattacherjee & Park, 2013). The main focus is adoption, and to a lesser extent the economic implications of decision-making, business modelling, and value transformation/creation.

1.2.1 Research topics

- **Adoption**

This is a traditional topic in the IS literature at individual, team and organizational levels. Sociological perspectives (see, for example, Giddens, among others) (Jones, Karsten, 2008) have been particularly useful in understanding the impact of IT artifacts on organizations. *Ad hoc* frameworks have been used to explain the migration to the cloud for specific applications (Bhattacherjee & Park, 2013). However, if cloud computing is viewed as a fuzzy system, we need to renew our understanding of why and how organizations adopt such approaches: What are the determining factors? Who are the key stakeholders? What are the governance structures? What is the role of IT vendors? What games can be observed around and within organizations? These issues need to be better documented, in terms of both practices and analytical approaches.

Existing research has made a great progress for the understanding of cloud computing adoption phenomenon. Lero and Kieran addressed the complex and multifaceted nature of cloud computing adoption drawing on three different case studies of providers and their customers (Lero and Kieran, 2013). Their findings reveal that factors impacting cloud adoption tend to be psychological and technical. (Asatiani, 2015) identified 43 relative factors with cloud computing adoption and classified them using Technology-Organization-Environment (TOE) framework. In addition, the author analyzed both quantitative and qualitative evidence between decision factors and cloud adoption. This review contributed to both cloud providers and organizations. (Low et al. 2011) tackled the cloud computing adoption problems using TOE framework and indicated that more different industries should be considered in order to better understand the influences of environmental and organizational factors on cloud computing adoption.

Besides the aforementioned cloud computing adoption research, several research has improved the understanding of cloud computing adoption phenomenon by segmenting the cloud computing characteristics from the perspective of firm sizes, specific sectors, different cloud services and models. Some research considered especially on certain size firms, (Safari et al. 2015), (Gupta et al. 2013), (Lian et al. 2014) on SMEs and (Repschlaeger et al. 2013) on startups. Some research focused on specific sectors, (Oliveira et al. 2014) on manufacturing and services sectors, (Lian et al. 2014) on hospitals. (Oliveira et al., 2014) developed a research model integrating the theory of the Diffusion of Innovation (DOI) and TOE. This model was evaluated based on 369 Portugal firms and their findings show that relative advantage, complexity, technological readiness, top management support, and firm size influence the adoption of cloud computing. Some papers addressed on specific cloud services, (Benlian and Hess, 2011) and (Lee et al. 2013) on SaaS, and (Naldi and Mastroeni, 2014) on IaaS. Naldi and Mastroeni proposed a methodological approach to the comparison of cloud versus in-house solutions, it is based on an assessment of the direct economic impact of migration to the cloud.

(Hsu et al. 2014) is the single paper that we found to deal with the adoption of different pricing models: pay-as-you-go; one-time license and monthly plan, and different deployment models: private cloud and public cloud. The authors alleged that perceived benefits, business concerns, and IT capability influence the intention of cloud computing adoption and external pressure is not a significant factor. Business concerns has an important impact on the choice of deployment models due to the security issues of cloud computing, since firms need a private space for some critical data. And the choice of pricing models depends on the IT capacity of firms. Generally, a higher IT capacity firm will choose pay-as-you-go payment for the flexibility.

This paper was well structured, yet there are some limitations. For example, the authors just considered four principal decision factors for the cloud computing adoption and use the same factors to discuss the adoption of different pricing models and deployment models, it's a lack of consideration of specific characteristics of the two types cloud models. Another issue is about the deployment models, based on the definition of NIST (Mell and Grance, 2001), deployment model is divided into 4 sub-models: private model, public model, community model and hybrid model. But the authors just considered private and public two models.

This literature review helped us to understand the background for cloud computing adoption and related research. Early studies on cloud computing adoption tend to be skewed toward benefits and challenges, yet in spite of some segmentation efforts, actually there is a lack of research framework focusing on the adoption of cloud services and cloud deployment models. The strategies of cloud computing is very different from traditional IT strategies. There is a need to discuss how to select cloud services and cloud deployment models.

- **Decision-making**

The economics of cloud computing is a topic that remains to be addressed by researchers (Etro, 2011). A few recent papers have addressed various dimensions, in particular by comparing in-house resources with external resources (Naldi & Mastroeni, 2014). However, there is a need to better document these dimensions, especially those related to pricing and cost mechanisms, scope, and economies of scale. This includes, for vendors, market stability and the bundle of resources (internal/ external, per application) that is best-suited to the needs of end users.

From a technical perspective, cloud computing is often associated with various dimensions of information. Virtualization refers to "the creation of a virtual version of a device or a resource". In the case of cloud computing, virtualization refers to the creation of a virtual machine(s), managed by hypervisor software. Cloud computing is also associated with grid computing, based on the use of different resources, "which are loosely-coupled and accessible through a network". Similarly, service-oriented architectures that provide software-based storage are other key ingredients in the implementation of cloud computing approaches, and help to make them viable. These technical innovations have enabled the development of various cloud computing configurations (XaaS, SaaS, PaaS, IaaS, TaasS, NaaS, MaaS, CaaS, etc.).

- **Business modelling**

An increasing body of work addresses cloud computing either from an IS or business perspective (Marston et al., 2011) or, more generally, from a service science perspective. For example, frameworks have been proposed to model information systems or aspects of business such as pricing. These frameworks can help to evaluate and compare 'configurations' (Garg, Versteeg, & Buyya, 2013), guide the selection of cloud services (Menychtas, Gatzioura, & Varvarigou, 2011), and evaluate their success (Walther et al., 2013). However, this non-technical perspective of cloud computing remains a work-in-progress that, to a large extent, has only attracted the attention of specialists and remains to be operationalized in real-world settings.

The generative nature of digital technology (Zhang et al., 2010; Yoo et al.2012) means that new digital business models, and therefore new ways of organizing, are continuously emerging, leading to ongoing change in the competitive landscape (El Sawy & Pereira, 2013). But despite their importance, these models and the associated organizational practices are rarely addressed systematically. This raises the question of what should the future modes of an organization be? Digital business models are closely related to value creation modalities in the knowledge economy.

- **Value creation**

Value creation has been widely-debated in economics and the business literature over the past ten years and has several implications. Notably, cloud computing could represent the next step in virtualization and "servicization" trends in IS. It could contribute to making organizations even more agile, by offering them the option to run "anything as a service" (XaaS). With cloud computing, IT (infrastructure and services) becomes even more flexible, allowing, for instance, an organization to manage and operate its IT as a utility. More specifically, and according to some of the vendors arguments, cloud computing solutions can allow an organization to scale up quasi-transparently its operations (even for short duration if necessary), paying mostly only for the usage (transforming its fixed costs into variable costs), and (out) sourcing its IT in the way it find the more convenient (e.g. selecting and changing external providers). Yet at the same time, this setting confronts organizations with a variety of new issues encompassing many dimensions (technical, legal, security, economical, organizational or societal) that they have to address in a holistic manner. In this context, we need to find better ways to evaluate the organizational stakes related to cloud computing. Questions concern the readiness of IT departments and, more generally, corporate management to deal with these new approaches to resources, while organizations may find it difficult to evaluate and compare the different options available to them.

The above suggests that, as a managerial practice, cloud computing challenges every dimension of a firm's business strategy: its speed, scope, scale and source of value creation (Bharadwaj et al., 2013). Moreover, there is a need for an overall and syncretic view of how cloud computing affects (or might affect) the performance of firms and organizations in terms of cost, value, risk, competences, data, and intellectual property rights (IPR) management. The cloud computing literature remains dominated by the technical and, to a lesser extent, security point of view, while business aspects are neglected.

- **Providers selection**

During earlier stages of cloud computing development, the primary focus was on technical factors; now, the focus is gradually moving towards a business perspective (Hoberg, Wollersheim and Krcmar, 2012; Son and Lee, 2011). Recently, the number of companies that have adopted cloud computing services has increased. Furthermore, cloud-experienced companies are confronted with various challenges as they must compare several alternatives based on incomplete decision criteria (Martens, Walterbusch and Teuteberg, 2012).

Numerous research results indicate that decisions involved in selecting cloud suppliers have become increasingly important (Aissaoui, Haouari and Hassini, 2007; Li and Wan, 2014). However, cloud provider selection has become a key issue due to the limited transparency of existing cloud services (Godse and Mulik, 2009). It is often difficult to judge the quality of cloud services and to make a decision (Martens, Walterbusch and Teuteberg, 2012). In essence, the selection of top suppliers is always a difficult task for decision-makers due to the growth of cloud computing and owing to the fact that various criteria (e.g., cost and performance) must be considered during the decision-making process. Therefore, cloud customers are faced with the challenge of identifying providers that can satisfy their requirements.

Despite the theoretical and practical need to understand dynamics of appropriate fit between a company and its cloud services providers, this issue has been infrequently studied. Although most existing studies assume that service attributes are independent of one another, in reality, attributes are interdependent (Saripalli and Pingali, 2011). Interdependent relationships between selection criteria are critical to rational decision-making.

1.2.2 Problem statement

Taking the aforementioned literature into account, we structure a framework to describe the research gaps and the research opportunities identified. First of all, the framework introduces a main research objective, and then, to realize the main objective, it is divided into 4 sub-objectives. The general objective of this thesis is to: **Address cloud computing adoption and decision-making challenges.** Especially, this thesis seeks to design a cloud computing framework that allows firms to decide whether they should move to cloud computing environment and how to choose cloud computing services and cloud computing providers.

Sub-objective 1: Address the challenges of cloud computing adoption determinants

Sub-objective 2: Address the challenges with regards to the selection of cloud computing services and cloud deployment models

Sub-objective 3: Address the challenges of the cloud computing services performance

Sub-objective 4: Address the challenges of the selection of cloud computing providers

This thesis aims to solve cloud computing adoption challenges to further our understanding of technology adoption phenomenon. Each chapter is structured as a single research paper to tackle a research gap. The thesis is structured as the following:

- A literature review identifies research questions and research opportunities
- A combination of different technology adoption frameworks contributes to determine cloud computing adoption factors
- A rule-based adoption model is designed to select cloud computing services and cloud computing deployment models
- A fuzzy logic decision model is defined to select cloud providers
- A comparison framework is created to compare cloud service performance

1.3 Chapter abstracts

- **Chapter 2: Cloud computing adoption determinants**

This chapter addresses the organizational transformation of firms for value creation resulting from cloud computing. With reference to the theory of organizational fit, we modelled organizational transformation as an output variable, as a function of five aspects of cloud computing practice: functionality, data management, roles and competences of information technology services, control, and organizational culture. The output variable was tested against a set of input variables defined with reference to the Technology–Organization–Environment (TOE) and Technology Acceptation Model (TAM). Based on a sample of 487 companies in seven countries in Europe, Asia, and the United States we distinguished two groups of firms: Transformational and Hyper Transformational. The results highlight the key factors that determine whether a firm falls into one of these two groups, and include: perceived usefulness and perceived ease of use, complexity and compatibility of cloud computing technology, and adequacy of resources. Top management support and government policy are found to only play a role for the Transformational group while, surprisingly, vendor support had no impact for either group.

- **Chapter 3: Cloud computing services and deployment models**

Current research on cloud computing adoption has focused on identifying factors influencing cloud computing decision and testing the impact of a predefined set of factors on the intention to adopt cloud. Our paper covers technical and economic factors governing the cloud adoption and proposes a set of dimensions: stable dimension, relatively stable dimension and variable dimension for positioning firms with respect to their pretention of cloud computing adoption, and also providing a guideline on the SPI stack for selecting appropriate cloud services. The findings reveal that our designed model for cloud adoption is very effective; the adoption of different cloud models is not influenced by the enterprise size; the adoption of CaaS and IaaS relate significantly to the rule IT know-how; SaaS is the most commonly used cloud service and Internal Private model is the most commonly used cloud model. The paper contributes to a set of fundamental dimensions of cloud computing adoption for the future research and the adoption theory development.

- **Chapter 4: Selection of cloud providers**

The increasing number of cloud service users renders it critical for firms to select cloud service suppliers that suit all company business strategies and goals. From the literature review, we found a lack of research addressing the interdependence of decision criteria. In this study, we address this crucial research gap by presenting an integrative research model that combines fuzzy logic theory and the analysis hierarchy process (AHP). We use this model to holistically evaluate cloud providers focused on PaaS and IaaS with predetermined criteria. The simulation results reveal a correlation between decision criteria, and cloud provider performance is found to vary considerably.

- **Chapter 5: Public cloud performance**

The objective of this paper is to perform a comprehensive performance comparison of public cloud services for computing and to analyze the correlation between their prices and performance. Eight representative public cloud providers were divided into two groups using market share: small cloud providers and large cloud providers. Results revealed that these offered computing services vary widely in performance and price; most small cloud providers have more stable and better computing performance than large cloud providers; the performance of CPU impact price significantly.

- **Appendix**

Cloud computing has both technical organizational dimensions, and the stakes are high for the performance of firms and organizations'. Until recently the organizational dimension has received little attention, and the cloud has essentially been considered from a technical perspective. However, the "cloudification" of information systems poses many economic and managerial questions that need to be evaluated. It is therefore important to enrich our understanding of phenomena related to the "virtualization" of information, through an examination of their multidimensional characteristics.

This survey forms part of the Cloud Based Organizational Designs (CBOD) project, supported by the French National Research Agency (ANR) (www.cbod.u-psud.fr). The objective of this multidisciplinary project is to deepen the scope of knowledge about the phenomenon known as "cloud computing" by developing a techno-economic analysis that will contribute to a better understanding of the practice of cloud computing.

This global survey aims to investigate the decision making context in relation to a set of technical, strategic, economic, and organizational criteria. It will be conducted in Europe (with the support of leading business associations), the United States and Asia.

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Chapter 2

How Do Firms Use Cloud Computing to Transform Their Organization ?

Ahmed Bounfour, Jean-Michel Etienne, Xiaolin Cheng

2.1 Introduction

Cloud computing (CC) is now considered as a major opportunity to develop innovative services and new ways of organizing for companies, public organizations and citizens in general. For companies, CC can help them to improve the flexibility and smooth operation of their business models (Accenture, 2012). Consequently, it would appear that adopting and migrating to CC is relatively easy. However, CC modalities are still a subject of debate (Khajeh-Hosseini et al., 2010) due to, among other issue, the question of risk (Barki, 2007; Eze et al., 2011; Silva, 2007).

CC solutions create a virtual space for infrastructure, platforms, and software. Their popularity is primarily due to their ease of use. As a result, several providers, including Amazon, Microsoft, and Google have begun to offer the technology. According to an analysis by Gartner, CC usage is still growing, and will account for the bulk of new information technology (IT) expenditure. Garnter indicates that by 2020 "a Corporate "No-Cloud" Policy Will Be as Rare as a "No-Internet" Policy Is Today" (Gartner, 2016). The most widely definition of CC is provided by the National Institute of Standards and Technology, "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models" (Mell & Grance, 2001).

Ahmed Bounfour, Jean-Michel Etienne, Xiaolin Cheng, "How do firms use cloud computing to transform their organisations", under submission to PACIS 2018, Pacific Asia Conference on Information Systems, Yokohama, 27/28 June 2018

In the earlier stages of CC development, the primary focus was on technical factors; now, it is gradually moving towards a business perspective (Hoberg, Wollersheim, & Krcmar, 2012; Son & Lee, 2011). Recently, the number of companies that have adopted CC services has increased, while companies that are still thinking about adopting the technology are confronted by various challenges, as they must compare several alternatives based on incomplete decision criteria (Martens, Walterbusch, & Teuteberg, 2012).

Numerous research results indicate that the selection of cloud suppliers has become increasingly important (Aissaoui, Haouari, & Hassini, 2007; Li & Wan, 2014). However, the choice is made difficult by the limited transparency of cloud services (Godse & Mulik, 2009) that make it difficult to judge their quality (Martens, Walterbusch, & Teuteberg, 2012), and the fact that various criteria (e.g. cost and performance) must be considered. Cloud customers are faced with the challenge of identifying providers that can satisfy their requirements.

CC research is still in its early days. Much of the current literature focuses on its benefits and risks, or examines case studies of cloud adoption and CC architectures (Bhattacherjee & Park, 2013). The main focus is adoption, and to a lesser extent the economic implications of decision-making, business modelling, and value transformation/creation.

- **Adoption**

This is a traditional topic in the IS literature at individual, team and organizational levels. Sociological perspectives (see, for example, Giddens, among others) (Jones, Karsten, , 2008) have been particularly useful in understanding the impact of IT artifacts on organizations. *Ad hoc* frameworks have been used to explain the migration to the cloud for specific applications (Bhattacherjee & Park, 2013). However, if CC is viewed as a fuzzy system, we need to renew our understanding of why and how organizations adopt such approaches: What are the determining factors? Who are the key stakeholders? What are the governance structures? What is the role of IT vendors? What games can be observed around and within organizations? These issues need to be better documented, in terms of both practices and analytical approaches.

- **Decision-making**

The economics of CC is a topic that remains to be addressed by researchers (Etro, 2011). A few recent papers have addressed various dimensions, in particular by comparing in-house resources with external resources (Naldi & Mastroeni, 2016). However, there is a need to better document these dimensions, especially those related to pricing and cost mechanisms, scope, and economies of scale. This includes, for vendors, market stability and the bundle of resources (internal/ external, per application) that is best-suited to the needs of end users.

From a technical perspective, CC is often associated with various dimensions of agencing information. Virtualization refers to "the creation of a virtual version of a device or a resource". In the case of CC, virtualization refers to the creation of a virtual machine(s), managed by hypervisor software. CC is also associated with grid computing, based on the use of different resources, "which are loosely-coupled and accessible through a network". Similarly, service-oriented architectures that provide software-based storage are other key ingredients in the implementation of CC approaches, and help to make them viable. These technical innovations have enabled the development of various CC configurations (XaaS, SaaS, Paas, Iaas, TaasS, NaaS, Maas, CaaS, etc.).

In this context, two issues should be noted: 1) Data center ownership and the geographical distribution of resources, especially with regard to resilience to hardware failure and natural disasters; and 2) Resource provisioning. CC limits resource provisioning as it is fundamentally an on-demand system that offers configurability, coordination, maintenance and flexibility of services, scalability and resource sharing, interoperability and security. Other issues are non-technical, and include legacy software, pricing, vendor lock-in and governance.

- **Business modelling**

An increasing body of work addresses CC either from an IS or business perspective (Marston et al., 2011) or, more generally, from a service science perspective. For example, frameworks have been proposed to model information systems or aspects of business such as pricing. These frameworks can help to evaluate and compare 'configurations' (Garg, Versteeg, & Buyya, 2013), guide the selection of cloud services (Menychtas, Gatzioura, & Varvarigou, 2011), and evaluate their success (Walther et al., 2013). However, this non-technical perspective of CC remains a work-in-progress that, to a large extent, has only attracted the attention of specialists and remains to be operationalized in real-world settings.

The generative nature of digital technology (Zhang et al., 2012; Yoo et al.2012) means that new digital business models, and therefore new ways of organizing, are continuously emerging, leading to ongoing change in the competitive landscape (El Sawy & Pereira, 2013). But despite their importance, these models and the associated organizational practices are rarely addressed systematically. This raises the question of what should the future modes of an organization be?

Digital business models are closely related to value creation modalities in the knowledge economy.

- **Value creation**

Value creation has been widely-debated in economics and the business literature over the past ten years and has several implications. Notably, CC could represent the next step in virtualization and "servicization" trends in IS. It could contribute to making organizations even more agile, by offering them the option to run "anything as a service" (XaaS). With CC, IT (infrastructure and services) becomes even more flexibile, allowing, for instance, an organization to manage and operate its IT as a utility. More specifically, and according to some of the vendors arguments, CC solutions can allow an organization to scale up quasi-transparently its operations (even for short duration if necessary), paying mostly only for the usage (transforming its fixed costs into variable costs), and (out) sourcing its IT in the way it find the more convenient (e.g. selecting and changing external providers). Yet at the same time, this setting confronts organizations with a variety of new issues encompassing many dimensions (technical, legal, security, economical, organizational or societal) that they have to address in a holistic manner. In this context, we need to find better ways to evaluate the organizational stakes related to CC. Questions concern the readiness of IT departments and, more generally, corporate management to deal with these new approaches to resources, while organizations may find it difficult to evaluate and compare the different options available to them.

The above suggests that, as a managerial practice, CC challenges every dimension of a firm's business strategy: its speed, scope, scale and source of value creation (Bharadwaj et al., 2013). Moreover, there is a need for an overall and syncretic view of how CC affects (or might affect) the performance of firms and organizations in terms of cost, value, risk, competences, data, and intellectual property rights (IPR) management. The CC literature remains dominated by the technical and, to a lesser extent, security point of view, while business aspects are neglected. There is a need to document the impact of the digital transformation (in particular CC) on company value. The issue is the focus of this paper, which considers the transformational nature of CC, based on its organizational dimension. Specifically, we investigate the following research question: *How do firms use CC to effectively transform their organization to create value*?

2.2 Theoretical background

This section reviews the most important recent work on adoption, which has been the focus of the CC literature. Research is based on three main theoretical perspectives: Diffusion of Innovation (DOI) theory (Rogers, 2003), the Technology Acceptance Model (TAM) (Davis, 1985, 1989), and the Technology–Organization–Environment (TOE) framework (Tonatzy & Fletcher, 1990). Beside these, the Political, Economic, Social, Technology (PEST) model proposed by Fahey and Narayanan (1986), was also considered by some researchers for the analysis of CC adoption.

The **Technology Acceptance Model** (TAM) was first introduced by Davis in his doctoral thesis while studying at the MIT Sloan School of Management (Davis, 1985). It relies on the theory of Reasoned Action proposed by Fishbein and Ajzen (1975). The model proposes a system of technology acceptance, with a focus on two dimensions of the user's motivation: perceived usefulness, and perceived ease of use. Davis's work was the first attempt to develop an overall approach to the issue of adoption in the domain of IS (Barki, 2007; Eze et al., 2011; Silva, 2007). The model has been refined along different scales (Davis, 1989), and has evolved into different versions (Davis, Bagozzi, & Warshaw, 1989; Venkatesh & Davis, 1996; Vankatesh, 2000; Venkatesh, Thong, & Xu, 2012). Despite its widespread diffusion and implementation in IS research, the model suffers from its narrow focus on two main dimensions, while other use factors are ignored[1].

The Technology–Organization–Environment (TOE) framework is the most widely-used approach in CC adoption research. It identifies various influential factors in technological, organizational, and environmental dimensions. Each dimension offers both constraints and opportunities for technology adoption (Tonatzy & Fletcher, 1990). TOE considers adoption and implementation from a 'context for change' perspective, rather than individual perceptions. Previous studies have demonstrated that the TOE framework is very useful for understanding critical determinants of adoption (Lian, Yen, & Wang, 2014).

Political, Economic, Social, Technology (PEST) analysis was proposed by Fahey and Narayanan (1986). It was initially used to analyze markets from a macroeconomic perspective (Lee, Chae, & Cho, 2013). More generally, PEST is considered as an external environmental analysis framework, and as such does not include micro-environmental and internal factors.

[1] For a review of the origins of the TAM model and its evolution see Chuttur (2009).

Diffusion of Innovation (DOI) theory was developed by Rogers (1995). It explains innovation adoption in an organization from a technological perspective and users' perceptions (Oliveira, Thomas, & Espadanal, 2014). DOI theory discusses five attributes: relative advantage, compatibility, complexity, triability, and observability. Using this model, Lin & Chen (2012) investigated the impact of the five attributes for CC adoption in hospitals in Taiwan. However, DOI does not take into account the impact of the environmental dimension.

Table 1 summarizes the most important recent work on CC adoption, and presents the theoretical frameworks as a function of four dimensions: technological, organizational, environmental, and human. The latter was added in reference to the TAM model, and complements the TOE framework.

[Appendix Table 1]

As the call for papers for this special issue clearly indicates, CC research has focused on issues of adoption and operation and much less, if at all, on its ability to transform and create value. The question of the transformational nature of CC in relation to the issue of value creation can be addressed from various angles: economic performance, organizational and business models, the consumer, or citizens and society in general. Here we examine the organizational dimension as a factor in economic performance, and therefore as a critical intangible asset (Bloom et al., 2012; Lev & Radhakrishnan, 2003; Kawakami , Aaba, 2015). Our aim is to go beyond the traditional approach to adoption as an output factor, and consider the effectiveness of business transformation due to CC. We build on the key dimensions of the theory of organizational fit, notably the seminal work of Soh et al. (2010), which is developed in the next section.

2.3 Research model and empirical data

We document the factors influencing the intensity of transformation from an organizational angle. Specifically, our aim is to go beyond adoption questions and look at the transformational nature of CC. We consider its key dimensions and, subsequently, identify the factors that have the most impact.

2.3.1 Research model

Like earlier research (Oliveira et al., 2014: 500–502), we develop an integrated approach to CC. However, we replace the traditional question of adoption with that of the intensity of transformation.

We consider a series of input variables (CC practices) and relate them to a series of output variables that reflect the intensity of organizational transformation due to CC (Figure 1)

[Appendix Figure 1]

On the input side, we develop a hybrid TOE/ TAM framework. The TOE framework is used to identy various influential factors in the innovation adoption process (Tornatzky & Klein, 1982, 1990) as it has features that make it appropriate for the investigation of CC adoption. CC services are usually provided to firms and organizations by a third party (cloud service providers). Thus, unlike conventional innovations, CC technology has three main actors: cloud-based services, cloud users and cloud service providers. As a result, its adoption is influenced by three major factors: (1) The characteristics of CC technology, which is a function of technologies that are both internal and external to the company; (2) The characteristics and resources of firms and organizations that provide the context; and (3) The environmental context in which a firm conducts its business; its industrial sector, competitors, access to resources supplied by others, and dealings with the government. In this study, we integrate constructs from both the TOE and TAM frameworks in order to include both human and non-human actors in the network.

On the output side, the model considers the key dimensions of transformation by reference to theories of organizational fit (Soh et al., 2000; Strong & Wolkoff, 2010). Organizational design is a critical dimension for understanding the role of artifacts in the transformation of firms (Markus, 2010). Here, we consider five specific dimensions: (1) *Functionality* (irregularities vs deficiencies) of IT services in terms of access, operations, services liability, reversibility, control of tasks, agility, procurement, and cost; (2) *Data management* (deficiencies vs efficiencies) including access, localization, security, compatibility, bandwidth, IPRs, service reports and delivery; (3) *Competences of IT services*, especially with regard to the clarity of roles, availability of internal competences, alignment of competences and formal roles, and bottlenecks in tasks and workloads; (4) *Control*. Here we consider the following variables: control of tasks, service delivery, task coordination (internal versus cloud providers), contractual arrangements, and managing contractual risks; and finally (5) *Organizational culture*, notably with regard to formal rules and standards of behavior, informal rules, and the development of a cloud culture (Table 2)

[Appendix Table 2]

2. 3.2 Hypotheses

The nine hypothesis developed from our model are presented hereafter.

Perceived usefulness

Davis defined perceived usefulness as "the degree to which an individual believes that using a particular system would enhance his or her job performance" (Davis, 1985: 26) and suggested that it refers to productivity, performance and effectiveness (Davis, 1989). Lu, Yu, Liu, & Yao (2003) focused on technology acceptance for wireless internet, and defined it as “a prospective user’s subjective probability that using a specific application improved operations”. In our case, perceived usefulness is evaluated using three variables:

- More efficient task completion with CC compared to existing technologies
- Reduced operational, maintenance, updating and training costs
- Increased company agility

Consequently, our hypotheses as follows:

H1 Perceived usefulness increases the likelihood of organizational transformation due to CC.

Perceived ease of use

Perceived ease of use refers to, "The degree to which an individual believes that using a particular system would be free of physical and mental effort" (Davis, 1985). It measures the prospective user’s assessment of the mental effort required to use the target application (Davis, 1993). Wu (2011) contributed to the SaaS adoption literature; he argued that perceived ease of use was “the degree to which individuals considered that using the SaaS was easy to access, learn and utilize” and suggested that it may affect perceived usefulness and behavioral intentions. In our work, our assessment of perceived ease of use is based on three factors: (1) CC allows a good internet connection and speed of cloud services; (2) CC allows the ability to use and access cloud tools and data anywhere, and (3) Implementing CC requires negligible learning time for all employees.

H2 Perceived ease of use increases the likelihood of organizational transformation due to CC.

Complexity

Complexity describes “the degree to which an innovation is perceived as difficult to understand and use”. If CC is a seen as a complicated new technology by firms, they may not have the confidence to use it and it may take them a long time to learn and implement. Complexity has been described as a barrier to the adoption of new technology (Low et al., 2011) and as "the degree to which using the innovation is perceived as difficult" (Lin & Chen, 2012). It is a key criterion for CC adoption and respresents a big challenge for firms that lack personnel with specialized knowledge (Oliveira et al., 2014). The integration of CC technology into current systems can be a complex process for such firms (Borgman et al., 2013).In this regards, knowledge intensity and the complexity of the process of integrating technology into business process was considered as critical factors (Wu et al. 201).

Here, six aspects of complexity are assessed: (1) CC is too complex for business operations; (2) The skills needed to adopt CC are too complex for the firm's employees; (3) The additional complexity of migrating current systems to a CC platform; (4) Uncertainty about the location of data limits the use of CC services; (5) The risk of a security breach limits the use of CC services; and (6) Having a full understanding of the conditions of data use in CC.

H3 Complexity decreases the likelihood of organizational transformation due to CC.

Compatibility

Compatibility reflects the degree to which an innovation is perceived as being consistent with existing values, past experience, and the needs of users. Rogers (1995) defined it as "the degree to which an innovation fits with the potential adopter's existing values, previous practices, and current needs". According to Lin and Chen (2012), compatibility is "the degree to which new technology is perceived to be consistent with internal information systems." When new technology is considered to be compatible with current systems, its adoption becomes more feasible; when it is incompatible, firms take a long time to learn and reorganize their systems (Low et al., 2011). Oliveira et al. (2014) concluded that compatibility was an important determinant if the aim was to take advantage of the agility and scalability of CC without security concerns. In a research by Safari et al. (2015), compatibility was considered along three dimensions : the internet, data and its application, and the legal level.

In our research, compatibility is assessed in terms of four factors: (1) Compatibility with current company practice; (2) Compatibility with firm's values and goals; (3) Ease of integration into existing IT infrastructure; and (4) Loose coupling and independence of applications.

H4 Compatibility increases the likelihood of organizational transformation due to CC.

Top management support

Top management support can contribute to innovation adoption by creating a fertile environment and providing resources (Premkumar & Roberts, 1999). The issue is naturally related to its leadership role in digitization (El Sawy et al., 2016). Abdollahzadehgan et al. (2013) defined top management support as "the degree of support provided by the higher management in adopting the new technology for business". An important issue is whether (or not) executives understand the technology enough to fully support its adoption. It can also create a fertile environment for the allocation of resources and the integration of services (Low et al., 2011; Oliveira et al., 2014). In our research, top management support is assessed in terms of two factors: (1) Willingness to provide strong leadership and engage in the process; and (2) Willingness to take risks in the adoption of CC.

H5 Top management support increases the likelihood of organizational transformation due to CC.

Adequate resources

Adequate resources are critical to successful adoption. If the budget is insufficient, positive support can be provided in the form of human resources. CC adoption is a large-scale project, and an appropriate budget, adequate human resources, and top management support all improve the chance of success (Lian et al., 2014). On the other hand, a lack of resources has the opposite effect.

In our research, we considered five parameters: (1) The provision of appropriate resources to develop CC; (2) The availability of development time; (3) A sufficient budget; (4) Sufficient human resources; and (5) The fact that CC allows the development of a 'shadow' IT department.

H6 Adequate resources increase the likelihood of organizational transformation due to CC.

Vendor support

In CC technology, the customer is highly dependent on the vendor to achieve the desired level of security. This dependency is particularly acute in low-tech companies that lack IT expertise. As data and applications are usually held on the providers' platform (Safari et al., 2015) vendors must guarantee security, availability, and performance through clear Service Level Agreements (SLA), and provide support in the form of guaranteed hardware, software, and networks (Thong, 2001). This is particularly important for SMEs that lack infrastructure and knowledgable personnel. Here, vendor support is assessed using five parameters: (1) SLA guarantees; (2) On-request return of data; (3) Adequate compensation following a vendor breach of the SLA; (4) Availability of vendor support; and (5) The availability of suitable training.

H7 Vendor support increases the likelihood of organizational transformation due to CC.

Government policy

Government policy is another environmental factor that affects innovation diffusion (Porter, 1985). Companies operating in an environment with restrictive government policies can be expected to have low levels of IT adoption. CC is one example of an internet-based technology that is subject to government policy (Safari et al., 2015). Hsu et al. (2014) indicated that government policy is one of three external pressures (the others being trading partners and competitive pressure) acting on companies. Here, government support is analyzed using three variables: (1) Encouragement given to firms to adopt CC; (2) The presence of mediating organizations that support enterprises in the implementation of CC; and (3) The comprehensiveness of regulations in addressing legal challenges related to CC.

H8 Government policy increases the likelihood of organizational transformation due to CC.

Competitive pressure

Competitive pressure refers to the degree to which competitors exert pressure on the firm (Oliveira & Martins, 2010). It has been defined as "the degree that the company is affected by competitors in the market" (Zhu, Xu, & Dedrick, 2003). Industrial forces are a critical element in firms' strategies and behavior (Porter, 1980). Competitive pressure has long been shown to have a positive effect on, and be a significant determinant of CC adoption, forcing firms to adopt new technology (Lian et al., 2014; Oliveira et al., 2014). For SMEs in a competitive environment, CC can be an appropriate solution (Safari et al., 2015).

Firms react by adjusting their offer, while greater competition forces them to allocate more resources to innovation. Here, we evaluate competitive pressure based on two determining factors: (1) Whether the firm thinks that CC, as a managerial practice, has an influence on competition in their industry; and (2) Whether the firm is under pressure from competitors to adopt CC.

H9 Competitive pressure increases the likelihood of organizational transformation due to CC.

2.3.3 Data and methods

We developed a database of 487 firms that use CC, in the context of an international research project supported by our National Research Agency. The database comprises seven, country-specific cross-sectional datasets, covering the United States (60 firms), China (83 firms), Japan (73 firms), France (60 firms), Germany (66 firms), Italy (76 firms), and the United Kingdom (69 firms). Data was drawn from a questionnaire that was designed by the project's partners and formed the basis for a survey that was conducted in 2016. The questionnaire consisted of 30 questions divided into the following six modules: (1) General company information (11 questions); (2) CC practices (4 questions); (3) CC adoption behavior (3 questions); (4) Organizational transformation/ fit (6 questions); (5) Regulation, Data & IPRs (3 questions); (6) Governance (3 questions); and (7) Cloud futures design (2 questions).

The questionnaire was distributed via a service provider[2]. Organizations with more than 10 employees were targeted, and respondents were CIOs (chief information officers), CEOs (chief executive officers), IT managers, and other managers with CC experience. The questionnaire was designed to address the questions at the heart of our research project, namely:

Question 1: How mature are firms with respect to CC?

Question 2: What are the main driving forces for firms' organizational design, based on CC?

Question 3: What options can be defined and proposed to firms with respect to their transformation (business models, data and services, IPRs, governance), based on CC?

The data that was collected provided key information on a variety of dimensions related to both CC practice and organizational transformation/ fit. They offer a detailed description of objective and subjective, current and historical measures of CC practices.

Modifications to organizational fit due to CC practices were captured by 33 self-assessment questions covering a wide range of issues. Each question corresponded to a variable, and variables were grouped into four dimensions, namely: human, technological, management, and environmental (Table 3).

[Appendix Table 3]

[2] Lightspeed GMI

2.3.4 Analysis

We constructed the dependent variables as follows. First, a qualitative variable (y_i) was developed for each question. It was given a value of 1 if respondents reported “Fully agree” or “Agree” and 0 otherwise. Next, we constructed a positive change score. This score took into account all items and was measured on a 28-point scale, with 28 indicating the highest possible positive change.

We adopted two measures of change in organizational fit that were considered to be represent organizational transformation:

The first qualitative variable ($output1_i$) took the value 1 for firms that declared at least 14 positive changes (in any combination of dimensions), and 0 otherwise.

The second qualitative variable ($output2_i$) took the value 1 for firms that declared a 50% positive change for each dimension3.

A firm was considered as **Transformational** if it recorded at least 14 positive changes in its organizational fit. The **Hyper Transformational** group was characterized by at least 50% positive changes in each dimension.

Other information concerned the environmental context in which firms took decisions. For a number of resources (e.g. IT and budgets), firms were asked to describe how they had changed over time. This resulted in the collection of a large amount of economic and environmental data including growth, market size, competitors, suppliers, and access to external resources.

As the change in organizational fit index was a binary dependent variable, we modelled it as a probit regression equation. Our benchmark specification takes the following form:

$$Y_i = \alpha X_i + \beta Z_i + \varepsilon_i$$

Where Y_i is an indicator of positive change in the organizational fit of firm i; X_i represents CC adoption or practice by firm i; Z_i represents a variety of company characteristics including sector, size, economic growth and the size of the IT budget; α and β are parameters to be estimated and ε_i is an error term.

[3] Specifically, this means: 4 positive changes for functionality; 3 positive changes for data management; 2 for competences; 2 for control; and 2 for culture (Table 2).

We ran a Maximum Likelihood Estimation of: (i) the probit model ignoring fixed country effects (Model 1), and (ii) compared it to the probit model taking into account fixed country effects (Model 2). We ran these models on the sample of 487 completed questionnaires. Two measures of the dependent variable (organizational fit) were used: (i) Whether there were at least 14 positive changes (output1); and (ii) whether there were at least 50% positive changes in each dimension (output2). Both output1 and output2 are considered as proxies for organizational fit.

2.3.5 Results

The marginal effects of probit models, and corresponding standard errors are presented in Tables 5 and 6. The first column estimates marginal effects without fixed country effects, while the last column includes this control. All covariates (independent variables) are binary, thus, marginal effects measure discrete change (i.e. how do the predicted probabilities change as the binary independent variable changes from 0 to 1?).

Our results provide important insights and are discussed in the context of our typology of firms (Transformational versus Hyper Transformational). Of the overall sample of 487 companies, 272 (56.86%) were found to be Transformational, while 158 (32.44%) were Hyper Transformational (Table 4). The latter is unexpectedly high, and suggests that CC has become a more widespread transformational practice than is generally accepted. Naturally, there is some overlap between the two groups: 158 Hyper Transformational firms are also members of the Transformational group (making a total of 272 firms) (see Table 4).

[Appendix Table 4]

Tables 5 and 6 show the results of the equality of proportions tests comparing the characteristics of the two groups. The second column of each Table shows the percentage of firms in the control group (non-Transformational or non-Hyper Transformational), while the third column shows the percentage of firms in the test group (Transformational or Hyper Transformational). The fourth column (Diff.) shows the difference between these two percentages. Finally, the last column shows the marginal significance level[4]. This analysis reveals that Transformational (Table 5) and Hyper Transformational (Table 6) groups differ in terms of their characteristics.

[Appendix Table 5]

[4]The marginal significance level corresponds to the probability of falsely rejecting the null hypothesis, the latter being equal proportions.

Table 5 shows that there are statistically significant differences between the test (Transformational) group and the control (non-Transformational) group. This is the case for the manufacturing (*sector_manu*) and financial (*sector_finan*) sectors. Financial services firms are overrepresented in the Transformational group (16.5%) compared to the non-Transformational group (9.3%). Conversely, firms in the manufacturing sector are more numerous in the non-Transformational group (14.9%) than in the Transformational group (8.1%).

Similar results were found for all variables describing human, technological, organizational and environmental dimensions of CC. The two human dimensions are "perceived usefulness" and "perceived ease of use". In the Transformational group, 91.9% of firms perceived CC as useful, and 91.2% perceived it as easy to use. The two technological dimensions are "compatibility of technology" and "complexity of technology". In the sample, 89.7% of companies perceived CC as compatible, and 54.4% as complex. The two organizational dimensions are "top management support" and "adequate resources". The analysis showed that 86.4% of firms thought that they had adequate resources. The three environmental dimensions are "vendor support behaviors" (88.6% perceived a positive change), "government policy" (75%) and "competitive pressure" (87.9%).

Overall, the results shown in Table 6 are similar to those presented in Table 5. However here, firms in the public (*sector public*) and manufacturing (*sector_manu*) sectors are more numerous in the non-Hyper Transformational group (7.9%, 12.8%) than in the Hyper Transformational group (3.8%, 5.2%) respectively.

[Appendix Table 6]

2.3.6 Characteristics of Transformational firms

The results of the marginal effects analysis for the two Models (with and without fixed effects) are presented in Table 7. Country effect applies only for Italy.

[Appendix Table 7]

The human dimension

Three independent variables were statistically significant at the 10% level, namely: "CC enables us to accomplish our tasks more efficiently" (*perceived_usefulness1*); "CC allows a good internet connection and speed of cloud services" (*perceived_ease_of_use1*); and "Cloud computing allows the ability to use and access cloud tools and data anywhere" (perceived_ease_of_use2). This result was found for Model 1 (no fixed effects) and Model 2 (fixed effects), at 10% and for the last two variables, and should be interpreted as follows: the change in the probability for a firm to Transformational increases by 42% as the perceived usefulness of CC moves from “Disagree” to “Completely agree”. This means that, from the perspective of the human dimension, a Transformational company has to consider both cost optimization, including for maintenance and training and ubiquity of access related to CC.

The technological dimension

Two independent variables were statistically significant. The first is “Our applications are loosely coupled and independent” (*compatibility4*), where change in the variable increases the probability by 40.7% in Model 1 (no fixed effects) and 39% in Model 2 (fixed effects). The second was “We fully understand the conditions of data use in the cloud” (*complexity6*). As it is to be expected, this variable has a negative effect and is only significant in Model 1. These two variables are important as they reflect the autonomy of applications and a real understanding of how data could be used, especially given the heterogeneity of regulations at the international level.

The organizational dimension

With respect to management and resources, two independent variables were significant at the 1% level for both models: “The company’s top management is willing to take risks in the adoption of CC” (*management_sup2*) and “Our firm has a budget that is sufficient to develop CC technology” (*adequate_res3*). Coefficients are relatively high for both variables, which suggests that CC is, above all, a management and resource issue. To be transformational, firms need clear and strong support from their top management, including in terms of budget.

The environmental dimension

Two variables were significant at the 1% level in both models: “The government encourages firms to apply CC technology” (*policy1*) and “Our firm thinks that CC has an influence on competition in its industry” (*competive_pressure1*). These results indicate that government support has an important role to play in encouraging firms to deploy CC. This is probably through both facilitating standards and creating a suitable regulatory framework (Porter, 1985).

2.3.7 Characteristics of Hyper Transformational firms

The results of the marginal effects analysis for the two Models with (Model 1) and without (Model 2) fixed effects are presented in Table 8.

[Appendix Table 8]

The human dimension

Four variables were significant. The first, “CC enables us to accomplish our tasks more efficiently” (*percieved_usefulness1*) was significant at the 1% level in both models with a high probability (85% and 86% respectively); “CC allows good internet connection and speed of cloud services” (*percieved_ease_of_use1*), was significant at the 10% level in Model 1 and 5% in Model 2; “CC offers the ability to use and access cloud tools and data anywhere” (*percieved_ease_of_use2*) has high coefficients for both models (71% at 5% for Model 1, 80% at 1% for Model 2); and “Implementing CC necessitates negligible learning time for all employees” (*percieved_ease_of_use3*), which was only significant (at the 10% level) in Model 1.

These results suggest that to be classified as Hyper Transformational, firms need to pay attention to the ubiquity of CC services, and a high level of adaptation of their human capital (with marginal costs). This suggests that high-quality CC services goes hand in hand with high-quality human capital. These are very complementary, intangible, organizational assets for firms with this profile.

The technological dimension

Two variables were statistically significant. The first is “CC can easily be integrated into our existing IT infrastructure” (compatibility3). The shift from “Disagree” to “Fully agree” leads to a 43% negative probability of a company being Hyper Transformational (Model 1, at the 10% level). This unexpected finding means that Hyper Transformational profile is not associated with the straightforward integration of CC into legacy infrastructure. The second is, “Transfer of current system to cloud is too complex” (complexity3), which is positively associated with a 22.6% probability of being Hyper Transformational.

The organizational dimension

Neither of the management support variables were significant for the Hyper Transformational group. With respect to resources, the variables “Our firm has a budget that is sufficient to develop CC technology” (*adequate_res3*) and “CC facilitates the development of a ‘shadow’ IT department” (*adequate_res5*) were statistically significant. The marginal effects of these two variables are 0.813 and 0.549 respectively, suggesting that for the management dimension a unit change in these variables leads to an increase in the probability of the event by about 81.3% and 54.9% respectively.

The environmental dimension

Vendor support variables were not significant in either model. With respect to competitive pressures, the variable "Our firm thinks that CC has an influence on competition in its industry" (*competive_pressure1*) was significant in both models at the 1% level, which is a relatively high coefficient. Change in these variables increases the event probability by 0.632 and 0.641 respectively in both models. The second variable, "Our firm is under pressure from competitors to adopt CC" (*competive_pressure2*), is significant at the 10% level, but only in Model 1. The relationship is negative with an event probability of 0.337. This means that although Hyper Transformational firms are insensitive to competitive pressures, they are probably the first movers in CC programs.

2.3.8 Application to hypotheses

The results presented above provide a foundation for a discussion of the validity of our models and hypotheses. Table 9 summarizes the main results for Transformational and Hyper Transformational groups and allows us to draw several conclusions with respect to our hypotheses.

[Appendix Table 9]

The human dimension

The results support hypotheses H1 and H2 for both groups. H1 ("Perceived usefulness increases the likelihood of organizational transformation due to CC") is supported by the variable "Tasks are accomplished more efficiently with CC" (*perceived_usefulness1*). This means that to be classified as Transformational or Hyper Transformational, a firm needs to use CC to improve task efficiency. Here, perceived usefulness is understood as the usefulness of CC in accomplishing tasks more efficiently.

H2 ("Perceived ease of use increases the likelihood of organizational transformation due to CC") is also supported for both groups, but with slightly different scope. Two variables were statistically significant for both groups, "CC allows a good internet connection and speed of cloud services" and "CC allows the ability to use and access cloud tools and data anywhere". This means that to be Transformational or Hyper Transformational, a firm needs to make effective use of their internet connection, and benefit from the speed and the ubiquity of access offered by CC. For the Hyper Transformational group, a third variable was also statistically significant, "The implementation of CC necessitates negligible learning time for all employees" (*perceived_ease_of_use3*). This means that for Hyper Transformational group, the ability of employees to learn is an important factor in digital transformation.

The technological dimension

H3 ("Complexity decreases the likelihood of organizational transformation due to CC") is supported, but by different variables in the two groups. For the Transformational group, the variable "We fully understand the conditions of data use in the cloud" (*complexity6*) is statistically significant, while the same is true for the Hyper Transformational group for the variable "transfer of current systems to cloud computing platform is too complex" (*complexity3*). This means that the conditions of data use are particularly relevant for the Transformational group, while transfer issues dominate for the Hyper Transformational group. From the technological point of view, both dimensions are critical for digitization.

Similarly, H4 ("Compatibility increases the likelihood of organizational transformation due to CC") is supported, but again, by different variables in the two groups: The loose less of applications is important for the transformational group whereas the easiness of integration into existing infrastructure is important for the hyper transformational one.

The organizational dimension

Here, the findings were again mixed. Only H5 ("Top management support increases the likelihood of organizational transformation based on CC") is supported for the Transformational group for the variable "The company's top management is willing to take risks in the adoption of CC" (*management_sup2*), while it is rejected for the Hyper Transformational group. This means that for the first group the involvement of the top management, especially with regard to risk, is essential, while this is not the case for the Hyper Transformational group. This could suggest that risk-taking is already embedded in Hyper Transformational firms.

H6 ("Adequate resources increase the likelihood of organizational transformation based on CC") is supported: budgetary aspects are important for the two groups. One further variable is to be considered for the hyper transformational group: the facilitation of the development of a shadow IT department.

The environmental dimension

For H7 ("Vendor support increases the likelihood of organizational transformation based on CC"), the null hypothesis cannot be rejected for either group. This means that vendor support does not impact the likelihood of being Transformational or Hyper Transformational. It appears that companies do not need to rely on vendor support as a condition for their digital transformation.

H8 ("Government policy increases the likelihood of organizational transformation based on CC") is supported for the Transformational group for the variable "The government encourages firms to apply CC technology" (*policy1*), while the null hypothesis cannot be rejected for the Hyper Transformational group. This attests to the importance of governance policy for Transformational but not Hyper Transformational companies.

H9 ("Competitive pressure increases the likelihood of of organizational transformation based on CC") is supported by the variable "The firm thinks that CC has an influence on competition in its industry" (competive_pressure1) for both groups. This attests to the role of CC as a competitive lever and in value creation, and highlights its importance as a strategic resource.

2.4 Discussion

Our research seeks to contribute to the literature on the role of digital transformation in value creation, notably by considering the contribution of CC to the organizational dimension. We develop a hybrid theoretical model that links adoption theories of IT artifacts and organizational fit theory. This hybridization allows us to characterize the transformational nature of CC and its determining factors. The research contributes to the emerging literature on the digitization of firms and organizational design.

2.4.1 Contributions to IS research

Hybridization of theories. Several scholars have called for the hybridization of theories, in order to understand the mechanisms underlying the adoption of digital artifacts (Venkatesh et al.2016). In line with these arguments, we developed a unified model that articulates elements of three established approaches: TOE and TAM (for input variables) and organizational fit theory (for output variables). This model allows us to explain the transformational nature of CC. To the best of our knowledge, this is the first study to make the link between these three models, thereby going beyond the general approach to adoption found in IS research. The model and its results expand upon research that sees organizational capital as a complement to investment in IT artifacts (Brynjolfsson, Hitt, & Yang, 2002).

Digitization and digital transformation. Bharadwaj et al. (2013) considered CC to be a key digital trend, and called for a renewal of digital business strategy based on four axes: its scope; its scale; the speed of decision-making; and as a source of value creation and capture. While these scholars consider CC as an external factor, our research suggests that it is also a source of value creation and capture, notably from the perspective of organizational design and fit. Specifically, our research contributes to the characterization of the digital transformation by identifying its key factors: functionality, data management, roles and competences, control, and culture, together with its four determining dimensions: human, technological, organizational and environmental. A second contribution is modelling value capture based on CC. Our work suggests that CC is more than a driving external factor; it is a transformational factor that should be embedded into firms' digital strategies.

Research into CC adoption. The adoption of IT technology has been a major field of research in IS, especially around the TAM model and its variations. For CC in particular, several researchers have considered the issue of adoption from various angles, including: the determinants of CC adoption in industries and services (Oliveira, Thomas, & Espadanal, 2014), the issue of risk (August, Niculescu, & Shin, 2014), the evaluation of specific components of CC (Lee, Park, & Lim, 2013), organizational design (Choudhary & Vithayathil, 2013), and dynamic capabilities (Lyer & Henderson, 2010, Battleson, et al., 2015). Our research contributes to the emerging field of research into CC adoption by examining the determining factors in four dimensions (human, technological, organizational and environmental), and analyzing their respective and relative importance for transformation. It therefore goes beyond the issue of adoption, and makes a bridge with another important issue in IS research: digital transformation.

Organizational fit/ capital. The research field of organizational design is undergoing a metamorphosis due to the ubiquity of digital technology. The question of organizational fit (Burton & Borge, 2004; Stroing & Volfoff, 2010; Soh, Kien, & Tay-Yap, 2000; Vankatraman, 1989) has been studied in IS research notably in terms of enterprise systems. In particular, Soh, Kien, and Tay-Yap (2000) proposed a taxonomy of misfits divided into several dimensions, including data and functions. Our research builds on this taxonomy and adapts it to the CC context. Furthermore, it provides the foundations for the identification and characterization of the key variables in organizational transformation. Our research indicates that these dimensions are key components of a company's organizational capital and complement CC as an IT artifact (Brynjolfsson, Hitt, & Yang, 2002; Lev & Radhakrishnan, 2003).

2.4.2 Managerial implications

Our research provides a framework for understanding the determinants of organizational transformation due to CC. For companies that seek to become Transformational or even Hyper Transformational, it indicates the key, determining factors. With respect to the human dimension, it shows the importance of perceived usefulness and perceived ease of use, notably with respect to the efficiency of CC and ubiquity of access. For the technological dimension, it highlights the importance of having a clear understanding of the conditions of data use (especially for large enterprises), and the fact that applications should be loosely coupled and independent. In terms of organizational aspects, top management support is important (at least for Transformational companies) as is having adequate resources (with respect to the budget (for the Transformational group), and a 'shadow' IT department (for the Hyper Transformational group). Finally, for the environmental dimension, vendor support appears as having no impact on becoming either Transformational or Hyper Transformational. Competitive pressure is another determining factor, while government policy is only somewhat important.

2.4.3 Limitations and future directions

While our study provides an overview of CC adoption factors and dimensions of organizational fit, there are some specific limitations. The first relates to the fact that the conclusions are based on survey data that mainly addresses the organizational dimension of CC. Further research should focus on other dimensions of value creation, such as products, services, and digital business models. Another limitation is related to the technology, in particular the CC architecture. It would be interesting to identify the determinants of different CC technologies. Finally, country effects were only seen for Japan (for the Transformational group) and Italy (for the Hyper Transformational group). It would be interesting to document country-level specificities in more detail.

2.5 Conclusion

Our research developed a framework for characterizing the organizational transformation of firms due to CC and identified its main determining factors. It proposes a hybrid model that articulates three models found in IS research: the TAM and TOE (for independent variables), and the organizational fit model (for the dependent variable). The model was used to develop nine hypotheses divided into four dimensions: human, technology, organizational and environmental. This research supplements previous work on CC adoption, and extends it to organizational fit. The results contribute to the emerging field of digitization and the transformation of companies by digital artifacts.

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Appendix

Figure 1: Research model and hypotheses

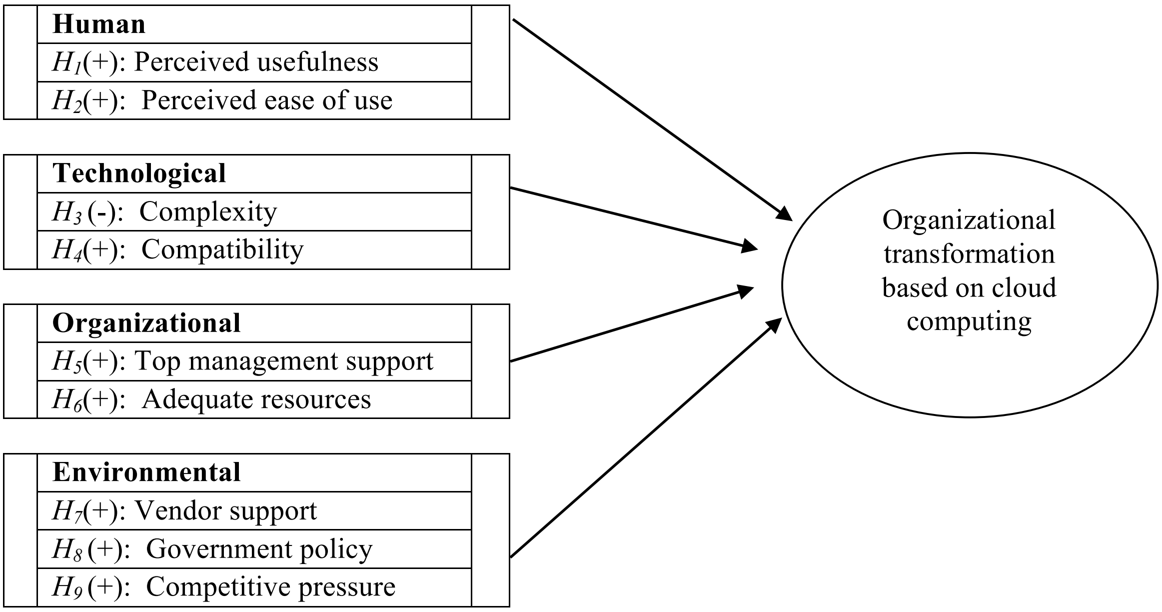

Table 1: A summary of the CC literature.

Article	Framework	Constructs			
		Technology	Organization	Environment	Human
Lin & Chen (2012)	DOI	√			
Wu (2011)	TAM	√			√
Abdollahzadehgan et al. (2013)	TOE	√	√	√	
Lee et al. (2013)	PEST	√		√	
Low, Chen & Wu (2011)	TOE	√	√	√	
Hsu et al. (2014)	TOE	√	√	√	
Lian et al. (2014)	TOE	√	√	√	
Nkhoma & Dang (2013)	TOE	√	√	√	
Che Hussin et al. (2013)	TOE	√	√	√	
Alshamaila et al. (2013)	TOE	√	√	√	
Lee, Park & Lim (2013)	PEST	√		√	
Safari et al. (2015)	TOE	√			
Hsu, Ray, & Li-Hsieh (2014)	TOE	√	√	√	
Wu et al. (2013)	DOI	√			
Oliveira et al. (2014)	TOE/DOI	√	√	√	
Borgman et al. (2013)	TOE	√	√	√	
Cegielski et al. (2012)	TOE	√	√	√	

Table 2: Variables used to measure transformation due to CC

Functionality
1. Access to services (SLA)
2. Operations/processes
3. Interoperability & standards (including between cloud providers)
4. Services liability
5. Reversibility, migration from one system to another
6. Control of tasks and services deliverable
7. Agility
8. Procurement
9. Cost
Data management
1. Data access
2. Data localization
3. Data security
4. Data compatibility
5. Bandwidth
6. Data ownership & IPRs
7. Services reports & delivery
Competences
1. Clarity of roles (who does what)
2. Availability of internal competences
3. Balance of competences (internal vs external)
4. Alignment of competences and formal roles
5. Bottlenecks in tasks and workloads
Control
1. Control of tasks
2. Services delivery
3. Task coordination (internal versus cloud providers)
4. Contractual arrangements
5. Managing contractual risks
Culture
1. Formal rules and standards of behavior (formal execution and coordination of tasks, reporting mechanisms)
2. Informal rules and standards of behavior (informal coordination of tasks, reporting mechanisms)
3. Development of cloud culture

Table 3: Survey questions and variables grouped into four dimensions (human, technological, management, and environmental).

Human	
Perceived usefulness	
perceived_usefulness1	Compared to current technologies, cloud computing enables us to accomplish our tasks more efficiently
perceived_usefulness2	Cloud computing technology will help us to reduce our operational, maintenance, updating and training costs
perceived_usefulness3	Cloud computing will contribute to the agility of the enterprise
Perceived ease of use	
perceived_ease_of_use1	Cloud computing allows a good internet connection and speed of cloud services
perceived_ease_of_use2	Cloud computing allows the ability to use and access cloud tools and data anywhere
perceived_ease_of_use3	Implementing cloud computing necessitates negligible learning time for all employees
Technological	
Compatibility	
compatibility1	Cloud computing technology is compatible with our current practices
compatibility2	Cloud computing technology is compatible with our firm's core values and goals
compatibility3	Cloud computing can easily be integrated into our existing IT infrastructure
compatibility4	Our applications are loosely coupled and independent
Complexity	
complexity1	Cloud computing is too complex for business operations
complexity2	The skills needed to adopt cloud computing are too complex for the firm's employees
complexity3	Transfer current systems to a cloud computing platform is too complex
complexity4	Uncertainty about the location of data limits the use of cloud computing services
complexity5	The risk of a security breach limits the use of cloud computing services
complexity6	We fully understand the conditions of data use in the cloud (terms of use, local regulations, etc.)
Management	
Top management support	
management_sup1	The company's top management provides strong leadership and engages in the process when it comes to information systems
management_sup2	The company's top management is willing to take risks in the adoption of cloud computing
Adequate resources	
adequate_res1	Our firm has enough resources to support the development of cloud computing technology
adequate_res2	Our firm has enough time to develop cloud computing technology
adequate_res3	Our firm has a budget that is sufficient to develop cloud computing technology

adequate_res4	Our firm has enough human resources to develop cloud computing technology
adequate_res5	Cloud computing facilitates the development of a "shadow" IT department
Environmental	
Vendor support behaviors	
environment_vend1	The service level agreement (SLA) is guaranteed by the vendor
environment_vend2	The vendor would cooperate in returning my data if I wanted to replace them
environment_vend3	Our firm would receive adequate compensation for a vendor breach of the SLA
environment_vend4	We can easily obtain support from cloud computing vendors during our cloud computing implementation
environment_vend5	We can be trained in cloud computing in appropriate sessions provided by vendors
Government policy	
policy1	The government encourages firms to apply cloud computing
policy2	There are mediating organizations that support enterprises in the implementation of cloud computing
policy3	There are enough regulations to deal with legal challenges related to cloud computing
Competitive pressure	
competitive_pressure1	Our firm thinks that cloud computing has an influence on competition in their industry
competitive_pressure2	Our firm is under pressure from competitors to adopt cloud computing

Table 4: Breakdown of the sample into Transformational and Hyper Transformational groups

	HyperTrans 0 Freq (Percent)	**HyperTrans 1 Freq (Percent)**
Transf 0	215*** (65.35)	
Transf 1	114*** (34.65)	158 (100)
Total	329	158

Significance level: xxxxxx

Table 5: Equality of proportions test between non-Transformational and Transformational groups

Variable	N_T	T	Diff.	(p-value)
size_1_9	0.000	0.000	0.000	
size_10_249	0.181	0.199	-0.017	0.634
size_10_249	0.181	0.199	-0.017	0.634
size_250_4999	0.656	0.618	0.038	0.386
size_5000_etplus	0.163	0.184	-0.021	0.545
sector_manu	0.149	0.081	0.068	0.018**
sector_ICI	0.172	0.173	-0.001	0.984
sector_engin	0.144	0.151	-0.007	0.840
sector_const	0.065	0.055	0.010	0.645
sector_dist	0.070	0.081	-0.011	0.647
sector_finan	0.093	0.165	-0.072	0.020**
sector_ICT	0.149	0.162	-0.013	0.697
sector_public	0.074	0.059	0.016	0.491
sector_other	0.084	0.074	0.010	0.678
percieved_usefulness1	0.465	0.908	-0.443	0.000***
percieved_usefulness2	0.535	0.853	-0.318	0.000***
percieved_usefulness3	0.535	0.919	-0.384	0.000***
percieved_ease_of_use1	0.437	0.871	-0.434	0.000***
percieved_ease_of_use2	0.526	0.912	-0.386	0.000***
percieved_ease_of_use3	0.474	0.805	-0.331	0.000***
compatibility1	0.479	0.890	-0.411	0.000***
compatibility2	0.488	0.897	-0.409	0.000***
compatibility3	0.451	0.871	-0.420	0.000***
compatibility4	0.442	0.790	-0.349	0.000***
complexity1	0.656	0.540	0.115	0.010**
complexity2	0.698	0.544	0.154	0.001***
complexity3	0.670	0.537	0.133	0.003***
complexity4	0.553	0.471	0.083	0.069*
complexity5	0.516	0.438	0.079	0.084*
complexity6	0.530	0.147	0.383	0.000***
management_sup1	0.423	0.882	-0.459	0.000***
management_sup2	0.409	0.853	-0.444	0.000***
adequate_res1	0.465	0.864	-0.399	0.000***
adequate_res2	0.419	0.798	-0.379	0.000***
adequate_res3	0.377	0.849	-0.473	0.000***
adequate_res4	0.442	0.790	-0.349	0.000***
adequate_res5	0.447	0.787	-0.340	0.000***
environment_vend1	0.451	0.835	-0.383	0.000***
environment_vend2	0.400	0.787	-0.387	0.000***
environment_vend3	0.405	0.801	-0.397	0.000***
environment_vend4	0.488	0.886	-0.398	0.000***
environment_vend5	0.507	0.868	-0.361	0.000***
policy1	0.381	0.732	-0.350	0.000***
policy2	0.358	0.750	-0.392	0.000***
policy3	0.367	0.699	-0.331	0.000***
competitive_pressure1	0.377	0.879	-0.502	0.000***
competitive_pressure2	0.405	0.695	-0.290	0.000***

Note: Values correspond to marginal significant effects thresholds.

Significance levels are: * 10%, ** 5%, *** 1%.

Table 6: Equality of proportions test between non-Hyper Transformational and Hyper Transformational groups

Variable	**N_HT**	**HT**	**Diff.**	**(p-value)**
size_1_9	0.000	0.000	0.000	
size_10_249	0.188	0.196	-0.008	0.839
size_10_249	0.188	0.196	-0.008	0.839
size_250_4999	0.644	0.614	0.030	0.515
size_5000_etplus	0.167	0.190	-0.023	0.538
sector_manu	0.128	0.076	0.052	0.089*
sector_ICI	0.155	0.209	-0.054	0.141
sector_engin	0.155	0.133	0.022	0.521
sector_const	0.061	0.057	0.004	0.868
sector_dist	0.073	0.082	-0.009	0.717
sector_finan	0.122	0.158	-0.037	0.266
sector_ICT	0.149	0.171	-0.022	0.533
sector_public	0.079	0.038	0.041	0.087*
sector_other	0.079	0.076	0.003	0.906
percieved_usefulness1	0.593	0.962	-0.369	0.000***
percieved_usefulness2	0.623	0.899	-0.276	0.000***
percieved_usefulness3	0.660	0.937	-0.277	0.000***
percieved_ease_of_use1	0.565	0.918	-0.352	0.000***
percieved_ease_of_use2	0.638	0.956	-0.317	0.000***
percieved_ease_of_use3	0.571	0.842	-0.270	0.000***
compatibility1	0.605	0.924	-0.319	0.000***
compatibility2	0.617	0.924	-0.307	0.000***
compatibility3	0.590	0.886	-0.296	0.000***
compatibility4	0.568	0.778	-0.210	0.000***
complexity1	0.620	0.532	0.088	0.063*
complexity2	0.635	0.563	0.072	0.128
complexity3	0.629	0.525	0.104	0.029**
complexity4	0.529	0.462	0.067	0.168
complexity5	0.483	0.449	0.034	0.484
complexity6	0.407	0.127	0.281	0.000***
management_sup1	0.562	0.924	-0.362	0.000***
management_sup2	0.550	0.880	-0.330	0.000***
adequate_res1	0.593	0.886	-0.293	0.000***
adequate_res2	0.532	0.835	-0.304	0.000***
adequate_res3	0.514	0.905	-0.391	0.000***
adequate_res4	0.541	0.835	-0.294	0.000***
adequate_res5	0.541	0.835	-0.294	0.000***
environment_vend1	0.565	0.873	-0.308	0.000***
environment_vend2	0.514	0.829	-0.315	0.000***
environment_vend3	0.520	0.848	-0.328	0.000***
environment_vend4	0.623	0.892	-0.269	0.000***
environment_vend5	0.611	0.911	-0.300	0.000***
policy1	0.498	0.741	-0.242	0.000***
policy2	0.483	0.772	-0.289	0.000***
policy3	0.468	0.728	-0.260	0.000***
competitive_pressure1	0.532	0.918	-0.386	0.000***
competitive _pressure2	0.508	0.690	-0.182	0.000***

Note: Values correspond to marginal significant effects thresholds.
Significance levels are: * 10%, ** 5%, *** 1%.

Table 7. Marginal effects for Models 1 and 2 for the Transformational group (dependent variable is at least 14 positive changes)

Variable	Model 1 Marginal effects	Model 2
percieved_usefulness1	0.425	0.356
	(0.225)+	(0.233)
percieved_usefulness2	-0.106	-0.142
	(0.196)	(0.207)
percieved_usefulness3	0.187	0.254
	(0.225)	(0.235)
percieved_ease_of_use1	0.347	0.482
	(0.207)+	(0.217)*
percieved_ease_of_use2	0.390	0.459
	(0.219)+	(0.232)*
percieved_ease_of_use3	0.221	0.132
	(0.192)	(0.201)
compatibility1	0.086	0.128
	(0.236)	(0.249)
compatibility2	0.186	0.254
	(0.224)	(0.242)
compatibility3	0.086	0.115
	(0.208)	(0.216)
compatibility4	0.407	0.396
	(0.198)*	(0.207)+
complexity1	0.253	0.264
	(0.215)	(0.226)
complexity2	0.293	0.201
	(0.199)	(0.206)
complexity3	0.070	0.059
	(0.193)	(0.202)
complexity4	0.082	0.040
	(0.207)	(0.217)
complexity5	0.160	0.134
	(0.189)	(0.198)
complexity6	-0.431	-0.312
	(0.199)*	(0.212)
management_sup1	0.271	0.359
	(0.208)	(0.222)
management_sup2	0.563	0.575
	(0.204)**	(0.215)**
adequate_res1	0.033	-0.038
	(0.211)	(0.221)
adequate_res2	-0.053	-0.166
	(0.201)	(0.213)
adequate_res3	0.581	0.574
	(0.184)**	(0.191)**
adequate_res4	-0.206	-0.126
	(0.204)	(0.210)
adequate_res5	0.199	0.132

	(0.194)	(0.204)
environment_vend1	-0.319	-0.339
	(0.234)	(0.244)
environment_vend2	-0.161	-0.108
	(0.210)	(0.222)
environment_vend3	0.082	0.050
	(0.195)	(0.204)
environment_vend4	0.093	0.020
	(0.219)	(0.234)
environment_vend5	-0.051	0.032
	(0.206)	(0.216)
policy1	0.368	0.355
	(0.192)+	(0.203)+
policy2	0.308	0.274
	(0.188)	(0.198)
policy3	-0.229	-0.159
	(0.195)	(0.208)
competitive_pressure1	0.681	0.752
	(0.189)**	(0.207)**
competitive_pressure2	-0.157	-0.070
	(0.199)	(0.211)
FR		0.145
		(0.293)
UK		-0.144
		(0.271)
GER		0.247
		(0.293)
IT		1.138
		(0.312)**
JAP		-0.154
		(0.296)
USA		0.488
		(0.302)
_cons	-3.109	-3.531
	(0.404)**	(0.482)**
N	487	487
Log Likelihood LL0	-334.22	-334.22
Log Likelihood LL	-187.56	-174.39

Significance levels are: + $p<0.1$; * $p<0.05$; ** $p<0.01$

Table 8. Marginal effects for Models 1 and 2 for the Hyper Transformational group (dependent variable is 50% positive change in each dimension)

Variable	**Model 1** **Marginal effects**	**Model 2**
percieved_usefulness1	0.853 (0.298)**	0.862 (0.309)**
percieved_usefulness2	0.212 (0.225)	0.213 (0.233)
percieved_usefulness3	0.008 (0.269)	0.067 (0.277)
percieved_ease_of_use1	0.419 (0.246)+	0.509 (0.258)*
percieved_ease_of_use2	0.717 (0.284)*	0.803 (0.302)**
percieved_ease_of_use3	0.438 (0.207)*	0.351 (0.214)
compatibility1	0.072 (0.297)	0.071 (0.309)
compatibility2	-0.072 (0.263)	0.027 (0.279)
compatibility3	-0.436 (0.256)+	-0.463 (0.265)+
compatibility4	-0.014 (0.208)	-0.019 (0.215)
complexity1	0.082 (0.237)	0.084 (0.250)
complexity2	0.555 (0.226)*	0.607 (0.234)**
complexity3	-0.115 (0.211)	-0.173 (0.218)
complexity4	-0.342 (0.244)	-0.376 (0.251)
complexity5	0.240 (0.206)	0.273 (0.213)
complexity6	-0.252 (0.216)	-0.176 (0.227)
management_sup1	0.263 (0.259)	0.361 (0.270)
management_sup2	0.258 (0.227)	0.170 (0.237)
adequate_res1	-0.181 (0.252)	-0.193 (0.261)
adequate_res2	-0.149 (0.214)	-0.244 (0.222)
adequate_res3	0.813 (0.226)**	0.824 (0.230)**
adequate_res4	0.036 (0.217)	0.093 (0.224)
adequate_res5	0.549	0.426

	(0.211)**	(0.219)+
environment_vend1	-0.108	-0.079
	(0.249)	(0.255)
environment_vend2	0.120	0.115
	(0.216)	(0.224)
environment_vend3	0.217	0.212
	(0.210)	(0.218)
environment_vend4	-0.281	-0.307
	(0.257)	(0.266)
environment_vend5	0.154	0.162
	(0.247)	(0.254)
policy1	0.047	0.057
	(0.201)	(0.210)
policy2	0.079	0.132
	(0.197)	(0.202)
policy3	-0.217	-0.181
	(0.196)	(0.204)
competitive _pressure1	0.632	0.641
	(0.225)**	(0.238)**
competitive _pressure2	-0.337	-0.196
	(0.198)+	(0.206)
FR		0.395
		(0.277)
UK		0.155
		(0.263)
GER		0.012
		(0.285)
IT		0.832
		(0.271)**
JAP		-0.102
		(0.314)
USA		0.652
		(0.257)*
_cons	-3.918	-4.500
	(0.482)**	(0.571)**
N	487	487
Log Likelihood LL0	-306.89	-306.89
Log Likelihood LL	-208.94	-199.76

Significance levels: + p<0.1; * p<0.05; ** p<0.01

Table 9: Summary of results

Dimensions/ Hypotheses	Transformational group	Hyper Transformational group
Human		
H1 Perceived usefulness increases the likelihood of organizational transformation due to CC.	**The null hypothesis is rejected** for 1 variable out of 3: "CC enables us to accomplish our tasks more efficiently" (*perceived_usefulness1*)	**The null hypothesis is rejected** for 1 variable out of 3: "CC enables us to accomplish our tasks more efficiently" (*perceived_usefulness1*)
H2 Perceived ease of use increases the increases the likelihood of organizational transformation due to CC.	**The null hypothesis is rejected** for 2 variables out of 3: "CC allows good internet connection and speed of cloud services" (*perceived_ease_of_use1*) and "CC allows the ability to use and access cloud tools and data anywhere" (*perceived_ease_of_use2*)	**The null hypothesis is rejected** for all 3 variables: "CC allows good internet connection and speed of cloud services "(*perceived_ease_of_use1*), "CC allows the ability to use and access cloud tools and data anywhere" (*perceived_ease_of_use2*), and "Implementing CC necessitates negligible learning time for all employees" (*perceived_ease_of_use3*).
Technological		
H3 Complexity decreases the likelihood of organizational transformation due to CC.	**The null hypothesis is rejected** for 1 variable out of 6: "We fully understand the conditions of data use in the cloud" (*complexity6*)	**The null hypothesis is rejected** for 1 variable out of 6: "The skills needed to adopt CC are too complex for the firms' employees" (*complexity2*)
H4 Compatibility increases the likelihood of organizational transformation due to CC.	**The null hypothesis is rejected** for 1 variable out of 4: "Our applications are loosely coupled and independent" (*compatibility4*)	**The null hypothesis is rejected** for 1 variable out of 4: "CC can easily be integrated into the firms' existing IT infrastructure" (*compatibility3*)
Organizational		
H5 Top management support increases the likelihood of organizational transformation due to CC.	**The null hypothesis is rejected** for 1 variable out of 2: "The company's top management is willing to take risks in the adoption of CC" (*management_sup2*)	**The null hypothesis cannot be rejected**
H6 Adequate resources increase the likelihood of organizational transformation due to CC.	**The null hypothesis is rejected** for 1 variable out of 5: "The firm has a budget that is sufficient to develop CC technology" (*adequate_res3*)	**The null hypothesis is rejected** for 2 variables out of 5: "The firm has a budget that is sufficient to develop CC technology" (*adequate_res3*) and "CC facilitates the development of a 'shadow' IT department" (*adequate_res5*)
Environmental		

H7 Vendor support increases the likelihood of organizational transformation due to CC.	**The null hypothesis cannot be rejected**	**The null hypothesis cannot be rejected**
H8 Government policy increases the likelihood of organizational transformation due to CC.	**The null hypothesis is rejected** for 1 variable out of 2: "The government encourages firms to apply CC technology" (*policy1*).	**The null hypothesis cannot be rejected**
H9 Competition increases the likelihood of organizational transformation due to CC.	**The null hypothesis is rejected** for 1 variable out of 2:"Our firm thinks that CC has an influence on competition in its industry" (*competitive_pressure1*)	**The null hypothesis is rejected** for 1 variable out of 2: "The firm thinks that CC has an influence on competition in its industry" (*competitive _pressure1*)

Chapter 3

Cloud Computing Adoption: A Rule-based Modeling

Xiaolin Cheng, Alessandro Solimando, Ahmed Bounfour, Emmanuel Waller

3.1 Introduction

Cloud computing has drawn significant attention from IS and IT industry and academic researchers in recent years. It is currently directing business towards utility computing by transforming PCs into terminals. However, there is no universal definition of cloud computing. For the purpose of our study, we use the most generally accepted definition of NIST (Mell and Grance, 2001): "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models."

As indicated in (Mell and Grance, 2001), cloud computing distributes three different services: Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS). SaaS provides the supplier's applications running on a cloud infrastructure; PaaS provides a plateform to deploy infrastructure or to create acquired applications using programming languages; IaaS provides storage, networks and fundamental computing resources to deploy and run arbitrary software. SaaS is the most popularly used cloud service due to its ease of use. On the contratry, PaaS and IaaS need relatively IT knowledge to operate and manage platform and infrastructure. Besides SaaS, PaaS and IaaS, Container as a Service (CaaS) has become the fourth important cloud service. CaaS is a type of container–based cloud service in which provides engines and compute resources.

Xiaolin Cheng, Alessandro Solimando, Ahmed Bounfour, Emmanuel Waller, "Cloud computing adoption: a rule-based modelling", presented in ICC 2017, The second international conference on internet of things, data and cloud computing, Cambridge, 22/23 March, 2017

Cloud services are based on different deployment models: public cloud, private cloud, hybrid cloud and community cloud. Public cloud is open for the general public, it can be managed and operated by any organizations, so there will be an issue of data privacy. However, private cloud is used just by a single organization which can be provided private espaces for critical data. Community cloud provides services for a specific community of organizations. They share the common network, storage and computing services that can be operated and managed by one or more of the community members. Hybrid cloud is a combination of different deployment cloud models (public, private and community), it provides more agility and stability compared to other mentioned models.

NIST definition makes an appropriate background for our research, since it defined a framework of different cloud services and deployment models. The different deployment models are defined from the perspective of cloud users, it depends if it is open for the public personals or organizations. If we define them from the perspective of manager of cloud resources, cloud computing will be divided into internal cloud and external cloud. One firm is fully in charge of used cloud resources, it is internal cloud. The cloud resources is ensured by a cloud service provider, it is external cloud. The combination of the two types of deployment models: internal private cloud, external private cloud, internal public cloud and external public cloud is our research objective.

Cloud Computing is no longer a buzzword, it's a strategy, a business model, and a set of technologies. It offers a vast opportunity for organizations and enterprises to improve the flexibility of their business models (Accenture, 2012). Consequently, it would appear that these organizations would find it very easy to migrate to cloud computing. However, in practice, the debate rages regarding cloud adoption (Khajeh-Hosseini et al., 2010). Earlier research works of cloud computing adoption focused on identifying decision factors or testing the impact of a predefined set of factors. This paper contributes to provider a guideline for selecting appropriate cloud services and cloud deployment models by designing a set of dimensions covering technical and economic factors: stable dimension, relatively stable dimension and variable dimension for positioning firms with respect to their pretention of cloud computing adoption.

The remainder of the paper is organized as follows. Section 2 contributes to the literature review and research question. In Section 3, we propose a research model and describe fundamental rules. To validate our research model, we introduce a survey and indicate some analysis results in Section 4. Finally, in Section 5, we discuss our research findings and limitations, and indicate some future research design.

3.2 Research Background

Cloud computing adoption is a complex phenomenon with a variety of opportunities and challenges, yet cloud computing research is still in its early days. Much of the current literature focuses on its benefits and risks, organizational case studies of cloud adoption and cloud computing architectures (Bhattacherjee and Park, 2013). Specifically, on business decisions about cloud computing, it mainly focuses on identifying determinants impacting cloud computing adoption and testing the impact of a predefined set of factors on the intention to adopt cloud (Oliveira et al. 2014). This section realized a detailed analysis of the literature on cloud computing adoption.

Theoretical background

Cloud computing adoption research generally based on some different theories. The Technology Acceptance Model (TAM) (Davis, 1989) was the first attempt to develop an overall approach to the issue of adoption in the domain of IS (Barki, 2007; Eze et al., 2011; Silva, 2007). The model considers perceived usefulness (PU) and perceived ease of use (PEOU) as the key determinants of the adoption of information technology. Despite its widespread diffusion and implementation in IS research, the model suffers from the narrow focus only on two main dimensions, while other use factors are ignored. Other research has extended the scope of the analysis and added other dimensions: the Technology, Organization and Environment (TOE) framework is a notable example (Awa, H.O. & Vkoha, and O. 2012). The TOE framework identifies various influential factors in the innovation adoption process (Tornatzky & Klein, 1982), it is the most popularly used approach in the research of cloud computing adoption domain. Diffusion of Innovation (DOI) theory was developed by Rogers (Rogers, 1995), it deals with five attributes: relative advantage, compatibility, complexity, triability and observability. Diffusion of innovation occurs when the new ideas or technologies spread to the organizations.

Research themes

Existing research has made a great progress for the understanding of cloud computing adoption phenomenon. Lero and Kieran addressed the complex and multifaceted nature of cloud computing adoption drawing on three different case studies of providers and their customers (Lero and Kieran, 2013). Their findings reveal that factors impacting cloud adoption tend to be psychological and technical. (Asatiani, 2015) identified 43 relative factors with cloud computing adoption and classified them using Technology-Organization-Environment (TOE) framework. In addition, the author analyzed both quantitative and qualitative evidence between decision factors and cloud adoption. This review contributed to both cloud providers and organizations. (Low et al. 2011) tackled the cloud computing adoption problems using TOE framework and indicated that more different industries should be considered in order to better understand the influences of environmental and organizational factors on cloud computing adoption.

Besides the aforementioned cloud computing adoption research, several research has improved the understanding of cloud computing adoption phenomenon by segmenting the cloud computing characteristics from the perspective of firm sizes, specific sectors, different cloud services and models. Some research considered especially on certain size firms, (Safari et al. 2015), (Gupta et al. 2013), (Lian et al. 2014) on SMEs and (Repschlaeger et al. 2013) on startups. Some research focused on specific sectors, (Oliveira et al. 2014) on manufacturing and services sectors, (Lian et al. 2014) on hospitals. (Oliveira et al., 2014) developed a research model integrating the theory of the Diffusion of Innovation (DOI) and TOE. This model was evaluated based on 369 Portugal firms and their findings show that relative advantage, complexity, technological readiness, top management support, and firm size influence the adoption of cloud computing. Some papers addressed on specific cloud services, (Benlian and Hess, 2011) and (Lee et al. 2013) on SaaS, and (Naldi and Mastroeni, 2014) on IaaS. Naldi and Mastroeni proposed a methodological approach to the comparison of cloud versus in-house solutions, it is based on an assessment of the direct economic impact of migration to the cloud.

(Hsu et al. 2014) is the single paper that we found to deal with the adoption of different pricing models: pay-as-you-go; one-time license and monthly plan, and different deployment models: private cloud and public cloud. The authors alleged that perceived benefits, business concerns, and IT capability influence the intention of cloud computing adoption and external pressure is not a significant factor. Business concerns has an important impact on the choice of deployment models due to the security issues of cloud computing, since firms need a private space for some critical data. And the choice of pricing models depends on the IT capacity of firms. Generally, a higher IT capacity firm will choose pay-as-you-go payment for the flexibility.

This paper was well structured, yet there are some limitations. For example, the authors just considered four principal decision factors for the cloud computing adoption and use the same factors to discuss the adoption of different pricing models and deployment models, it's a lack of consideration of specific characteristics of the two types cloud models. Another issue is about the deployment models, based on the definition of NIST (Mell and Grance, 2001), deployment model is divided into 4 sub-models: private model, public model, community model and hybrid model. But the authors just considered private and public two models.

Research design

This literature review helped us to understand the background for cloud computing adoption and related research. Early studies on cloud computing adoption tend to be skewed toward benefits and challenges, yet in spite of some segmentation efforts, actually there is a lack of research framework focusing on the adoption of cloud services and cloud deployment models. The strategies of cloud computing is very different from traditional IT strategies. There is a need to discuss how to select cloud services and cloud deployment models. Consequently, we designed the following research question: *How do firms select cloud services and deployment models?*

To bridge the research gap in the domain of cloud computing adoption, we proposed a research model of cloud computing adoption considering three dimensions: stable dimension, relatively stable dimension and variable dimension. Different from the traditional adoption theories, our research addresses the problem of proposing a set of dimensions for positioning enterprises with respect to their pretension for adopting cloud technology, providing also a guideline on the SPI stack level for different situations.

The general interest in a single taxonomy contrasts with the complexity of the different dimensions guiding cloud adoption in practice. We advocate that identified dimensions are orthogonal, this therefore makes the clustering of such dimensions, at the basis of the development of a comprehensive taxonomy, an extremely difficult task. The orthogonality of the dimensions makes the space of possible configurations practically equivalent to the product of all the possible values for the aforementioned dimensions.

For this reason, we consider as more appropriate a set of dimensions that should be used as fuzzy rules, allowing for the co-existence of dimensions in contrast between them, with respect to their indication. The suggestions provided by these rules can be combined and reconciled with known techniques dealing with contrasting outcomes, such as voting algorithms.

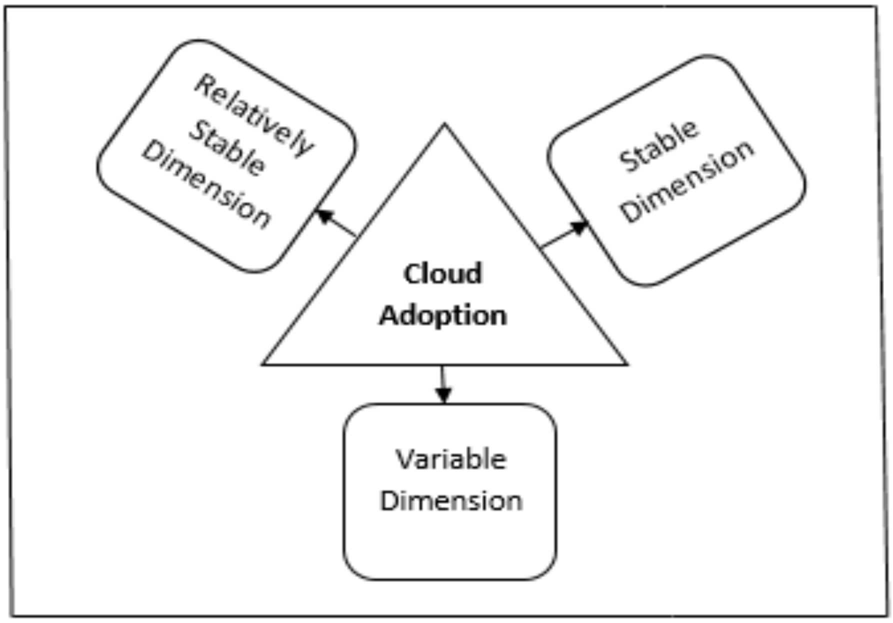

Figure 1. Cloud Adoption Dimensions

3.3 Research model

Rule-based Formalism

In this section we introduce the rule-based formalism that will be used in the reminder of the paper. The general form of the rules we consider is as follows:

$$A_0 \wedge \ldots \wedge A_n \rightarrow B_0 / \ldots / B_m \wedge \ldots \wedge C_0 / \ldots / C_m$$

The A_i elements compose the body of the rule, and they serve as the precondition necessary for applying the rule. When $n > 1$, all the conjuncts A_i must be true for the rule to be applicable (i.e., the $\wedge$ operator is a logical conjunction). The B_i and C_j elements, if any, compose instead the head of the rule, and can be seen as the logical consequence of the body.

The symbol "/" separates different possible alternatives for the same conjunct, and is only used for compacting multiple rules into a single one. For instance, the rule $A \rightarrow B_0/B_1 \wedge C_0/C_1$ is simply a short-hand for the following rules:

$$A \rightarrow B_0 \wedge C_0$$

$$A \rightarrow B_0 \wedge C_1$$

$$A \rightarrow B_1 \wedge C_0$$

$$A \rightarrow B_1 \wedge C_1$$

Finally, head elements can also be negated, such as in “A → no B”, meaning that from the truth of A we can derive that B will be false. There are several dimensions, intermixing technical, economic and organizational factors that can be considered for suggesting if cloud computing adoption is appropriate or not, given the characteristics of a given enterprise.

One source of complexity comes from the inherently variable nature of some of these aspects, during the life of the organization itself and its evolution. For this reason, the positioning is not always fixed, but might vary over time. The first macro-categorization is therefore among stable, relatively stable and variable dimensions.

A. Stable dimensions

Stable dimensions are usually tightly related to the company’s inner-nature.

A.1 Firm size

In general, small companies tend not to have an IT department at all, or a much reduced one, and extremely limited hardware resources, therefore the natural target are SaaS services. Medium-sized enterprises could target public cloud or internal solutions, possibly based on the same technologies used in cloud computing, such as virtualization, but in a less structured and coordinated way, due to the expectably reduced know how, hardware and human-time that can be devoted to the administration and tuning of a cloud datacenter. Solutions ranging from SaaS to PaaS can be appropriate for enterprises falling into this category.

Big enterprises can possibly run hybrid cloud solutions, or fully internal ones. If they already fully rely on external IT service providers, they can also opt for SaaS services, while it is more frequent that they would require services at the PaaS and IaaS level, in order to achieve higher configurability and gaining more control over their software applications. Usually, enterprises of this size have the resources for complementing any lack preventing the cloud computing technologies adoption, but they take higher risks when redesigning or adapting IT services that are crucial for the core business.

The financial resources typically available in big enterprise, however, might allow to run in parallel different solutions and minimize in this way the risk of a failure of one of the alternatives. This option is rarely viable for medium-sized enterprises, and practically inexistent for small ones.

A.2 Location(s) of the enterprise

The physical location of a company imposes different restrictions related to geographical factors such as the problem of cooling a local datacenter (strongly influenced by the climatic conditions of the geographical area), economic factors and availability of adequate services (e.g., the cost of electricity and availability of sufficient power to run the specific datacenter), to legal restrictions (e.g., data privacy laws) etc.

Therefore, the location could influence the feasibility and sustainability of internal cloud datacenters. Additionally, disparity in terms of resources and/or services (such as adequate bandwidth and speed for the broadband networking) might affect the possibility of adopting some specific cloud services, if some of the final users does not match the minimal requirements for the cloud service of interest.

Consider, for instance, an enterprise with retail shops in different geographical areas and countries, with different availabilities in terms of networking infrastructures. If some of the core tasks of the retail shops (like inventory or orders to the enterprise's warehouses) cannot be performed offline, but must access an application located remotely, this might cause unacceptable service disruptions.

Another example are videos and music played in retail shops. In such a scenario, limitations in the bandwidth in a subset of the shops would prevent the reproduction of the multimedia files using a cloud-based streaming service (very convenient for favoring centralization and control by the marketing department, which can remotely enforce the content to be displayed, the audio level and other settings in a uniform way for all the shops).
Concluding, on one hand, multiple locations might provide better alternatives for placing a private cloud service, but disparity in terms of resources might prevent the adoption of remote solutions.

A.3 confidentiality and security

The focus here is on the extent to which the organization's functioning is based on data which must be kept private and/or is security-sensitive and thus the company is reluctant to share or ship it to a cloud service. Having only data that can be publicly shared reduces the problem to economic and technical factors.

When, instead, data is mainly private, or extremely confidential (e.g., medical records), the issues related to data security and privacy become prominent. SLA and QoS are fundamental to assess the compatibility with the requirements imposed by data privacy laws. For private data, a natural choice is the use of private and internal datacenters. In presence of a mix of private and public data, instead, a hybrid solution can be envisioned. If the data can be easily split between the two categorization, there are no further technical details to consider. However, in some cases, this partitioning can be only achieved by means of complex technical solutions, requiring an effort and know-how that is not always available.

It is true that some of these dimensions could vary in time, but we advocate that in such cases, while the company is formerly the same, the underpinning change transformed it so drastically that the result can be seen as a different entity from practical point of view (e.g., the growth of a small/medium enterprise up to the level of a large multi-national enterprise).

A summary of the aforementioned dimensions, expressed using the rule-based formalism introduced is provided in Table 1.

Dimension	Description	Rules
A.1	Enterprise size	Small Enterprise → SaaS/PaaS Medium Enterprise → PaaS/CaaS/IaaS Big Enterprise → PaaS/CaaS/IaaS
A.2	Location(s) of enterprise	Location Cheap with Services → Internal cloud Location Expensive with Services → External cloud Location no Services → No cloud
A.3	Confidentiality and security	Public Data → Cloud Private Data → Internal cloud Mixed Data → Hybrid cloud

Table 1: Decision rules associated to the stable dimensions

B. Relatively Stable Dimensions

Among the relatively stable dimensions we have the ones defining the company's profile.

B.1 IT effort:

This dimension aims at covering the initial level of commitment, in terms of financial resources and effort. On one extreme, there are enterprises which cannot (or prefer not to) invest in designing and implementing durable and scalable solutions that usually involves a substantial initial investment. On the other extreme, there are enterprises which consider the IT infrastructure as strategic, and they are willing to invest resources in research and development (R&D), or simply in the realization of performant and reliable solutions.

If the initial investment is substantial, the full spectrum of solutions is available: building and running a private datacenter, redesigning all the IT infrastructure in order to exploit, totally or partially, cloud services (internal or external), and any possible intermediate configuration. If the initial investment is reduced, and does not cover the expenses for equipping the enterprise with the needed hardware, software or IT staff, a mixture of outsourcing and the employ of external cloud services can be conceived, in order to cope with the needs of the enterprise.

This is a typical setting for nowadays small-medium enterprises (SMEs), for which the increasing need of IT solutions (from the website and e-commerce platforms, to email accounts etc.), with the corresponding required know-how, does not always match the financial constraints of the enterprise itself. Even in enterprises with higher financial resources, a limited initial investment can be dictated by the business plan, in order to limit financial losses when dealing with high risk projects. The capital can be invested for the development of the service, and for an initial attempt to run it, and decide how to proceed based on the outcome.

B.2 Horizon for improvements in the IT infrastructure

Durable and scalable solutions, as discussed in B.1, require a substantial investment, with benefits in medium or, even more frequently, long term. Cloud computing, in general, helps reducing the effort of developing high-quality IT artefacts, compared to traditional programming and computing paradigms. This comes from the inherent characteristics of cloud computing that are, in turn, inherited from that of Service-Oriented Architecture (SOA), which has been conceived as a technical solution to enhance modularity and reuse across different softwares and users. Therefore, in cloud computing, it is extremely natural to design software which complies with the highest quality standards in software development.

As a rule of thumb, durable solutions require a high level of customization, which is hardly achievable when relying on providers of SaaS. This follows from the observation that, despite a certain level of configurability of the system, its level of abstraction does not allow to target all the possible needs that can be very specific. For this reason, custom solution relying on PaaS (or even IaaS), are more advisable. At the opposite range of the spectrum, when a temporary solution is acceptable, the closest approximation to the enterprise's needs, among the products of the different SaaS providers, could be preferable, in order to cut also time and effort in the achievement of the required service.

B.3 Level of IT know-how

Orthogonal to the dimension above, here the stress is on the capability of understanding in-depth technical design, evaluating competing technologies, foreseeing risks and advantages deriving by technical alternatives. For instance, on one extreme one might have an expert IT manager being able to take informed decisions on extremely technical aspects while practically having no IT department at all. On the other, the IT department can be present, but having an extremely specialized know-how that does not include some specific aspect of interest, such as cloud computing.

From a technological perspective, the higher the level of abstraction in the SPI stack, the lower the requirements in terms of human resources and know-how for the IT staff in order to adopt and use the solution. However, despite it is true that SaaS is conceptually and practically less complex than IaaS and PaaS, at least from the user perspective, this is not necessarily true in terms of evaluating both the appropriateness of a particular solution for the business needs, and the compatibility of the novel cloud service with existing soft- wares and data storages.

The real challenge is to precisely evaluate the organizational and technical impact of adopting one particular solution, given the unique situation that characterizes each different enterprise. For instance, in presence of a high level of standardization in the formats used by the IT artefacts and their manipulation procedures, a migration to cloud-based solutions, at any appropriate level of the SPI stack, which are compatible with those standards (either directly, or by means of converters) does not represent a problem, and the migration could be operated quite easily.

The choice between internal and external cloud solutions is again not the main focus here, because in both cases what cannot be handled directly by the IT staff of the enterprise, it can be outsourced, but even the technically easiest option might have an impact which is difficult to predict beforehand. In summary, excluding situations in which the level of standardization is very high and the impact of adopting cloud-based solutions is trivial to foresee, a high level of IT know-how about cloud computing and any technology in use in the enterprise ecosystem is strongly recommended. If not present inside the enterprise itself, such knowledge can be obtained by means of an IT consulting company.
A summary of the aforementioned dimensions by means of rules is provided in Table 2.

Dimension	Description	Rules
B.1	IT effort	High → PaaS/CaaS/IaaS Low → SaaS
B.2	Horizon for improvements in the IT infrastructure	Long → SaaS/PaaS/CaaS/IaaS Medium → SaaS/PaaS/CaaS Short → SaaS
B.3	Level of IT know-how	Low Knowledge→ SaaS Medium Knowledge→ SaaS/PaaS/CaaS High Knowledge→ SaaS/PaaS/CaaS/IaaS

Table 2: Decision rules associated to the relatively-stable dimensions

C. Variable Dimensions

Variable dimensions are those related to the kind of data analysis and usage the enterprise is performing.

C.1 Volume and/or fraction of private data

The level of privacy for stored data and/or data produced as output by means of a query or data processing strongly guides in the adoption of cloud computing services. As already discussed in A.7, a high level of data confidentiality favors the use of private and internal cloud infrastructures. Independently from privacy concerns, high data volumes can pose problems to data transfer in case of remote services, while can be generally coped with more effectively when high-speed local networks are employed (the case of a datacenter hosted inside the enterprise's premises).

However, despite possible high volumes of data, if the private fraction (raw or derived through computations) is limited, hybrid solutions can be envisioned, in order to process internally only the confidential fraction of the data. But when the fraction of private data is significant (i.e., it corresponds almost to the overall quantity of data to process), the coordination effort for the hybrid solution is not worth, and again the natural solution is the use of internal resources.

C.2 Data processing flow

Different data processing flows impose different needs, we review the most frequent ones, trying to derive general guidelines for other different services:

Data analysis: modern data analysis techniques are mainly based on statistical machine learning. Machine Learning (ML) approaches usually require significant data volumes for building the predictive models (supervised learning), some of them might require heavy algebraic computations, and are usually computationally demanding.

Data integration/aggregation: if the integration or aggregations tasks involve only internal data, this does not necessarily require cloud computing, if not needed for massive volumes of data or other contingent aspects. Instead, if data is coming from multiple sources, and could or should be consumed also by third-parties, data sharing is extremely easier when performed on top of a public cloud service, which usually provides a mechanism for supporting access from multiple clients.

Business Intelligence (BI) and Reports: these tasks are usually composed by heavy analytical workloads, which requires a tight interaction with the user, and possibly unknown patterns of interaction, which are decided live by the user, depending on the answers to previous queries and the goal of the exploratory analysis itself. BI analyses are usually performed by means of data warehousing technologies, where replicas of the data to analyze are created, in a format that is more convenient for the analytical processing, with respect to the transactional platform which originated the data. Several challenges are posed to analytical workload in the cloud, such as the extremely high volume of data, that is exacerbated by the required replicas (which implies higher usage, and therefore higher cost), the high volume of data to be exchanged during the analysis (possibly problematic when the exchange is through the Internet), and the requirement of integrating many different data sources for creating the unified data warehouse (not always exposed externally). All these challenges are clearly mitigated when an internal solution is employed.

Business-to-Clients and E-commerce: this task can be generally placed inside the broad categorization of transactional workloads, where relatively contained delays can be acceptable, and the amount of exchanged information is usually limited, and most of the processing load can be performed remotely. This task is generally well compatible also with external cloud. Moreover, given that many basic services exploited by e-commerce platforms are extremely standardized (e.g., credit card transaction systems), it is not uncommon that they can be already available inside the computing platform proposed by the cloud provider (reuse is favored by cloud computing, as already in SOA).

C.3 Fault-tolerance and high-availability

If on the one hand, one of the major points for cloud computing adoption is exactly the increase of system availability and tolerance to faults (given the higher resources that big cloud providers can afford with respect to most enterprises, and similarly for the expertise that such providers have), on the other hand are exactly these needs that are usually posing concerns for (external and public) cloud adoption.

If high-availability is a strong requirement for an enterprise, it is usually favorable that the same enterprise has full control over critical tasks, for which fault-tolerance is a must. If such tasks are delegated to third-party service providers, the already mentioned problems in case of outages might occur (lack of transparency, clash in the outages management between the customer and the service provider etc.). For this reason, externally managed cloud service should be employed for tasks that are not critical, while keeping a direct control over those for which high-availability is a must. Again, hybrid solutions can be used for amortizing the expenses of managing an internal datacenter, and reduce it to the minimum.

A summary of the aforementioned dimensions by means of rules is provided in Table 3.

Dimension	**Description**	**Rules**
C.1	Volume and/or fraction of private data	no Privacy → cloud Privacy → no cloud Privacy→ Internal cloud
C.2	Data processing flow	Data Analysis → cloud Data Integration → cloud Business Intelligence → Internal cloud B2C/E-Commerce → cloud
C.3	Fault-tolerance and high-availability	High ∧ Critical Tasks → Internal cloud High ∧ no Critical Tasks → cloud High ∧ Mixed Tasks → Hybrid cloud Low ∧ Critical Tasks → Internal cloud Low ∧ Critical Tasks → no cloud

Table 3: Decision rules associated to the variable dimension

3.4 Data and validation

The objective of our research work is to evaluate IT capacity and cloud computing needs of firms, and to help them to select appropriate services and deployment models. We introduce a survey and report some descriptive statistics and data analysis in this section in order to characterize our proposed dimensions in this paper. Also, based on our research model and analysis results, we discussed the current cloud strategy of French firms and offered some propositions for their future adoption of cloud computing.

Data

To test our research model, a survey was developed. This survey forms part of the Cloud Based Organization Designs (CBOD) project, supported by the French National Research Agency http://www.cbod.u-psud.fr/. IT managers and Chief Information Officers or equivalent role were targeted to respond the questionnaire. We considered this type of audience as the most appropriate for responding to our survey since they are usually the leading decision makers for technology adoption. This survey was distributed in France via a service provider Lightspeed GMI. Total of 60 responses were collected, 40 of them were valid. The available response rate of the respondents was 66.7%. The aforementioned sept dimensions disclosed different aspects of cloud computing practices and addressed our core research objectives. Our sampling focused on the firms that have adopted cloud computing and it was composed by 10 SMEs (10-249 employees), 23 medium enterprises (250-4999 employees) and 7 big enterprises (5000+ employees), more than 50% of respondents are from medium enterprises.

Measurement and validation

In our research model, three adoption dimensions and nine attributes were created based on the previous research. This sub-section contributes to the description of the measurement and the validation of our research model.

- Stable dimension

  A.1 Table 4 tells us that, for SaaS and PaaS, different sizes enterprises have a relatively consistent adoption rate. Big enterprises have a higher adoption rate of IaaS than small and medium enterprises. It is consistent with the rule A.1 about cloud services. We also found an interesting result in the chart, it's about the CaaS adoption. No small enterprises adopted CaaS and medium enterprises selected more CaaS than big enterprises. How to explain this situation? CaaS is a container-based service positioning between PaaS and IaaS, it provides compute resources by using a subset of IaaS. Therefore, CaaS is ease of use without installing infrastructure and charged less than IaaS, that's why medium enterprises selected CaaS rather than IaaS. However, for big enterprises, they have sufficient IT capacity to operate IaaS, so they selected IaaS directly.

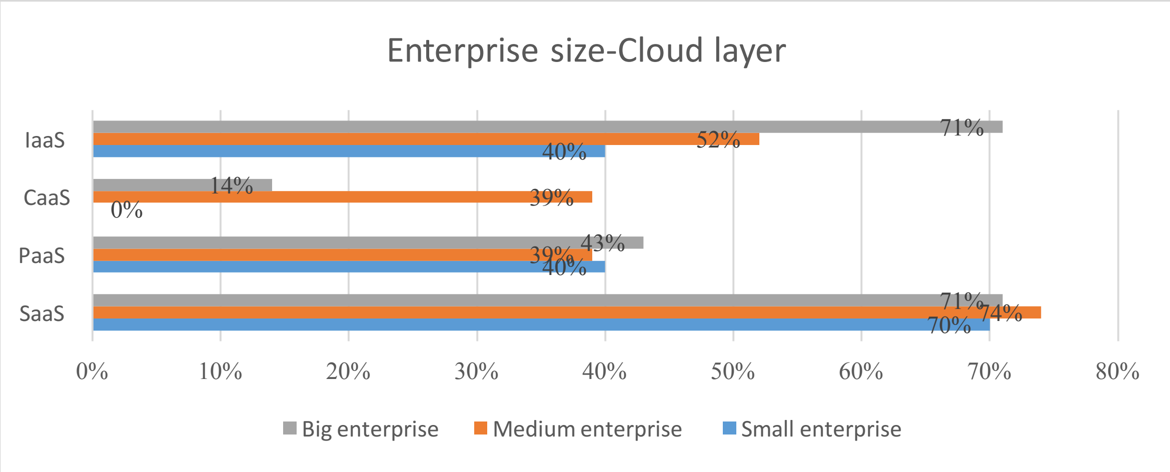

Table 4. Enterprise size-Cloud layer

From Table 5, we can find that big enterprises adopted more hybrid models. Yet, small enterprises have a higher internal private adoption rate than medium and big enterprises, big enterprises selected more external private models than medium enterprises. Therefore, there is not a significant relation between enterprise size and cloud deployment models, therefore the rule of A.1 about deployment model is not confirmed.

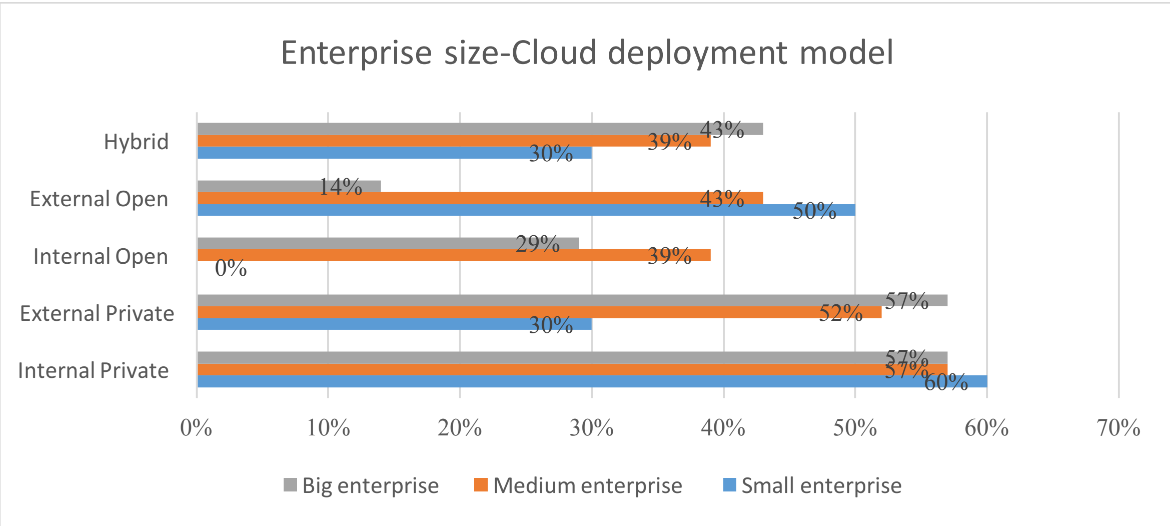

Table 5. Enterprise size - Cloud deployment model

The enterprises who adopt internal models generally need some private space for their critical data. And critical data is generally related with some specific sectors. Therefore, we suppose that the adoption of internal models is influenced by the different types of sectors. Our analysis result confirms our hypotheses ($p=0.008<0.01$), the influence is quite significant. That is, the higher level of privacy required, the more adoption opportunities of internal private models. Therefore the type of sector is an important factor that impacts the adoption of cloud deployment models.

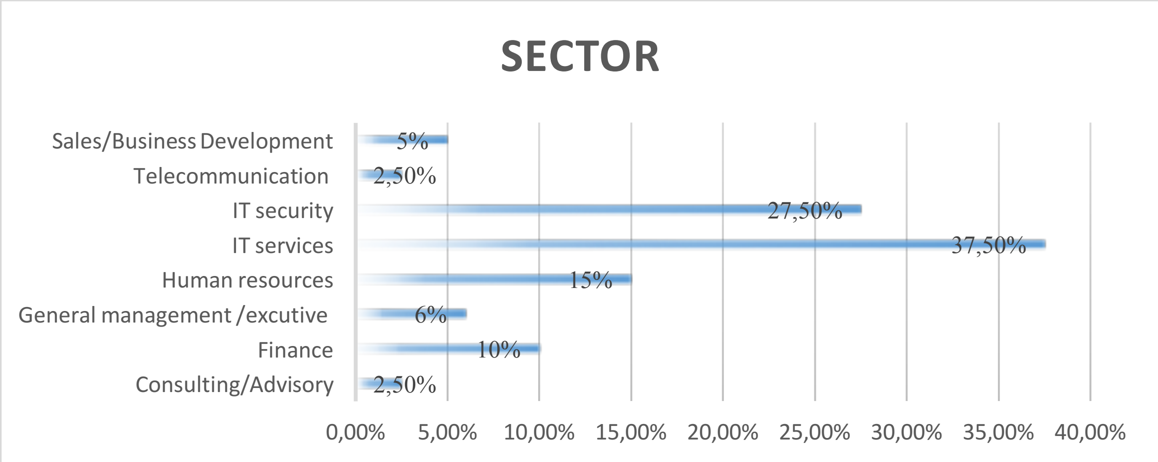

Table 6. Sector

A.2 The target enterprises of our survey are all in France. To test the influence of the enterprise location on cloud computing adoption, we have compared cloud service prices of American market, Asian market and European market. Because of the popularity of cloud computing in France, there are numerous low-cost cloud providers, such as OVH, Cloudwatt, Numergy and Ikoula. We found that they have better performance in price than the other providers. That is, French enterprises locate in the area with cheap cloud services. From Table 5, we found that French enterprises adopted more internal cloud services than external cloud services. So this result confirms our rule A2: enterprises located in the area with low price of cloud services prefer to adopt internal cloud services.

A.3 Viewing the rule A3 about confidentiality and security, we couldn't get the information about the volume of public data, private data and hybrid data of the enterprises by the survey. However, we have tried to track this challenge by considering data from the perspective of sectors. The results of the survey indicate that most of the finance and IT security sectors have adopted external private or external private cloud based on their IT capacity due to the substantial volume of private data. However, for IT services and sales sectors, they selected more public cloud services than private because of the ease of use and no privacy issue of their data.

From the aforementioned analysis, we can find that the rule A.1 in the stable dimension is not valid, the rules A.2 and A.3 are valid. The rule A.1 contributes to analyse the influence of enterprise size on cloud services and deployment models. Unfortunately the latter is not valid, and through the analysis, we can conclude that the adoption of deployment models relates to the different sectors.

Rule	Description	Validation
A.1	Enterprise size	No
A.2	Location of enterprise	Yes
A.3	Confidentiality and security	Yes

Table 7. Stable dimension validation

- Relatively stable dimension

B.1-B.3 Three rules are defined in the relatively stable dimension, IT effort, horizon for improvements in the IT infrastructure and level of IT know-how. To test the validation of these attributes, we have designed some items in our survey.

Relatively stable dimension rules	Measurement items
IT effort	Percentage of cloud budget in the total IT budget
Horizon for improvements in the IT	The overall IT budget of the past three years
IT know-how	The decision-maker's personal experience

Table 8. Relatively stable dimension measurement

IT effort is measured by the percentage of cloud budget in the total IT budget of 2015, it's an index about the level of investment of enterprise in IT development. Horizon for improvements in the IT infrastructure is determined by the overall IT budget of the past three years (increase, remain stable or decrease) that describes the durable and substantial of investment. IT know-how is evaluated by the decision-maker's personal experience (less than 1 year, 1-3 years, 4-5 years and more than 5 years) in cloud computing. The personal experience of cloud computing represents relatively the level of cloud computing know-how.

	IT effort	Horizon for improvements	IT know-how
IaaS	0.459**	0.247	0.187*
PaaS	0.453**	0.298	-0.167
CaaS	0.244	0.420*	0.323***
SaaS	0.451*	0.402**	-0.192*

*P<0.1 **p<0.05 ***p<0.01 Table 9. Relatively stable dimension analysis

We consider the influence is significant if $p<0.1$ as described in (Hsu et al. 2014). Table 10 indicates that IaaS is influenced by the IT effort and IT know-how. From the survey, we can find that all the decision-makers with 1-3 years of cloud computing experience adopted SaaS, PaaS and CaaS yet no IaaS, most of the participants with more than 5 years' experience have used IaaS. As the table described, PaaS is not impacted by the IT know-how, because PaaS is easier to install and operate than IaaS. CaaS is influenced significantly by the IT know-how ($p<0.01$), we inferred that CaaS is a new type cloud service, there is no definition and introduction in the document of NIST, the adoption of CaaS needs a higher knowledge of cloud computing to manage and operate. SaaS is generally the first step of cloud computing adoption, therefore it is impacted by all the three mentioned relatively stable rules. After the analysis of different rules in the relatively stable dimension, we can conclude that all the three rules B.1, B.2 and B.3 are valid.

Rule	**Description**	**Validation**
B.1	IT effort	Yes
B.2	Horizon for improvements	Yes
B.3	IT know-how	Yes

Table 10. Relatively stable dimension validation

- Variable dimension

C.1-C.3 Variable dimension is about the data analysis and business concerns, such as the volume of private data, data processing flow, fault tolerance and high-availability. As it is defined, it is a dimension about variable rules, it's quite difficult to quantify them. In the stable dimension, as indicated in the discussion of the rule A.3, we considered private and public data from the perspective of sectors. In this dimension, we have used the same technique to analyse the relation between different variable rules and cloud computing adoption.

For data processing flow, business intelligence is an interesting subject. How to use big data and key information to output an effective dashboard for the decision-makers has become more and more important. Most of the data used for analysing is about the strategy of enterprise, therefore all the operations are in the internal cloud environment. Finally, it's about fault-tolerance and high-availability, adoption of different deployment models depends on the critical level of tasks proceeded by the enterprises. Anyway, we consider these three variable rules C.1, C.2 and C.3 are valid qualitatively, we can't do a detailed quantitative analysis of this dimension because of a lack of relative supported data. We will focus on this issue in the future research.

Rule	**Description**	**Validation**
C.1	Volume and/or fraction of private data	Yes
C.2	Data processing flow	Yes
C.3	Fault-tolerance and high availability	Yes

Table 11. Variable dimension validation

3.5 Discussion and conclusion

This paper was motivated by the need to address cloud adoption theories. The objective of traditional adoption theories is to make the decision of adoption using different technological, organizational and environmental factors. In our research, we presented a rule-based decision model with different dimensions: stable dimension, relatively stable dimension and variable dimension for guiding in the positioning of enterprises with respect to cloud computing adoption. The aim of this rule-based model is to verify firms' cloud strategy and to help them choose appropriate cloud services and cloud deployment models.

First, we advocate here for a rule-based model, asserting the difficulty in grouping these patterns into a single taxonomy, due to the inner nature of the characteristics of cloud computing adoption. Moreover, in order to validate our assumptions, and to show how to apply the suggested rules in practice, we have designed a survey to collect firms' information. Furthermore, this study made a detailed analysis of different firms' cloud strategy.

The analysis results reveal that internal private deployment model and SaaS were the most commonly used cloud deployment model and service in French firms. Internal private model guaranty the security of privacy data, however, this type of model charge a lot. To solve the data security challenge and reduce the cost, we can try to move to external private model if cloud providers could offer guaranteed services. We also found that some large firms also considered SaaS as the first step when they intend to move to cloud computing, because it is the easiest service to use and manage since it is based on software.

Our research seek to contribute to the literature of cloud commuting adoption. Providing a different dimensions based model for cloud computing adoption is one of the most important contributions to IS research and cloud computing adoption theories development. For enterprises, this model allows us to explain how to make a decision of cloud computing services adoption and cloud deployment models adoption. While our studies provides a comprehensive overview of cloud computing adoption theories and a detailed validation of proposed model, there are some limitations.

Overall, through this paper we have addressed the cloud adoption problem and proposed a new contribution for the technology adoption theories. However, we hold some limitations. Considering the aforementioned rules of different dimensions, most of them are confirmed except A.1 that is about the influence of enterprise size on cloud deployment models. The designed rules of different dimensions were not all measured by the survey, such as the rules in the variable dimension, we did a qualitative analysis to test the validation. Finally, our target surveyed participants were French enterprises, it holds the possibility of impacting the perception of a geographical area. In our future research, we will focus on these issues.

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Chapter 4

Cloud Computing Decision-Making Using a Fuzzy AHP Approach

Xiaolin Cheng

4.1 Introduction

Cloud computing is used as a solution that creates a virtual space for infrastructure, platforms, and software (Pépin, 2013). It has acquired considerable popularity primarily owing to its ease of use. As a result, several providers, including Amazon, Microsoft and Google, have begun to offer this form of technology. According to an analysis by Gartner, cloud computing usage is still growing and will account for the bulk of new IT expenditures by 2020. The most generally accepted definition of cloud computing is provided by the National Institute of Standards and Technology (Mell and Grance, 2001): "*Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models*."

4.1.1 Research background

Cloud computing is primarily described as a model based on virtualization technology and pay-per-use pricing models (Jula, Sundararajan and Othman, 2014). It can manage three layers:

Xiaolin Cheng, "Cloud computing decision-making using a fuzzy AHP approach", published in the journal "Système d'Information et Management". No 4-Vol.20 (2015), 89-116

Infrastructure as a Service (IaaS) programs serve as environments for deploying, running and managing virtual machines and storage products. Technically speaking, IaaS programs offer incremental computing resource scalability (scale up and down) and on-demand storage. In a cloud infrastructure, a user or company client is the master of his virtual environment and can install whatever he sees fit (e.g., virtual servers) configured on demand, making it possible to execute an application. The most representative IaaS products include Amazon EC2, Google Compute Engine and Rackspace.

Platform as a Service (PaaS) systems serve as platforms for developing additional applications, (e.g., the Google App Engine (GAE)). Whereas IaaS systems are primarily concerned with production and operations, PaaS systems are concerned with providing two levels of service: development platforms and applications that provide superior services. PaaS systems allow developers to create frameworks that adapt to their development needs and allow applications to provide execution frameworks will deliver SaaS services. Compared to flourishing SaaS products, PaaS products are more concise. Well known products include Force.com, Google App Engine and Windows Azure Platform.

Software as a Service (SaaS) products provide access to complete applications (e.g., customer relationship management (CRM)). Such products often take the form of application catalogs that are accessible to users. In a model SaaS product, the application is already complete and operational; the focus is not on development but on preferences. For a company, model SaaS cloud products may prove particularly instrumental during prototyping as they allow users, with a short delay and reduced costs, to evaluate solutions without using their own resources. SaaS products were developed before PaaS and IaaS systems were created. Furthermore, related costs of development are very low, and thus in the current market, SaaS products are rich in both in quantity and sophistication. There are a variety of classic products, with the most representative being Google Apps, Salesforce CRM, and Office Web Apps.

Thus, a key challenge that businesses face when evaluating cloud computing services involves selecting those services best suited to their various business needs.

4.1.2 Research framework

Design science seeks to develop technologically-based solutions to important and relevant business problems (Hevner et al., 2004). Amandine Pascal identifies three design-science research cycles—the relevance, design, and rigor cycles—and decision criteria for effective design research (Pascal, 2012). In the present study, we aim to design a decision-making model for selecting appropriate cloud providers from the perspective of design science based on previous studies.

Design is both a process (set of activities) and a product (artifact). March and Smith (1995) identify two design processes and four design artifacts produced via design-science research in IS. The two processes involve building and evaluating, and artifacts include constructs, models, methods, and instantiations. Our design is based on these two design processes and four design artifacts. During the first phase of our study, evaluation criteria on providers were determined. During the second phase, a fuzzy AHP method was used to select the most appropriate providers. Finally, we describe the feasibility of the method.

Based on the Publication Schema for a Design Science Research Study (Gregor and Hevner, 2013), we have divided this paper into six sections. The remainder of the paper is organized as follows. A literature review and analysis are given in the following section. Section 3 describes the structure of the decision model for cloud supplier selection. Section 4 evaluates and analyzes the model in greater detail. Finally, a discussion and conclusion are outlined in sections 5 and 6, respectively. This article contributes a framework that allows cloud users to compare cloud services and that allows cloud suppliers to gradually improve their services. Such a systematic methodology for comparing and rating cloud providers can generate healthy competition between cloud providers.

4.2 Literature review and analysis

Cloud computing represents a new means of outsourcing IT resources. For SaaS products, outsourced resources are application software; for IaaS products, outsourced resources are computing hardware (e.g., servers, storage devices); and for PaaS products, outsourced resources include hardware, development and software hosting platforms. Through a literature review, Stefanie Leimeister found that cloud computing is primarily described as an IT outsourcing model on the basis of virtualization technologies (Leimeister et al., 2010). Benedikt Martens and Frank Teuteberg described cloud computing and IT outsourcing using the same decision model and showed that both provide similar benefits to their users; methods developed for IT outsourcing can also be applied to analyses of cloud computing (Martens, Walterbusch and Teuteberg, 2012). To summarize, the literature on IT outsourcing decisions serves as a background for our research on cloud computing.

Cloud computing research is still in its early stages. Much of the existing literature focuses on benefits and risks associated with cloud computing, on organizational case studies of cloud adoption, and on cloud-computing architecture (Bhattacherjee and Park, 2014). A methodological approach to the comparison of cloud solutions vs. in-house solutions has been proposed based on the direct economic effects of migration on the cloud (Naldi and Mastroeni, 2014). This approach is based on the use of net present values and stochastic models for storage prices and memory needs. The adoption of new technologies (e.g., cloud computing) is a complex phenomenon that is highly ambiguous and that presents a variety of opportunities and challenges (Luoma and Nyberg, 2011). We conducted a detailed analysis of cloud-related decision criteria and decision models. The identified articles are summarized in Table 1.

4.2.1 Research gaps & research questions

During earlier stages of cloud computing development, the primary focus was on technical factors; now, the focus is gradually moving towards a business perspective (Hoberg, Wollersheim and Krcmar, 2012; Son and Lee, 2011). Recently, the number of companies that have adopted cloud computing services has increased. Furthermore, cloud-experienced companies are confronted with various challenges as they must compare several alternatives based on incomplete decision criteria (Martens, Walterbusch and Teuteberg, 2012).

Numerous research results indicate that decisions involved in selecting cloud suppliers have become increasingly important (Aissaoui, Haouari and Hassini, 2007; Li and Wan, 2014). However, cloud provider selection has become a key issue due to the limited transparency of existing cloud services (Godse and Mulik, 2009). It is often difficult to judge the quality of cloud services and to make a decision (Martens, Walterbusch and Teuteberg, 2012). In essence, the selection of top suppliers is always a difficult task for decision-makers due to the growth of cloud computing and owing to the fact that various criteria (e.g., cost and performance) must be considered during the decision-making process. Therefore, cloud customers are faced with the challenge of identifying providers that can satisfy their requirements.

Despite the theoretical and practical need to understand dynamics of appropriate fit between a company and its cloud services providers, this issue has been infrequently studied. Although most existing studies assume that service attributes are independent of one another, in reality, attributes are interdependent (Saripalli and Pingali, 2011). Interdependent relationships between selection criteria are critical to rational decision-making. Based on these gaps in existing research, we seek to address the following research questions:

RQ1: Which attributes drive cloud provider selection?

RQ2: How is the value of each attribute determined?

RQ3: Are selected attributes interdependent?

RQ4: Which algorithm should be applied for ranking purposes?

4.2.2 Identification of criteria

This section shows that the existing cloud-research literature presents a number of partial explanations for factors that affect cloud provider selection. What is missing is an integrated view; such a view would be valuable. This paper contributes to this important topic by synthesizing numerous existing studies and identifying factors to include in and exclude from the model.

Generally speaking, cloud provider selection processes are shaped by various factors. Relevant cloud provider selection criteria presented in previous studies are shown in Table 1. This section synthesizes this literature and presents a preliminary test of a model of key factors that reflect cloud provider selection. We also explain why various features of the model contribute to cloud provider selection.

Table 1 shows that most researchers agree that various criteria are relevant when selecting a vendor. Generally speaking, security and reliability constitute critical challenges for users (Géczy, Izumi and Hasida, 2012; Koehler et al., 2010). Additionally, when using cloud services, it is important to properly manage data and to ensure that a provider offers appropriate support. Nevertheless, costs constitute a relevant decision criterion during provider selection, and agility concerns have been highlighted as the most significant benefit of cloud computing service adoption. Our decision model thus includes four principal factors: cost, risk, agility and quality.

4.2.3 Decision-making methods

Although several methods of decision-making support exist multi-attribute utility theory (MAUT) and the preference ranking organization method for enrichment evaluations (PROMETHEE)), the AHP is the most popular method due to its user friendliness and effectiveness (Lee et al., 2012).

Analysis hierarchy process (AHP)

Saaty developed the AHP model in 1990 to create a systematic approach to solving multi-criteria decision problems (Saaty, 1990). Decision makers can use the AHP to identify priorities and to make structured comparisons between different providers in selecting the most appropriate one (Tam and Tummala, 2001). Additionally, because of its user friendliness and systematic support in identifying and prioritizing relevant criteria, the AHP is easy to apply (Ishizaka, 2014).

When formulating an AHP model, a hierarchical structure can allow individuals or groups of individuals to systematically visualize a problem in terms of relevant criteria and sub-criteria (Tam and Tummala, 2001). Elements of this hierarchy can be divided into groups and are compared pairwise on each hierarchy level. The results are translated into corresponding pairwise comparison judgment matrices, and the eigenvector with the highest eigenvalue is identified. A disadvantage of this approach lies in the fact that the number of pairwise comparisons can become very large (more specifically: n (n-1)/2).

Analytic network process (ANP)

The ANP is an extension of the AHP, and it offers solutions to problems that cannot be structured hierarchically. In an ANP network, criteria and alternatives are arranged in clusters rather than in layers. Arrows between the clusters denote effects among criteria and alternatives. The ANP has become a popular method due to its capacity to manage relationships between decision factors and alternatives.

Multi-attribute utility theory (MAUT)

Unlike the AHP, which focuses on the relative importance of decision criteria through pairwise comparisons, MAUT is based on utility functions. A utility function quantifies the preferences of a decision-maker and aggregates several of a decision-maker's degrees of satisfaction with a particular criterion. However, utility functions are difficult to derive. Rather, numerous utility questions must be posed, and such functions are too subjective as utility levels may change across users.

Fuzzy logic

Appropriate decisions are difficult to make in an uncertain environment when vagueness factors are not considered. Fuzzy logic theory addresses this issue by considering the ambiguous nature of decision-making problems (Zadeh, 1965). A fuzzy set is defined by a membership function through which elements are mapped to a certain interval ([0, 1]). A value of zero shows that an element does not belong to a set, whereas a value of one reflects the complete membership of an element to a set. Other values in the described interval denote a specific degree of membership to a set. Finally, a closeness coefficient for each alternative is defined to rank all alternatives.

Total cost of ownership (TCO)

TCO-based models for supplier choice primarily involve the summarization and quantification of all or several costs associated with the choice of vendors (de Boer, Labro and Morlacchi, 2001). This method and philosophy extends beyond purchasing prices to include several other purchase-related costs. TCO models are further classified by usage, i.e., vendor selection and vendor evaluation. TCO models are limited in that they consider only one decision-factor cost.

Optimization-based approaches for cloud service selection

In the field of service selection, optimization is defined as "finding the most suitable services for clients or providers and thereby maximizing or minimizing one or several criteria while still adhering to the constraints."

Elimination and Choice Translating Reality (ELECTRE)

ELECTRE belongs to a family of outranking methods, which form another category of MCDM methods. It assesses candidates in terms of each criterion and identifies the degree of dominance of one candidate over another. MAUT and outranking methods mainly differ in that the former identifies the best choice, whereas the latter identifies a shortlist of alternatives. The approach can address several conflicting performance criteria. The ELECTRE method is advantageous in that users can conduct another MCDA based on a restricted set of alternatives, thus saving a considerable amount of time.

Preference ranking organization method for enrichment evaluation (PROMETHEE)

The PROMETHEE does not offer structuring capabilities. In cases involving several criteria (more than seven), it may be very difficult for a decision maker to obtain a clear understanding of a problem and to evaluate results. The PROMETHEE offers no specific guidelines on weight determination. In addition, generalized criteria must be defined, and this may pose a challenge for inexperienced users.

Decision-making trial and evaluation laboratory (DEMATEL)

The DEMATEL has been widely used to extract complex problem structures. The DEMATEL allows users to quantitatively extract interrelationships between multiple factors included in a problem.

Linear programming (LP)

Linear programming can be employed to analyze several different areas of life. It serves as a good approach to solving complex problems and is flexible. However, as not all variables are linear, final solutions are often limited and unrealistic expectations arise as a result.

Discrete choice analysis (DCA)

Past research in econometrics, marketing, and in other social sciences shows that DCA serves as an effective methodology for analyzing choices made in complex decision-making situations (e.g., supplier selection). Discrete choice analyses serve as a systematic approach to identifying the relative weights of attributes that a decision maker trades off when making a selection from a possible set of alternatives. This approach is based on the multinomial logit (MNL) econometric model, which uses a maximum likelihood estimation scheme to maximize the probability of an alternative's selection based on given attribute levels. The multinomial logit model is limited in three key ways: it cannot represent random taste variations, it presents restrictive substitution patterns, and it cannot be used with panel data when unobserved factors are correlated over time for each decision maker.

Conclusion

All the above approaches present unique advantages and limitations. Identifying such advantages and limitations is instrumental to the preparation of an efficient ranking system. The purpose of service ranking is to help users evaluate and compare different services so that they can select the most appropriate services that meet their requirements. The key factors that are of relevance to provider selection are presented in Table 1. As is shown, the AHP has been the most common approach used in recent years. However, this approach cannot capture the subjectivity (or fuzziness) of human judgments as verbal assessments are converted into crisp values. Meanwhile, fuzzy logic cannot measure the consistency of judgments provided by a decision maker. The fuzzy analytic hierarchy process (FAHP) constitutes a merger of the two methods that inherits the advantages of both and that therefore addresses the above mentioned problems.

Reference	Factor	Approach	Evaluation
(Ghodsypour and Brien, 1998)	Cost, on-time delivery, quality, capacity	LP and AHP	Simulation
(Verma and Pullman, 1998)	Cost, quality, flexibility (agility), on-time delivery, delivery lead time	DCA	Simulation
(Yang and Huang, 2000)	Cost, strategy, quality, technology, management	AHP	Simulation
(de Almeida, 2001)	Cost, risk	MAUT	Simulation
(de Almeida, 2007)	Cost, dependability, on-time delivery	ELECTRE and MAUT	Simulation
(Araz, Mizrak Ozfirat and Ozkarahan, 2007)	Cost, capacity, quality, flexibility, on-time delivery	FGP and PROMETHEE	Case study
(Yang et al., 2007)	Cost, capacity, risk, quality	AHP	Simulation
(Cao et Wang, 2007)	Cost, quality	Not mentioned	Simulation
(Wang et Yang, 2007)	Cost, resource, strategy, risk, management, quality	AHP and PROMETHEE	Simulation
(Wang, Lin and Huang, 2008)	Cost, risk, quality, environment, strategy	AHP and ELECTRE	Simulation
(Chen and Wang, 2009)	Quality, technology, capacity, flexibility	FV	Simulation
(Li et al., 2010)	Cost, capacity, quality, response time	Not mentioned	Case study
(Martens and Teuteberg, 2012)	Cost, risk	LP	Simulation
(Martens, Walterbusch and Teuteberg, 2012)	Cost	TCO	Case study
(Tajdini and Nazari, 2012)	Cost, political, technology, strategy	AHP	Case study
(Hsu and Liou, 2013)	Cost, on-time delivery, risk, compatibility, quality, flexibility	DEMATEL	Case study
(Li and Wan, 2014)	Cost, quality, technology, flexibility, on-time delivery	FLP	Case study
(Garg, Versteeg and Buyya, 2013)	Cost, agility, accountability, performance, assurance, security,	AHP	Simulation
(Godse and Mulik, 2009)	usability	AHP	Case study
(Ye, Bouguettaya and Zhou, 2012)	Cost, vendor reputation, architecture, functionality, usability	Optimization	Simulation
(Menzel and Ranjan, 2012)	Cost, response time, throughput	ANP	Simulation
	Cost, benefits, opportunities, risk		

Table 1. Decision Factors and Approaches

4.3 Fuzzy AHP decision model

4.3.1 Model description

The fuzzy AHP decision-making approach to supplier selection is based on the multi-criteria AHP decision-making method and on fuzzy set theory. The AHP allows one to derive ratio scales from paired comparisons. Using the AHP, expert opinions and evaluations can be integrated, and a complex problem can be devised into a simple hierarchical system with higher and lower levels. In this work, the AHP is used to calculate weights of each decision factor.

Provider selection often occurs in a fuzzy environment. For example, demand changes occur from one period to another with a probability distribution that is difficult to estimate due to a lack of historic data. Therefore, demand must be characterized as a fuzzy variable. In our decision model, fuzzy set theory is used to rank cloud services. This merger of two methods differs from approaches employed in previous FAHP methods (extent analysis and fuzzy preference programming). As our numerical simulation is based on real datasets, we do not need experts to assess the performance of each supplier.

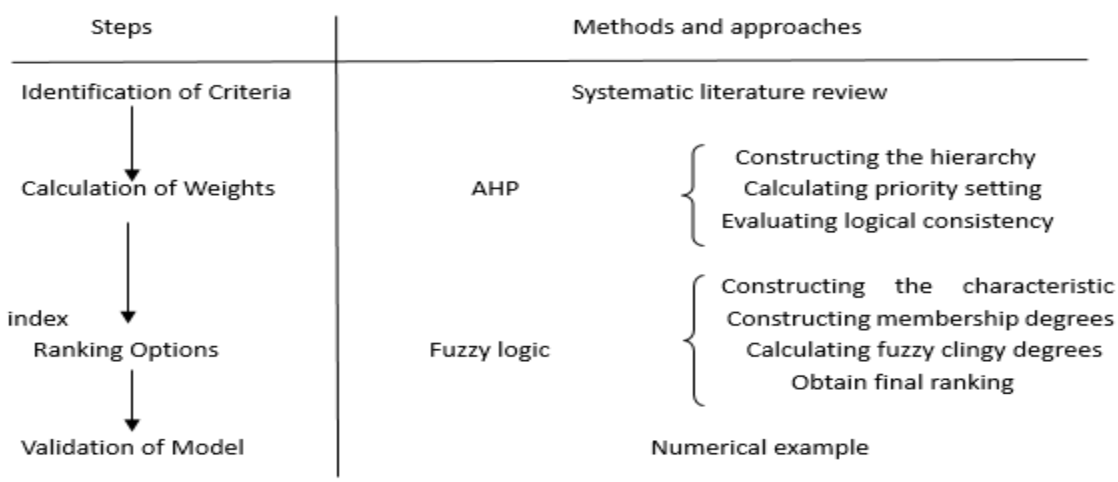

Figure 1. Model description

4.3.2 Hierarchy construction

A complex decision-making problem is structured and decomposed into sub-problems (e.g., sub-objectives, criteria, and alternatives) within a hierarchy. We consider sub-criteria for each main factor.

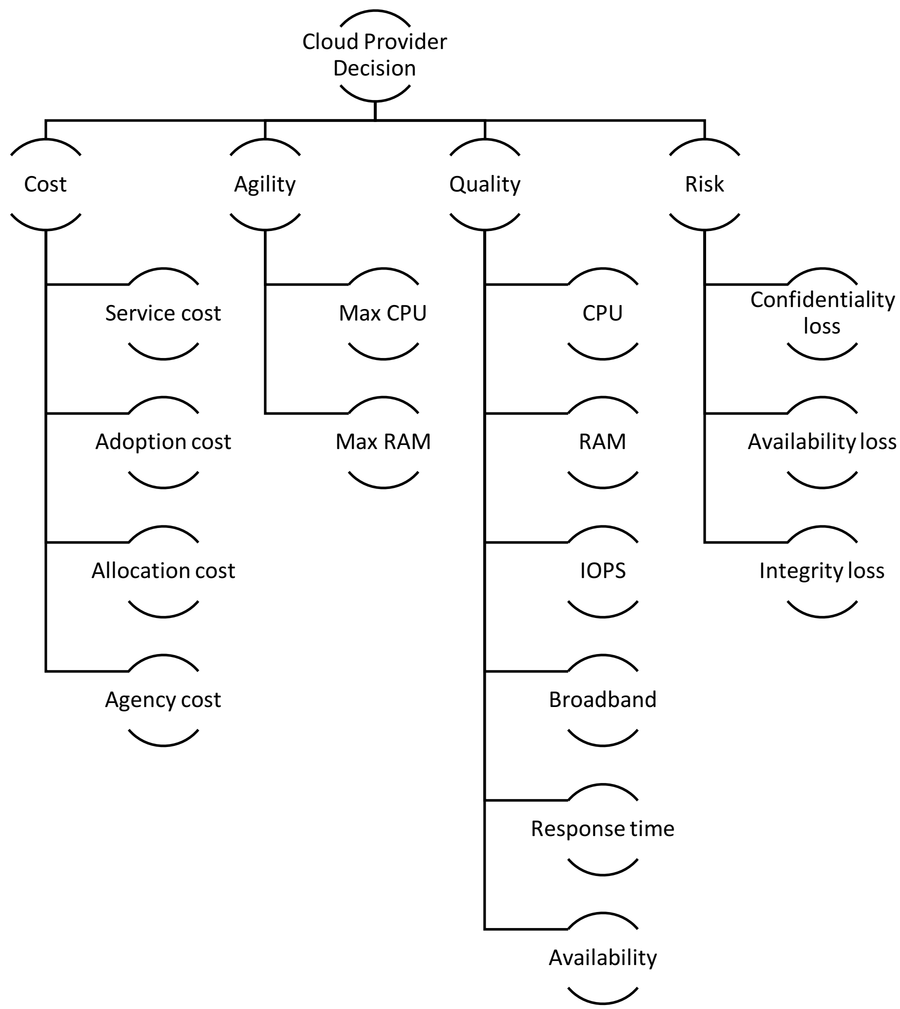

Figure 2. Hierarchy process

Cost - The first question that arises before shifting to cloud computing concerns whether cloud computing is cost effective. Our model makes basic distinctions between cost-oriented factors (service, adoption, allocation and agency costs). Agency costs are incurred via monitoring and performance management. Allocation costs are costs associated with multi-sourcing and provider management. Adoption costs include integration and interoperability costs.

Agility - Agility refers to how quickly new capabilities are integrated into an existing IT system as needed by an organization, and it is measured as a rate-of-change metric. One of the most significant advantages of cloud computing relates to its improvement of operation process agility levels. When considering agility levels, organizations wish to determine whether a service is elastic. Under this category, two sub-criteria—max CPU and max RAM—are considered when measuring the agility of different cloud services.

Quality - One main concern for enterprises that are considering adopting cloud computing relates to potential bottlenecks that can arise from the limitations of their surroundings, e.g., computing resources housed in a cloud provider's data center-processing facilities, memory, virtual machines per physical server, storage architecture, and network bandwidth. In our model, CPU, RAM, IOPS, broadband, availability, and response time are the 6 factors used to measure the quality of cloud services. The response time of an operation pertains to the point at which a client begins the operation to the point at which the last byte reaches the client. Availability refers to period during which a system is functioning and is often described as a mission capable rate.

Risk - Risk is defined as a broad set of policies and technologies deployed to protect data, applications and associated cloud computing infrastructures. It is recognized as one of the most significant barriers to broader cloud adoption. Risks are structured in support of three common security objectives: integrity, confidentiality and availability. A number of security concerns are associated with cloud-computing services (e.g., understanding who owns your data and ensuring that the selected cloud provider offers strong security measures to protect your confidential information).

Criteria	Sub-Criteria	Requirement/Characteristic
Cost	Service cost	Pricing (pay-per-use), licensing costs
	Allocation cost	Multisourcing, Provider management
	Adoption cost	Integration costs, interoperability
	Agency cost	Monitoring costs
Agility	Max CPU	Max CPU per instance
	Max RAM	Max RAM per instance
Quality	CPU	Events per seconds
	RAM	RAM writing speed

	IOPS	4k random write I/O speed
	Broadband	1M sequential write latency
	Availability	Mission capable rate
	Response time	Time from instance begins to byte reaches
Risk	Confidentiality loss	Data protection measures
	Availability loss	Interruption of data availability
	Integrity loss	Undesired data manipulation

Table 2. Requirements for a formal decision model

4.3.3 Calculating priority vectors

The relative importance of each criterion is determined through a pairwise comparison of contributions of each criterion to the hierarchy. AHP multiple pairwise comparisons are based on a scale of nine levels.

Importance Intensity	Description
1	Equal importance of both elements
3	Weak importance of one element over another
5	Strong importance of one element over another
7	Demonstrated importance of one element over another
9	Absolute importance of one element over another
2,4,6,8	Intermediate values between two adjacent judgments

Table 3. Scale of relative importance

C= $\{c_i | i=1, 2, \cdots, n\}$ is the set of criteria. An (n×n) evaluation matrix A can be obtained from the results of a pairwise comparison of n criteria, wherein every element a_{ij} is the quotient of criteria weights

$$A=(a_{ij}), (i, j=1, 2, \cdots, n) \qquad (1)$$

The right eigenvector W corresponding to the largest eigenvector (λ_{max}) refers to relative priorities

$$AW=\lambda_{max} W \qquad (2)$$

When pairwise comparisons are completely consistent, matrix A is ranked 1, and λ_{max}=n. In such cases, we can normalize any row or column of matrix A to obtain all weights.

4.3.4 Evaluating logical consistency

A consistency measure of the given pairwise comparison is needed. Consistency is determined as the relation between entries of matrix A. The consistency index (CI) is defined as

$$CI = (\lambda_{max} - n)/(n-1) \qquad (3)$$

From the final consistency ratio (CR), we can determine whether the evaluations are sufficiently consistent. The CR is calculated as the quotient of the consistency index (CI) and random consistency index (RI).

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 4. Random consistency index

We can evaluate the consistency of decision makers and of an entire hierarchy through consistency measurements. A value of 0.1 denotes the upper limit that we can accept for CR. When the final consistency value exceeds 0.1, the evaluation procedure must be repeated to improve consistency levels.

$$CR = CI / RI \qquad (4)$$

After determining the normalized priority weight of each AHP hierarchy criterion, it is necessary to identify a means of solving cloud-provider selection problems (Tam and Tummala, 2001; Saaty, 1990).

4.3.5 Fuzzy logic

Fuzzy decision theory is employed to resolve human decision-making problem uncertainty. Let P={ p_j |j=1, 2, ···, m} be the set of alternatives and let $W = (\omega_1, \omega_2, \cdots, \omega_m)^T$ be the set of weights of criterion C. $S_{ij} = f(c_{i,} p_j)$ is a characteristic index value of c_i, i=1, 2, ···, and n corresponds to the n criterion. In turn, we obtain an m×n characteristic index matrix.

$$S = \begin{pmatrix} s_{11} & s_{12} & \cdots & s_{1n} \\ s_{21} & s_{22} & \cdots & s_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ s_{m1} & s_{m2} & \cdots & s_{mn} \end{pmatrix} \qquad (5)$$

We assume that all membership functions are linear and are divided into two types:

a. The larger value is better

$$r_{ij}=\begin{cases}1 & s_{ij}>s_{ip}\\ (s_{ij}-s_{if})/(s_{ip}-s_{if}) & s_{if}\le s_{ij}\le s_{ip}\\ 0 & s_{ij}<s_{if}\end{cases} \quad (6)$$

b. The smaller value is better

$$r_{ij}=\begin{cases}0 & s_{ij}>s_{ip}\\ (s_{ip}-s_{ij})/(s_{ip}-s_{if}) & s_{if}\le s_{ij}\le s_{ip}\\ 1 & s_{ij}<s_{if}\end{cases} \quad (7)$$

r_{ij} is the membership function of p_j, j=1, 2, ⋯, m, which corresponds to c_i, i=1, 2, ⋯, n. s_{if} and s_{ip} are the lower and upper limits, respectively. If there is no upper limit, $s_{ip}=\max_{j\in(1,2,\cdots n)} s_{ij}$; if there is no lower limit, $s_{if}=\min_{j\in(1,2,\cdots n)} s_{ij}$.

From functions (6) and (7), we can transform the characteristic index matrix (5) into a membership degree matrix:

$$R=\begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n}\\ r_{21} & r_{22} & \cdots & r_{2n}\\ \cdots & \cdots & \cdots & \cdots\\ r_{m1} & r_{m2} & \cdots & r_{mn}\end{pmatrix} \quad (8)$$

From the maximum membership degree principle, we can obtain the following ideal option:

$$G=(r_{11}\vee r_{21}\vee\cdots\vee r_{m1},\ldots,r_{1n}\vee r_{2n}\vee\cdots\vee r_{mn})^T=(g_1,g_2,\cdots g_n)^T \quad (9)$$

V is a max operation. The fuzzy clingy degree is

$$N(p_{j,}G)=1-D_w(p_{j,}G) \text{ j=1, 2, ⋯, m} \quad (10)$$

Where $D_w(p_{j,}G)$ is the weighted distance. In turn,

$$N(p_{j,}G)=1-\sum_{i=1}^{n} w_i(g_i-r_{ij}) \text{ j=1, 2, ⋯, m} \quad (11)$$

The alternative corresponding to the highest weighted clingy degree is the selected ideal option. The chosen alternative has the shortest possible distance from the ideal option, which is the basic principle of this method. Using method, in the presence of different criteria, rankings can be performed by comparing the measure of closeness to the ideal option.

4.4 Numerical example evaluation

In this section, we present our simulation-based evaluation of the fuzzy AHP approach and describe its benefits to end users. Through this evaluation, we compare cloud providers (i.e., Amazon EC2, Windows Azure, and Numergy), which are domestic and international providers for France's cloud-service market. Criteria and sub-criteria of the proposed decision-making model are introduced and identified based on cloud provider characteristics and we assume that they are independent.

To validate our decision model, we use a large French enterprise as a case and design a questionnaire to collect data for determining the importance of each criterion and sub-criterion instead of calculating the average of various experts' options. We want only to check whether our designed model works well, not to give an official ranking of cloud services. We believe that the ranking of cloud services will vary based on various user requirements. An IT executive was interviewed, and decisions related to each level were discussed using the nine-point scale shown in Table 6. General information about the interviewer is shown in Table 5.

Question	**Interviewer**
Job position	CXO
Industry sector	Sales and service
Personal experience in the cloud	> 3 years
The size of enterprise	More than 250 employees
Stage of cloud-computing adoption	Starting to experiment with the cloud
Time involved in the cloud	> 3 years

Table 5. Interview record

Criteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria
Cost	○	○	○	x	○	○	○	○	○	○	○	○	○	○	○	○	○	Quality
Cost	○	○	x	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Risk
Cost	○	○	○	○	○	○	○	○	x	○	○	○	○	○	○	○	○	Agility
Quality	○	○	○	○	○	○	x	○	○	○	○	○	○	○	○	○	○	Risk
Quality	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	x	○	Agility
Risk	○	○	○	○	○	○	○	○	○	○	○	○	x	○	○	○	○	Agility

Table 6. Pair-wise comparison

4.4.1 Data

Compared to previous qualitative studies on cloud-provider selection, our paper focuses on the CloudScreener (payment) and Cedexis (free) databases. This paper presents the first academic study that uses a database to rank cloud services; this is one of the most important contributions of our study. Table 7 shows the sources of data on each criterion selected through the literature review.

Criteria	Data source (March, 2015)
Service cost	CloudScreener
CPU	CloudScreener
RAM	CloudScreener
IOPs	CloudScreener
Broadband	CloudScreener
Risk	CloudScreener
Max CPU	CloudScreener
Max RAM	CloudScreener
Response time	Cedexis
Availability	Cedexis

Table 7. Database

4.4.2 Weight calculation

Table 6 presents comparaison matrix A:

$$A = \begin{pmatrix} 1 & 6 & 1 & 7 \\ 1/6 & 1 & 1/8 & 3 \\ 1 & 8 & 1 & 5 \\ 1/7 & 1/3 & 1/5 & 1 \end{pmatrix}$$

After generating a comparison matrix, we compute the priority vector, which is the normalized eigenvector of the matrix. Four eigenvectors are concatenated into 4 columns in matrix V:

$$V = \begin{pmatrix} 0.6833 & 0.8747 & 0.3110 - 0.0338i & 0.3110 + 0.0338i \\ 0.1455 & -0.0420 & -0.1258 + 0.1850i & -0.1258 - 0.1850i \\ 0.7099 & -0.4826 & 0.9140 & 0.9140 \\ 0.0892 & -0.0150 & -0.0684 - 0.1094i & -0.0684 + 0.1094i \end{pmatrix}$$

Corresponding eigenvalues are the diagonal values shown in matrix λ:

$$\lambda = \begin{pmatrix} 4.2306 & 0 & 0 & 0 \\ 0 & 0.0398 & 0 & 0 \\ 0 & 0 & -0.1352 + 0.9839i & 0 \\ 0 & 0 & 0 & -0.1352 - 0.9839i \end{pmatrix}$$

The largest eigenvalue, $\lambda_{\max} = 4.2306$, is referred to as the principal eigenvalue and corresponds to the highest eigenvector.

$$V^* = \begin{pmatrix} 0.6833 \\ 0.1455 \\ 0.7099 \\ 0.0892 \end{pmatrix}$$

The normalized principal eigenvector is

$$V^{**} = \begin{pmatrix} 0.42 \\ 0.09 \\ 0.43 \\ 0.06 \end{pmatrix}$$

In turn, we obtain the consistency index (n=4).

$$CI = \frac{\lambda_{\max} - n}{n - 1} = \frac{4.2306 - 4}{4 - 1} = 0.077$$

Table 4 shows that for n=4, the random consistency index is denoted as RI=0.9.

$$CR = \frac{CI}{RI} = \frac{0.077}{0.9} = 0.085 < 10\%$$

Therefore, our subjective evaluation of this criteria preference is consistent, and weights of the main criteria are $(0.42,\ 0.09,\ 0.43,\ 0.06)^T$. Cloud provider selection is thus based on specific customer requirements, and these requirements are changeable according to different uses of cloud services. Decision parameters are prioritized and weighted and user requirements are assigned through this procedure.

Criteria	Sub-Criteria	User requirement
Cost (0.42)		≤0.4$/h
Quality (0.09)	Response time (0.20)	≤300ms
	Availability (0.20)	≥99.5%
	CPU(0.15)	≥60events/s
	RAM(0.15)	≥1000Mo/s
	IOPS(0.15)	≥2000
	Broadband(0.15)	≥100000Ko/s
Agility (0.43)	Max vCPU (0.7)	≥16
	Max RAM (0.3)	≥100GB
Risk (0.06)		≥8

Table 8: Simulation setting-design of the simulation study

4.4.3 Cloud service ranking

Each cloud provider offers computing capabilities to different regions and computer systems. We choose France as the assessment site, Windows as the evaluation system, and the medium instance as an example to evaluate our decision model.

$$Y = x_0 + 0.42x_1 + 0.09x_2 + 0.43x_3 + 0.06x_4 + u \qquad (12)$$

Provider	Medium Instance	Large Instance	Extra-large Instance
AWS	m3.medium	M3.large	Extra large
Cloudwatt	n1.cw.standard-1	n1.cw.standard-2	n1.cw.standard-4
Google	n1.standard-1	n1.standard-2	n1-standard-4
Ikoula	m1.medium	Large	Extra
Windows Azure	standard A2	A3	A4
Numergy	small+	L+	XL+
Rackspace	4GB	8GB	15GB
Softlayer	Instance "Medium"	Instance "Large"	Instance "Extra"

Table 9. Types of instances

First, we determine the quality priority vector for the suppliers using fuzzy logic. For the CPU, RAM, IOPS, broadband and availability sub-criteria, we use “the larger value is better” membership function;

however, for the factor response time, we use "the smaller value is better" membership function. In a similar way, we can obtain the priority vectors for all remaining criteria: cost, agility and risk. Then, we aggregate all criteria to determine the relative service rankings of cloud providers using the fuzzy clingy degree N. Because of legal concerns, we anonymize the providers' names and refer to them as A to H. For instance, A.1 is one of the data center locations.

Ranking	Provider	Composite Index
1	A.8	0.638455
2	A.4	0.619122
3	A.6	0,616346
4	A.5	0.536647
5	A.7	0,52856
6	E.1	0.518421
7	A.9	0,516338
8	E.2	0.506845
9	B	0,495442
10	A.1	0,45991

Table 10: Numerical results-Composite Index

Ranking	Provider	Quality/cost Index
1	E.1	3.49679
2	E.2	2.853652
3	B	2.580538
4	G.1	2.570219
5	G.2	2.194801
6	G.3	2.079185
7	G.4	1.886343
8	C.1	1.830227
9	D	1.439463
10	F.4	1.391491

Table 11: Numerical Results-Quality/Cost Index

The numerical results show that the composite index (0.222495-0.638455) and the quality/cost index (0.017677-3.49679) differ considerably. Figure 3 shows that there is no correlation between these two rankings. Provider A performs better than other providers included in the composite index; however, B and E are at the top of the quality/cost ranking. Therefore, determining how to define decision criteria is essential when selecting appropriate cloud providers.

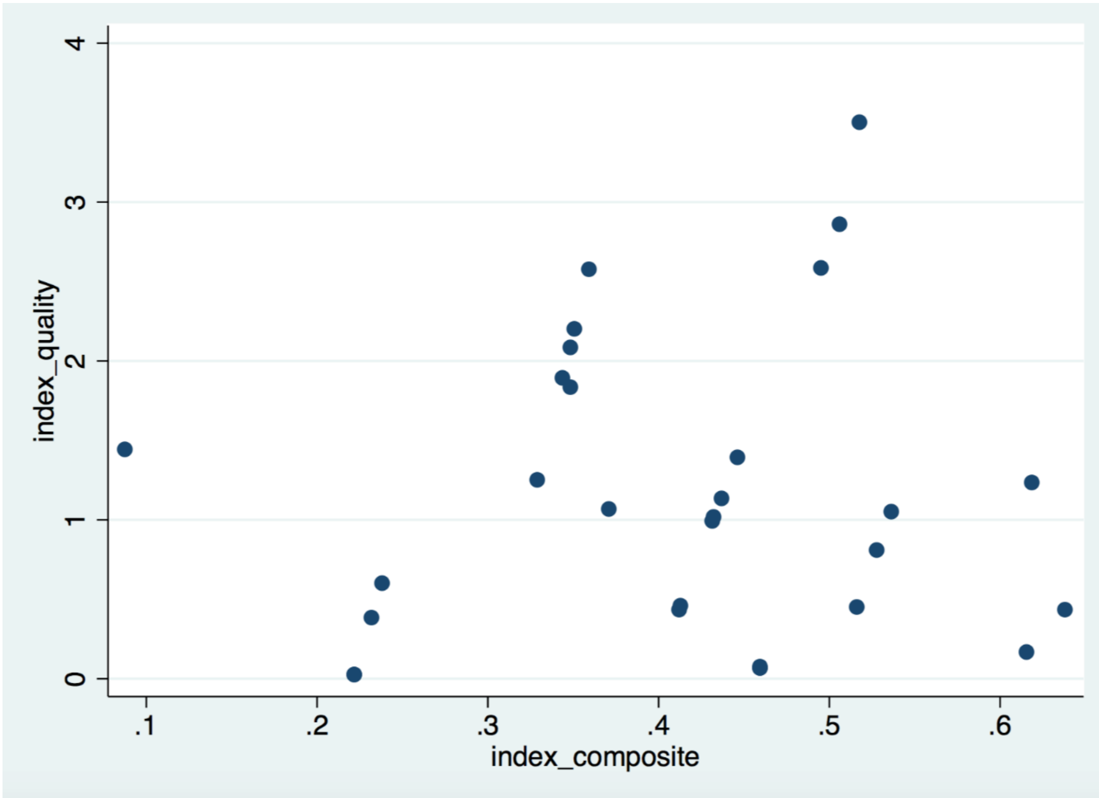

Figure 3. Results Analysis

4.4.4 Interdependence of criteria

Although we assume that the decision criteria are independent of one another, in reality, they are interdependent. To address this limitation, we modeled relationships between several attributes. Spearman's rank correlation coefficient was used to address the interdependence of multiple criteria. Using a monotonic function, it assesses and describes the strength of the relationship between two variables.

This approach is defined as the Pearson correlation coefficient between ranked variables. For a sample of size n, n raw scores Xi and Yi are converted to ranks x_i, y_i, and $d_i = x_i - y_i$ is the difference between ranks, and the Spearman's rank correlation coefficient is computed from

$$\rho = 1 - \frac{6\sum d^2_i}{n(n^2-1)} \quad (13)$$

When each of the variables is a perfect monotone function of the other, we will have a perfect correlation. The data shown in Appendix 3 indicate no interdependence between agility and the other criteria. What is left to do is to analyze levels of interdependence between cost, risk and quality levels using Spearman's rank correlation, which shows that $\rho_{quality-\cos t} = 0.17$, $\rho_{quality-risk} = 0.524$ and $\rho_{\cos t-risk} = 0.262$. The high $\rho_{quality-risk}$ value shows that the correlation between quality and risk is very high. We must therefore account for this correlation in our decision model. Equation (12) is thus transformed into (14).

$$Y = x_0 + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \alpha_4 x_4 + \alpha_5 x_2 x_4 + u \quad (14)$$

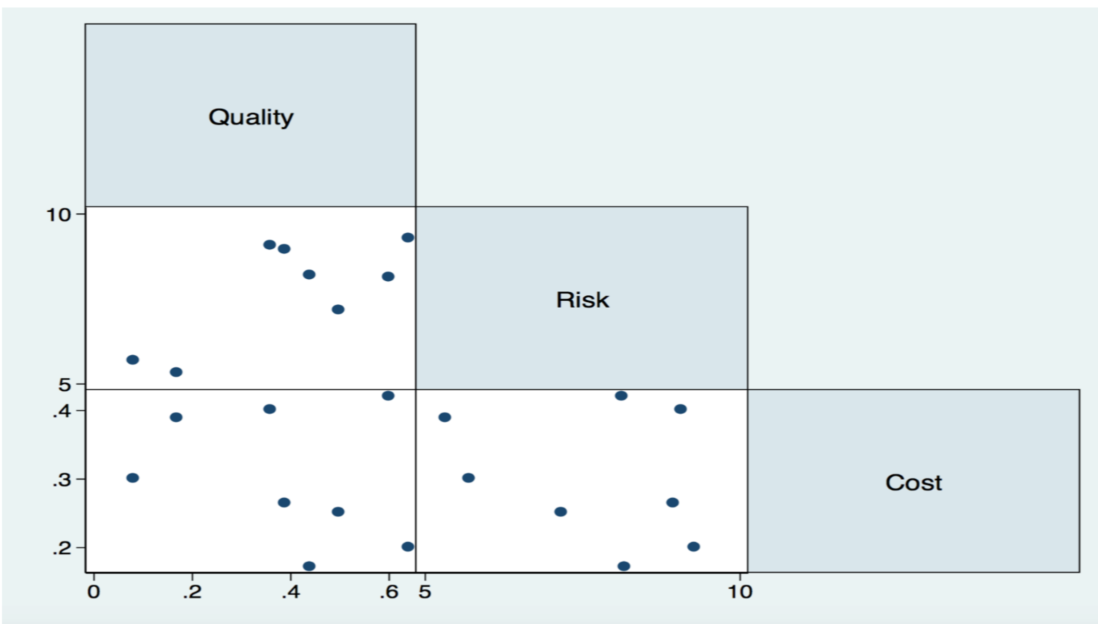

Figure 4. Correlation

4.5 Discussion

With growing attention toward long-term partnerships with better suppliers, supplier selection is increasingly viewed as an important aspect of the supply chain. Our design is based on two processes of design science, i.e., research model development and evaluation and four artifacts (hierarchy process construction, research model design, AHP method and fuzzy logic combination, and instantiation).

The simulation results show that cloud provider quality levels vary considerably. The composite and quality/cost indices show that the selection of decision criteria affects cloud service rankings. Additionally, we found a correlation between decision criteria quality and risk levels, demonstrating that it is necessary to consider correlations between multi-attributes.

Elements	**Current Study**	**(Garg, Versteeg and Buyya, 2013)**
Deployment model	IaaS+PaaS	IaaS
Decision methods	AHP and Fuzzy logic	AHP
Decision criteria	Cost, Quality, Risk, Agility	Accountability, Performance, Cost, Security, Assurance, Agility
Compared cloud providers	Amazon AWS, Cloudwatt, Google, Ikoula, Windows , Numergy, Rackspace, Softlayer	Amazon AWS, Windows, Rackspace
Data	Providers' official website and CloudScreener	Various previous studies
Interdependence	Yes	No
Results	Composite index and Quality/cost index	Composite index

Table 12. Comparison

Table 12 shows that this paper contributes to the IS community as prior work has not adequately addressed an important question addressed here: Is there interdependence between the selected attributes?
The contributions of this paper are outlined as follows:

- It applied the AHP method and fuzzy logic theory in identifying appropriate cloud providers.
- Simulations were based on the CloudScreener and Cedexis databases.
- It addressed interdependence between selected decision criteria.
- It proposed two comparison indexes (the composite and quality/cost indices).

4.6 Conclusion and future research

The model presented in this article employs a fuzzy AHP approach to compare cloud-computing services focused on IaaS and PaaS products under each selected criterion. The results of the simulation ensure the validity of the model. The research findings show that the proposed fuzzy logic theory and AHP method present a well-structured architecture and a high degree of computational power. They allow cloud customers to enhance decision-making quality levels when uncertain decision-making processes are involved.

The presented fuzzy AHP approach can be used to compare cloud providers on all service models, thus supporting teams or individuals during decision processes. We believe that our decision model is a significant step toward analyzing the process of cloud provider selection. However, there remains much to do in this paper. Like all quantitative models, our model presents some limitations that must be accounted for. In particular, our model currently focuses on cost, performance, agility and risk factors; it does not account for extensive qualitative factors that may influence cloud-computing decisions. Integrating these factors into a complete framework is a substantial challenge. Future studies must focus on these issues.

As time goes by, providers update their infrastructure and there will be more cloud providers entering the cloud market. In the future, we must update and compare more cloud providers. Developing a multi-cloud service that combines diverse strengths of different providers is another interesting subject in this area.

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Appendix 1. Numerical results

Provider	Composite index	Quality/cost index
A.1	0.459915	0.066566
A.2	0.459915	0.066566
A.3	0.459915	0.068728
A.4	0.619122	1.231611
A.5	0.536647	1.04547
A.6	0.616346	0.16005
A.7	0.52856	0.806481
A.8	0.638455	0.430131
A.9	0.516338	0.445315
B	0.495442	2.580538
C.1	0.348588	1.830227
C.2	0.371531	1.066826
D	0.088032	1.439463
E.1	0.518421	3.49679
E.2	0.506845	2.853652
F.1	0.432142	0.987289
F.2	0.412972	0.454796
F.3	0.437184	1.127345
F.4	0.446693	1.391491
F.5	0.43306	1.01278
F.6	0.412115	0.430987
G.1	0.359593	2.570219
G.2	0.351112	2.194801
G.3	0.3485	2.079185
G.4	0.344144	1.886343
G.5	0.329653	1.244875
H.1	0.222495	0.017677
H.2	0.222495	0.017677
H.3	0.232237	0.378461
H.4	0.238166	0.598069

Appendix 2. Questionnaire

Selection of Cloud Providers

The purpose of this questionnaire is to collect data both on the given situation and on enterprise cloud service selection. The results of this questionnaire are designed to support stronger enterprise understanding of cloud computing and the creation of effective cloud-based organizations.

1. Job Position
○ IT Manager
○ IT Executive
○ CXO (CEO, COO, CTO, CIO)
○ IS Manager
○ Other

2. Industry Sector
○ IT
○ Manufacturing
○ Sales and services
○ Engineering
○ Public and healthcare
○ Construction
○ Information and communication
○ Other

3. How many years of experience do you have with cloud computing?
○ 0
○ > 1 year
○ > 3 years
○ > 5 years
○ > 7 years

4. What is the size of your enterprise?
○ Micro-enterprise: 1-9 Employees
○ Small enterprise: 10-50 Employees
○ Medium enterprise: 50-250 Employees
○ Large enterprise: 250+ Employees

5. How long has your enterprise been involved in cloud computing?
○ 0
○ > 1 year
○ > 3 years
○ > 5 years
○ > 7 years

6. Cloud provider selection: The selection of cloud-computing suppliers is based on quantitative criteria: cost, performance, risk and agility. Quality refers to broadband access, response times, availability levels, IOPS, etc. Please rate the relative importance of each pair of items from 1 (equal importance) to 9 (high importance).

Criteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria
Cost	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Quality
Cost	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Risk
Cost	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Agility
Quality	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Risk
Quality	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Agility
Risk	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Agility

Appendix 3. Data

Provider	Quality	Risk	Cost	Agility
A	0.17	5.32	0.389	1
B	0.44	8.18	0.172	0
C	0.39	8.94	0.264	0.008
D	0.60	8.14	0.42	0
H	0.64	9.28	0.2	0
E	0.36	9.08	0.4	0.740
F	0.50	7.16	0.251	0
G	0.08	5.7	0.3	0.025

Provider	Quality Q_i	Cost C_i	Rank q_i	Rank c_i	d_i	d_i^2
G	0.08	0.2	1	2	-1	1
A	0.17	0.389	2	6	-4	16
E	0.36	0.264	3	4	-1	1
C	0.39	0.251	4	3	1	1
B	0.44	0.3	5	5	0	0
F	0.50	0.4	6	7	-1	1
D	0.60	0.42	7	8	-1	1
H	0.64	0.172	8	1	7	49

Provider	Quality Q_i	Risk R_i	Rank q_i	Rank r_i	d_i	d_i^2
G	0.08	5.7	1	2	-1	1
A	0.17	5.32	2	1	1	1
E	0.36	9.08	3	7	-4	16
C	0.39	8.94	4	6	-2	4
B	0.44	8.18	5	5	0	0
F	0.50	7.16	6	3	3	9
D	0.60	8.14	7	4	3	9
H	0.64	9.28	8	8	0	0

Provider	Risk R_i	Cost C_i	Rank q_i	Rank c_i	d_i	d_i^2
A	5.32	0.389	1	6	-5	25
G	5.7	0.2	2	5	-3	9
F	7.16	0.4	3	3	0	0
D	8.14	0.42	4	8	-4	16
B	8.18	0.3	5	1	4	16
C	8.94	0.251	6	4	2	4
E	9.08	0.264	7	7	0	0
H	9.28	0.172	8	2	6	36

Chapter 5

Performance Analysis of Public Cloud Computing Providers

Xiaolin Cheng, Ahmed Bounfour

5.1 Introduction

Cloud computing technology is a virtual technology which distributes different services (infrastructure, platform, and software) based on different deployment models (public, private, hybrid and community). It is no longer a buzzword, it's a strategy, a business model, and a set of technologies. It has drawn significant attention from firms in recent years due to its agility, variety and ability to reduce cost. However, each company has different needs and constraints; cloud market is complex; more and more American and European companies are entering IT. These cloud computing providers offer different services which vary widely in performance and price. It is a big challenge to select appropriate cloud services which meet all the business strategies of the company.

This research in progress paper aims to provide a continuous comparison framework for public cloud services between small and large providers and a detailed analysis of the correlation between price and performance. Our research work has the following objectives:

- To compare the performance between small and large public providers
- To compare the prices of different public cloud providers
- To analyse the correlation between price and performance

Xiaolin Cheng, Ahmed Bounfour, "Performance analysis of public cloud computing providers", Presented in MCIS 2016, The 10th Mediterranean Conference on Information systems", Raphos, Cyprus, 4-6 September, 2016

The remainder of this article is organized as follows. Section 2 and Section 3 contribute to research background and literature review. Measurement methodology and selected cloud services are described in Section 4. Then, in Section 5 we focus on discussing benchmarking results and analyzing the correlation between the prices of public cloud services. Finally, we present our conclusions and introduce potential future research topics in Section 6.

5.2 Research background

Due to popularity of public cloud in different organizations, cloud performance evaluation is particularly important, and this evaluation can help users make right decisions. Public cloud computing is used by the general public and offer pay-as-you go charging model that enables customers to pay what they use. It is different from private cloud, internally used by some organizations. In contrast, public cloud infrastructure exists on the premises of cloud provider. The first public cloud Amazon Web Services was launched in 2006, and then more and more IT companies are riding their wave to offer a variety of public cloud computing services such as Google, Microsoft and IBM. Various public cloud providers offer different types of services with different pricing schemes raising big challenges on how to choose the best suited cloud services.

Ang Li identified common services of public cloud: elastic computing cluster, persistent storage, intra-cloud network and wide-area network (Li et al., 2010). Cluster runs application's codes using numerous virtual instances. Persistent storage is used to keep data of application and accessed through API calls. Intra-cloud network provides connection between application instances, wide-area network connects different data centers where the applications are hosted. This paper focuses on comparing the performance of elastic computing cluster between small and large public cloud providers. (Lenk et al., 2009) indicated that cloud storage is a major example of IaaS (Infrastructure as a Service). Computing service is another major example of IaaS.

5.3 Literature review

Simon L.Garfinkel measured the performance of Amazon's Grid Computing Services and details his experience working with these commodity computing services including analysis of Amazon's security model, implementation of the S3 client API and measurement of S3 performance from EC2 (Garfinkel, 2006). (Iosup et al., 2008) contributes to evaluate the performance of the Amazon Elastic Compute Cloud (EC2) using micro-benchmarks, kernels, and e-Science workloads and compare the performance characteristics and pricing models of clouds with those of other scientific computing alternatives using long-term traces. (Ward, 2009) compared the performance of Amazon EC2 and Ubuntu Enterprise Cloud (UEC) using memory bandwidth, storage speed and application performance. Ward showed that for most computational tasks, UEC provides better performance than EC2, although EC2 provides the most mature IaaS cloud technology.

Yahoo! Cloud Serving Benchmark (YCSB) (Cooper et al., 2010) is a framework to benchmark cloud serving systems that provide online read/write access to data. Authors defined a set of benchmarks and presented comparison results of some widely used systems: Cassandra, HBase and PNUTS. CloudCmp (Li et al., 2010) is another framework to compare the performance and cost of cloud providers. This framework can be used to measure elastic computing, persistent storage, and networking services offered by a cloud service, however it only provides snapshot benchmarking results. Considering this research gap, we strive to compare elastic computing services and provide some more detailed continuous benchmarking results.

(Singh, 2014) emphasized that response time is a major factor that has the significant impact on cloud computing performance and it is reduced by selecting the appropriate type of broker service policies, i.e. closest data center, optimum response time and re-configure dynamically with load. Singh also indicated that response time is reaching towards constant value after 6 data centers. (Khanghahi & Ravanmehr, 2013) evaluated cloud computing performance in various scenarios considering different major factors in cloud computing performance. Their simulation and evaluation based on three categories: data centers, users and geographical region. Authors emphasized that distribution of data centers and use of the closest data center are better and more optimal than increasing its power and speed. It is also revealed that increasing the number of cloud users has increased the average response time, response time reduced drastically up to 10 data centers, so putting more than that only increases the cost.

(Iosup et al., 2011) aims to test whether the performance of clouds sufficient for Many-Task computing (MTC) based scientific computing. Authors performed an empirical evaluation of four public computing clouds using micro-benchmarks and suggested that computing performance of the tested cloud services is lower than traditional computing technologies grids and parallel infrastructures.

From literature review, it is inferred that majority of the research papers were focused on evaluating the performance of cloud providers and offered different comparison frameworks. The first worldwide public cloud service EC2 was the most popularly used service to make an analysis and response time was a major factor that contributed a lot to the performance. It is apparent that there is a need to compare the performance between small and large providers in order to help cloud users make right decisions.

5.4 Dataset and research model

CloudScreener dataset provides information and standardized metrics related to various aspects of the performance of cloud computing technology. It provides a comprehensive set of indicators which helps to understand the variance of cloud performance. The dataset included 8 cloud providers in American and European countries for March and October of 2015. The extraction process yielded a total of 6 indicators, which described various aspects of cloud performance. Table 1 displays the selected indicators, their classification according to the framework proposed by CloudScreener.

Service	**Metric**	**Characteristic**
Server	CPU	Events per seconds with 32 threads (numbers/s)
	Memory	RAM writing speed (MB/s)
Disk	IOPs	4k random write I/O speed (IOPs)
	Broadband	1M sequential write latency (Ko/s)
Network	Response time	Delay processing at server + Delay network(milliseconds)
	Availability	Interruption of data availability
Price	Linux/Windows	Dollars/Month

Table 1. Cloud Performance Metrices

Response time is the time taken by a cloud provider to respond to a request for cloud services, it is measured by subtracting start request from start response. Total response time is the delay of processing at server and network (Ristov, Gusev, & Kostoska, 2012)

H1: Response time is negatively related with the price of public cloud service.

IOPs is a common performance measurement used to benchmark computer disk devices. In the benchmark, this measure is computed as the average number of operations that go in and out per second obtained by using 4K random write operations and a standard block size.

H2: IOPs is positively related with the price of public cloud service

Availability is the proportion of time a system is in a functioning condition, it is measured by the ratio of a total time cloud service is capable of being used during a given interval to the length of the interval.

H3: Availability is positively related with the price of public cloud service.

CPU is measured by the average number of treated events per seconds with 32 threads, Memory is measured by the average throughput expressed in MB/s, and Broadband is measured by throughput (Ko/s) 100% 1M sequential write. And finally we should consider that whether cloud computing is cost effective before shifting to cloud computing. To analyze the correlation between price and other performance criteria is one of the important objects of our research work.

H4: CPU is positively related with the Price of public cloud service.

H5: Memory is positively related with the Price of public cloud service.

H6: Broadband is positively related with the Price of public cloud service.

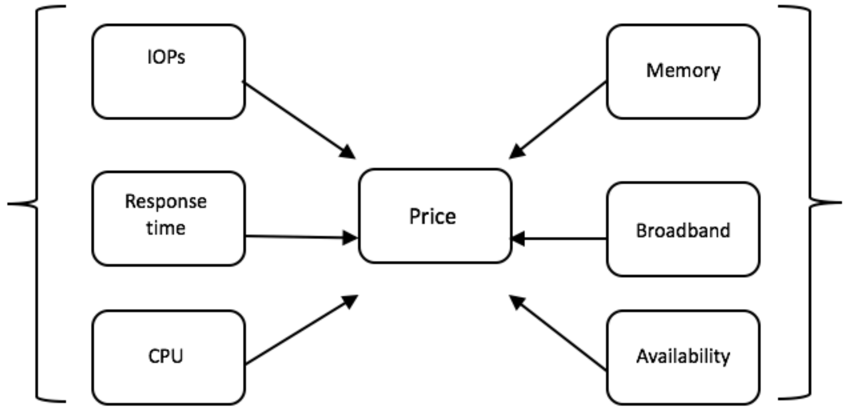

Figure 1. Research Model

Before analyzing how these indicators may explain cloud performance, careful attention should be given to the different instances. In order to focus on understanding the performance variance of different cloud providers, medium instance was selected as a target.

Provider	**Medium Instance**	**Large Instance**	**Extra-large Instance**
AWS	m3.medium	M3.large	Extra large
Cloudwatt	n1.cw.standard-1	n1.cw.standard-2	n1.cw.standard-4
Google	n1.standard-1	n1.standard-2	n1-standard-4
Ikoula	m1.medium	Large	Extra
Windows Azure	standard A2	A3	A4
Numergy	small+	L+	XL+
Rackspace	4GB	8GB	15GB
Softlayer	Instance "Medium"	Instance "Large"	Instance "Extra"

Table 2. Type of instances

Classifying cloud providers

The second object of our paper is to analyze the public cloud service performance between small and large providers. Classifying selected cloud providers is the first step, we begin with some background and describe how to classify them by Wikibon Public Cloud Market Shares 1H 2015 (Cloud & Shares, 2015).

Provider	IaaS Market Share 1H 2015	
Amazon	3153	27.2%
Microsoft	1874	16.2%
IBM	1370	11.8%
Google Compute Engine	420	3.6%
Oracle	318	2.7%
Rackspace	282	2.4%
Other	4160	35.9%

Table 3. Wikibon cloud market shares

Selected public cloud providers from CloudScreener database were divided into two groups: large providers (Google, Amazon, Microsoft, Rackspace) and small providers (Aruba, Cloudwatt, Numergy, Ikoula). Because the large cloud providers' services were popular and widely used by different types of firms, in this section, we just exhibit 4 selected small providers: Aruba, Numergy, Cloudwatt and Ikoula).

Ikoula is a French cloud provider and founded in 1998. It offers public cloud services from 2013 focusing on three different cloud services, more or less packaged. The first service Flex'Server offers dedicated virtual servers with processors, memory and different predefined storage spaces. Half of its clients are SMEs of websites or e-commerce. The second service FlexiCloud allows his clients to pick processors, memory and hard disk, in this case instances are often used for large architecture. The last one offers virtual machine at one euro, which offers the true automatic resource allocation without user validation. These virtual machines have also found an unexpected market in the financial world.

Aruba is a public cloud provider offering formally IaaS and cloud storage, it was created in 1994 in Italy. Aruba cloud would be similar with Amazon Web Services (AWS), but it is cheaper, more flexible and better mastered. To succeed in the highly competitive French market, they decided to focus on innovation, ease of use and transparency. Aruba cloud settled especially on the reputation and strength of its parent that already has thousands of customers, and well established infrastructure. It also leverages its global strategy, in both local and global market. The implementation of Aruba in France fits into a broader strategy of extending its offer to European markets, including Germany, Spain and England. Aruba already presented in the Eastern European countries, such as the Czech Republic, Slovakia and Hungary.

Numergy and CloudWatt are two French cloud providers born from the will of the French government to establish a sovereign cloud services, they were launched in 2012. Four years later, the two firms are neck and neck. CloudWatt is managed by Orange and Thales, on the other side, Numergy is controlled by SFR and Dassault. Enjoying the data center and SFR expertise, Numergy entered to cloud market faster than CloudWatt and it offered servers, storage and network services, but there was no data centers abroad. While Numergy already had some distributors, CloudWatt chose the same indirect marketing model and hoped catch up. Compared to Numergy, CloudWatt positioned to target large organizations, public or private, with significant cloud projects, so it highlights concerns of hybrid cloud. Also, CloudWatt implemented OpenStack that introduced several differences with the strategy of Numergy. One of the main differences was that CloudWatt has not chosen the same network solutions as Numergy, however it deployed its own virtual private network infrastructure.

5.5 Benchmarking results

In this section, we present some preliminary benchmarking results of the common services offered by eight representative public cloud providers. The goal of cloud service benchmarking is to generate a comparison framework of performance. Our preliminary benchmarking results indicated that small cloud providers such as Ikoula, CloudWatt, Aruba and Numergy perform better than larger providers Amazon, Microsoft, Google and Rackspace in almost all the selected indicators except CPU. Also, in Table 5, we can find that the performance of public cloud services vary widely in different indicators.

The results inferred that conclude that market share is not positively related with the performance of public cloud services. It's an important point to be considered in the process of the selection of public cloud services. Considering legal concerns and keep focus on the comparison of performance for computing service, we anonymize the names of public cloud providers and refer to them as C1-C4 (large providers) and C5-C8 (Small providers). Table 4 and Table 5 display the selected indicators and their corresponding summary statistics.

Large Provider	Availability		Broadband		CPU		IOPs		Memory		Response time	
	March	October	March	October	March	October	March	October	March	October	March	October
C1	99.4	98.96	35857	28055	36	36	2721	2664	**196**	**265**	70	**67**
C2	**96.15**	99.32	73959	73976	80	81	1332	1498	1849	1876	49	47
C3	**96.91**	98.94	34501	30512	67	58	**235**	**362**	230	884	**84**	71
C4	99.45	99.31	187920	77980	**261**	**254**	1332	1301	360	**418**	53	51
Average	97.98	99.21	83059.25	52630.75	111	107,75	1405	1456.25	658.75	860.75	64	59

Small Provider	Availability		Broadband		CPU		IOPs		Memory		Response time	
	March	October	March	October	March	October	March	October	March	October	March	October
C5	99.34	99.32	79860	84514	52	51	5479	7671	2335	2224	45	46
C6	99.34	**98.73**	175088	193421	62	62	7063	1483	1389	1393	44	42
C7	99.36	99.33	170292	181007	130	**126**	6485	8988	2325	2287	45	45
C8	99.35	99.31	**692571**	**484560**	68	69	**22845**	**13806**	2707	2715	44	43
Average	99.3475	99.1725	279452,8	235875,5	78	77	10468	7987	2189	2154,75	44,5	44

Table 4. Benchmarking results

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Price	52.11111	20.79561	27	97
IOPs	5041.167	5770.64	235	22845
Response time	52.61111	11.75805	42	84
CPU	89	66.25264	36	261
Memory	1571.389	944.8402	196	2715
Broadband	204696.1	220939	28055	785852
Availability	98.97278	.9146303	96.15	99.45

Table 5. Summary statistics

5.6 Comparison of the Service Price between Small and Large Providers

Performance and pricing are both key considerations of the public cloud services. A firm needing to use computing services must compare the alternatives of owning its computing infrastructure or leasing it from a cloud provider. Also, they should choose cost effective services with fewer resources on better performing services. In this subsection, we provide an overview of the cost items associated to Medium Instances. Table 6 indicated that small cloud providers have better performances than large providers in both of the systems (Windows and Linux) for March and October of 2015.

Service Price	**Medium instance Linux**		**Medium instance Windows**	
	March	**October**	**March**	**October**
C1	52	49	88	86
C2	33	27	58	53
C3	78	78	193	122
C4	95	70	121	89
Average	64.5	56	115	87.5

Service Price	**Medium instance Linux**		**Medium instance Windows**	
	March	**October**	**March**	**October**
C5	40	40	40	40
C6	41	36	72	55
C7	44	44	76	76
C8	40	40	56	56
Average	41.25	40	61	56.75

Table 6. Price of instance M (dollars/month)

Correlation between the Price of Public Cloud Service and Performance

Table 7 shows the correlations between identified factors. One of the important objects of our research is to find which factor influence the most the price of public cloud service. For the interpretation of this analysis, we look at the first column to identify which variable has the largest value. We found that there is a highlighted, positive correlation between price and CPU. Therefore, we can conclude that CPU is the major factor impacting the price of public cloud service. Return to the hypotheses that we did, the results confirmed that H5: CPU is positively related with the price of public cloud service.

Variable	Price	IOPs	Res.Time	CPU	Memory	Broadband	Availability
Price	1.0000						
IOPs	-0.2232	1.0000					
Response time	0.1902	-0.4132	1.0000				
CPU	**0.6415**	-0.1553	-0.2057	1.0000			
Memory	-0.3546	0.6658	-0.6882	-0.2805	1.0000		
Broadband	0.3103	0.5429	-0.4195	0.4624	0.1716	1.0000	
Availability	0.2333	0.3046	-0.3384	0.1101	0.1753	0.2467	1.0000

Table 7. Correlations between different indicators

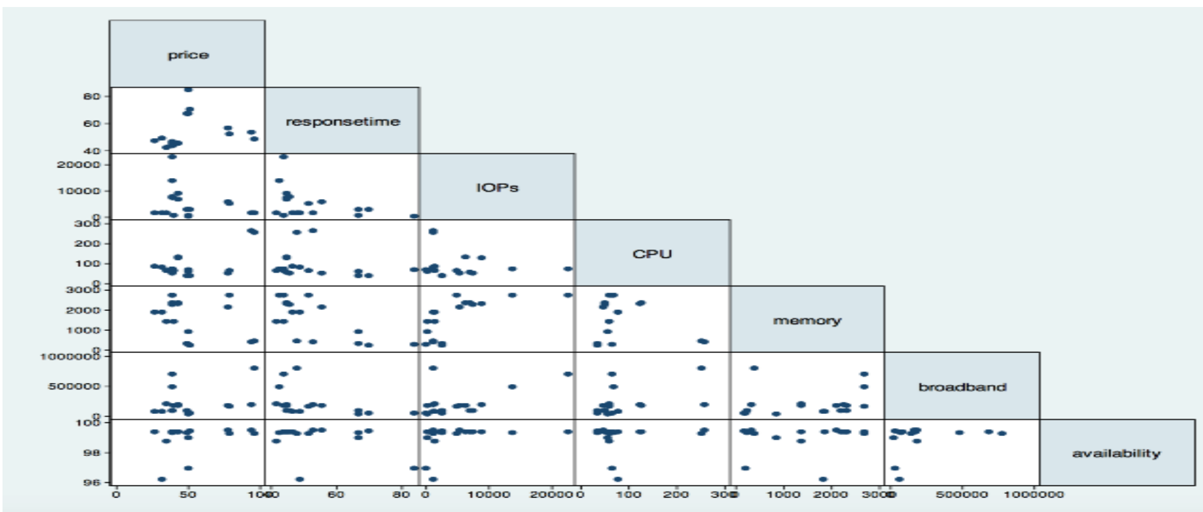

Figure 2. Correlations between different indicators

5.7 Conclusion and Future research

This section contributes to discuss contributions and limitations of our research work and also future research directions. This study not only examined the performance of different public cloud providers, but also tracked performance variability for two month periods. The methodology allowed us to capture performance variability over time. The current study complements previous work by analyzing the correlation between price and performance factors, comparing the performance between small public cloud providers and large providers. From our premium results, we can find that CPU is the key factor of the performance that has significant impact on the price of public cloud services. Small cloud providers offer more stable services and pricing models than large providers. Such a systematic benchmarking research work to compare public cloud performance can make a significant impact and create healthy competition among cloud providers. We believe that our comparison framework is a significant step toward analyzing different public cloud performance. As it stands, one of our current research limitations is that the hypothesis are not based on literature, and also, it lacks some technical depth. In our future research, we will focus on these issues, to proceed with a deep analysis statistically; to analyze more public cloud providers and offer toolboxes to evaluate applications' performance based on the results that we obtained

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Chapter 6

Conclusion: Cloud computing adoption and decision-making

The growth of cloud computing is amazing due to its various advantages in the last decade. This dissertation addresses cloud computing adoption and decision-making issues. It analyzes adoption determinants, discusses cloud services, and compares cloud providers. This chapter recapitulates the main finds and contributions, it is organized as follows. Section 6.1 reviews the main findings of this thesis. Section 6.2 indicates the important contributions, relevant implications and some limitations. Lastly, section 6.3 describes some operational future research directions.

6.1 Main findings

- **Transformative value of cloud computing**

Chapter 2 provides a framework for understanding the determinants of organizational transformation due to cloud computing. For companies that seek to become Transformational or even Hyper Transformational, it indicates the key determining factors. With respect to the human dimension, it shows the importance of perceived usefulness and perceived ease of use, notably with respect to the efficiency of cloud computing and ubiquity of access. For the technological dimension, it highlights the importance of having a clear understanding of the conditions of data use (especially for large enterprises), and the fact that applications should be loosely coupled and independent. In terms of organizational aspects, top management support is important (at least for Transformational companies) as is having adequate resources (with respect to the budget (for the Transformational group), and a 'shadow' IT department (for the Hyper Transformational group). Finally, for the environmental dimension, vendor support appears as having no impact on becoming either Transformational or Hyper Transformational. Competitive pressure is another determining factor, while government policy is only somewhat important.

- **Cloud computing services and deployment models**

Chapter 3 was motivated by the need to address cloud adoption theories. The objective of traditional adoption theories is to make the decision of adoption using different technological, organizational and environmental factors. In our research, we presented a rule-based decision model with different dimensions: stable dimension, relatively stable dimension and variable dimension for guiding in the positioning of enterprises with respect to cloud computing adoption. The aim of this rule-based model is to verify firms' cloud strategy and to help them choose appropriate cloud services and cloud deployment models. The results reveal that companies' sizes does not influence the selection of cloud services and cloud deployment models.

The analysis results reveal that internal private deployment model and SaaS were the most commonly used cloud deployment model and service in French companies. Internal private model guaranty the security of privacy data, however, this type of model charge a lot. To solve the data security challenge and reduce the cost, we can try to move to external private model if cloud providers could offer guaranteed services. We also found that some large firms also considered SaaS as the first step when they intend to move to cloud computing, because it is the easiest service to use and manage since it is based on software.

- **Cloud computing providers**

The model presented in chapter 4 employs a fuzzy AHP approach to compare cloud-computing services focused on IaaS and PaaS products under each selected criterion. The results of the simulation ensure the validity of the model. The research findings show that the proposed fuzzy logic theory and AHP method present a well-structured architecture and a high degree of computational power. They allow cloud customers to enhance decision-making quality levels when uncertain decision-making processes are involved. The presented fuzzy AHP approach can be used to compare cloud providers on all service models, thus supporting teams or individuals during decision processes. Selection of appropriate providers relates to the location of companies because of the data center. We believe that our decision model is a significant step toward analyzing the process of cloud provider selection.

- **Cloud computing services' performance**

The study in Chapter 5 not only examined the performance of different public cloud providers, but also tracked performance variability for two month periods. The methodology allowed us to capture performance variability over time. The current study complements previous work by analyzing the correlation between price and performance factors, comparing the performance between small public cloud providers and large providers. From our premium results, we can find that CPU is the key factor of the performance that has significant impact on the price of public cloud services. Small cloud providers offer more stable services and pricing models than large providers. Such a systematic benchmarking research work to compare public cloud performance can make a significant impact and create healthy competition among cloud providers. We believe that our comparison framework is a significant step toward analyzing different public cloud performance.

6.2 Contributions and limitations

Our research seeks to contribute to the literature on the adoption and decision-making of cloud computing. The contributions of the dissertation are twofold. One is theoretical contributions and the other is managerial implications. On the basis of the aforementioned findings, theoretical and managerial contributions emerge. The same as with other studies, there exist various limitations in each chapters, our future research will focus on these issues.

6.2.1 Theoretical contributions

- ***Hybridization of theories***

Several scholars have called for the hybridization of theories, in order to understand the mechanisms underlying the adoption of digital artifacts (Venkatesh et al.2016). In line with these arguments, in Chapter 2, we developed a unified model that articulates elements of three established approaches: TOE and TAM (for input variables) and organizational fit theory (for output variables). This hybridization allows us to characterize the transformational nature of cloud computing and its determining factors. The research contributes to the emerging literature on the digitization of firms and organizational design. To the best of our knowledge, this is the first study to make the link between these three models, thereby going beyond the general approach to adoption found in IS research. The model and its results expand upon research that sees organizational capital as a complement to investment in IT artifacts (Brynjolfsson, Hitt, & Yang, 2002).

In Chapter 4, fuzzy logic and AHP method have be merged to select appropriate cloud providers. AHP method cannot capture the subjectivity (or fuzziness) of human judgments as verbal assessments are converted into crisp values. Meanwhile, fuzzy logic cannot measure the consistency of judgments provided by a decision maker. The fuzzy analytic hierarchy process (FAHP) constitutes a merger of the two methods that inherits the advantages of both and that therefore addresses the above mentioned problem.

- ***Digitization and digital transformation***

Bharadwaj et al. (2013) considered cloud computing to be a key digital trend, and called for a renewal of digital business strategy based on four axes: its scope; its scale; the speed of decision-making; and as a source of value creation and capture. While these scholars consider cloud computing as an external factor, our research suggests that it is also a source of value creation and capture, notably from the perspective of organizational design and fit. Specifically, our research contributes to the characterization of the digital transformation by identifying its key factors: functionality, data management, roles and competences, control, and culture, together with its four determining dimensions: human, technological, organizational and environmental. A second contribution is modelling value capture based on cloud computing. Our work suggests that cloud computing is more than a driving external factor; it is a transformational factor that should be embedded into firms' digital strategies.

- ***Organizational fit/ capital***

The research field of organizational design is undergoing a metamorphosis due to the ubiquity of digital technology. The question of organizational fit (Burton & Borge, 2004; Stroing & Volfoff, 2010; Soh, Kien, & Tay-Yap, 2000; Vankatraman, 1989) has been studied in IS research notably in terms of enterprise systems. In particular, Soh, Kien, and Tay-Yap (2000) proposed a taxonomy of misfits divided into several dimensions, including data and functions. Our research builds on this taxonomy and adapts it to the cloud computing context. Furthermore, it provides the foundations for the identification and characterization of the key variables in organizational transformation. Our research indicates that these dimensions are key components of a company's organizational capital and complement cloud computing as an IT artifact (Brynjolfsson, Hitt, & Yang, 2002; Lev & Radhakrishnan, 2003).

- ***Research into cloud computing adoption***

The adoption of IT technology has been a major field of research in IS, especially around the TAM model and its variations. For cloud computing in particular, several researchers have considered the issue of adoption from various angles, including: the determinants of cloud computing adoption in industries and services (Oliveira, Thomas, & Espadanal, 2014), the issue of risk (August, Niculescu, & Shin, 2014), the evaluation of specific components of cloud computing (Lee, Park, & Lim, 2013), organizational design (Choudhary & Vithayathil, 2013), and dynamic capabilities (Lyer & Henderson, 2010, Battleson, et al., 2015). Our research contributes to the emerging field of research into cloud computing adoption by examining the determining factors in four dimensions (human, technological, organizational and environmental), and analyzing their respective and relative importance for transformation. It therefore goes beyond the issue of adoption, and makes a bridge with another important issue in IS research: digital transformation. Secondly we also designed an adoption model based on stable dimension, relatively stable dimension and variable dimension in Chapter 3..It asserts the difficulty in grouping these patterns into a single taxonomy, due to the inner nature of the characteristics of cloud computing adoption.

6.2.2 Managerial implications

Chapter 2 and Chapter 3 relate to the adoption of cloud computing. They provide a framework for understanding the determinants of organizational transformation due to cloud computing. For companies that seek to become Transformational or even Hyper Transformational, it indicates the key, determining factors. With respect to the human dimension, it shows the importance of perceived usefulness and perceived ease of use, notably with respect to the efficiency of cloud computing and ubiquity of access. For the technological dimension, it highlights the importance of having a clear understanding of the conditions of data use (especially for large enterprises), and the fact that applications should be loosely coupled and independent. In terms of organizational aspects, top management support is important (at least for Transformational companies) as is having adequate resources (with respect to the budget (for the Transformational group), and a 'shadow' IT department (for the Hyper Transformational group). Finally, for the environmental dimension, vendor support appears as having no impact on becoming either Transformational or Hyper Transformational. Competitive pressure is another determining factor, while government policy is only somewhat important. Chapter 4 and Chapter 5 focus on the selection of cloud providers and the evaluation of cloud performance. It's the second step for cloud users, our research framework offers a guide of the key criteria and important elements for their selection.

6.2.3 Limitations

- **Country affects**

While our study in Chapter 2 provides an overview of cloud computing adoption factors and dimensions of organizational fit, there are some specific limitations. The first relates to the fact that the conclusions are based on survey data that mainly addresses the organizational dimension of cloud computing. Further research should focus on other dimensions of value creation, such as products, services, and digital business models. Another limitation is related to the technology, in particular the cloud computing architecture. It would be interesting to identify the determinants of different cloud computing technologies. Finally, country effects were only seen for Japan (for the Transformational group) and Italy (for the Hyper Transformational group). It would be interesting to document country-level specificities in more detail.

- **Measurement**

Through Chapter 3, we have addressed the cloud adoption problem and proposed a new contribution for the technology adoption theories. However, we hold some limitations. Considering the aforementioned rules of different dimensions, most of them are confirmed except A.1 that is about the influence of enterprise size on cloud deployment models. The designed rules of different dimensions were not all measured by the survey, such as the rules in the variable dimension, we did a qualitative analysis to test the validation. Finally, our target surveyed participants were French enterprises, it holds the possibility of impacting the perception of a geographical area. In our future research, we will focus on these issues.

- **Qualitative factors**

We designed a decision-model for the selection of cloud providers in Chapter 4. However, there remains much to do. Like all quantitative models, our model presents some limitations that must be accounted for. In particular, our model currently focuses on cost, performance, agility and risk factors; it does not account for extensive qualitative factors that may influence cloud-computing decisions. Integrating these factors into a complete framework is a substantial challenge. Future studies must focus on these issues

- **Hypothesis**

As Chapter 5 stands, one of our current research limitations is that the hypothesis are not based on literature, and also, it lacks some technical depth. In our future research, we will focus on these issues, to proceed with a deep analysis statistically; to analyze more public cloud providers and offer toolboxes to evaluate applications' performance based on the results that we obtained.

6.3 Future research designs

This dissertation contributes a lot to the theoretical and managerial dimensions of cloud computing research, however, there exists more research work to do as the aforementioned research limitations. The thesis consists of two parts: cloud computing adoption (Chapter 2 and Chapter 3) and cloud computing decision-making (Chapter 4 and Chapter 5). From the perspective of cloud adoption, firstly, further research should focus on other dimensions of value creation, such as products, services, and digital business model. Secondly, we have to validate the hypothesis of variable dimension by quantitative methods in Chapter 3. From the perspective of cloud decision-making, we should detail the research of cloud performance and offer more comparison results. As time goes by, providers update their infrastructure and there will be more cloud providers entering the cloud market. In the future, we must update and compare more cloud providers. Developing a multi-cloud service that combines diverse strengths of different providers is another interesting subject in this area.

Appendix

Cloud Computing practices and firms' performance

The first Worldwide Global Survey (Europe, USA, Asia)

This survey forms part of the Cloud Based Organizational Designs (CBOD) project, supported by the French National Research Agency (ANR) (www.cbod.u-psud.fr).The objective of this multidisciplinary project is to deepen the scope of knowledge about the phenomenon known as "cloud computing" by developing a techno-economic analysis that will contribute to a better understanding of the practice of cloud computing.

This global survey aims to investigate the decision making context in relation to a set of technical, strategic, economic, and organizational criteria. It will be conducted in Europe (with the support of leading business associations), the United States and Asia.

Thank you for taking a few minutes to complete this questionnaire

If you would like to receive a copy of the analysis of the results please provide your e-mail address at the end of the questionnaire. You can also receive feedback in the form of the Executive Summary of the research program, together with ongoing interim results.

Data will be used for research purposes only. No other party will have access to any of the data from this questionnaire. Data will be analyzed in aggregate and anonymously (European directive 2002/58/EC).

Questionnaire

A-GENERAL INFORMATION
A-1 Information about yourself

Q 1. Position
- CXO (CEO, COO, CTO, CFO, CIO) (please specify)
- IT Manager / IT Executive/ IS Manger
- Business Manager
- Other manager in IS Department (please specify)
- Other manager in business /functional lines
- Other (please specify):

Q 2. Industry Sector
- Manufacturing (please specify)
- Information & communication industries (electronics, etc.)
- Engineering
- Construction
- Distribution services
- Financial services
- ICT services
- Public sector
- Other (please specify) :

Q 3. How much personal experience do you have in cloud computing practices (contracting, services coordination, etc.)?
- Less than 1 year
- 1 – 3 years
- 3 – 5 years
- > 5 years

A-2 Information about your company

Q 4. How many employees does your company have?

- Micro-enterprise: 1–9 employees
- Small enterprise: 10–250 employees
- Medium-sized enterprise: 250–5000 employees
- Large enterprise: more than 5000 employees

Q 5. What is the annual revenue of your company (million euros, 2014)

- < 2 M
- 2 – 50 M
- 50 – 500 M
- 500 – 1500 M
- More than 1500 M

Q 6. How long has your company been involved in cloud computing?

- Never
- < 1 year
- 1 – 5 years
- More than 5 years

A-3 IT Ressources

Q 7. Over the past three years (2012-2015) did your overall IT budget:

- increase
- remain stable
- decrease

Q 8. What was your company's IT budget in 2015 (million euros)?

- Below 1 million
- 1 – 5 million
- 5 – 10 million
- 10 – 20 million
- 20 – 100 million
- 100 – 500 million
- More than 500 million

Q 9. What percentage of your annual IT budget is dedicated to cloud services (approximate value)?

- Less than 5%
- 5% to 10%
- More than 10%

Q 10. What is the size of the workforce dedicated to IT services?

- 0 – 10 employees
- 11 – 50 employees
- 50 – 100 employees
- 100 – 500 employees
- 500 – 1000 employees
- More than 1000 employees

Q 11. How would you characterize your company's economic behavior and positioning with respect to…?

- **Economic growth** *(turnover): declining (<0%) / stable (0–5%) / growing (5–10%) / fast growing (>10%)*
- ***Innovation*** *(products, services): slightly lagging behind/ around the average of reference markets/ above competitors in reference markets*
- ***Data -driven decision making and innovation*** *: in the early stages / some experiments / programs routinely in place in some parts of the organization / generalized programs in critical business lines*

B- CLOUD COMPUTING GENERAL PRACTICES

Q 12. Which of the following cloud services applications are available in your company?

	Already migrated	Currently migrating	Future migration planned	No migration planned so far
IT tools				
Email				
Storage				
CRM applications				
ERP applications				
Database hosting				
Office software				
Data analytics				
Social networks				
IT Applications				
HR applications				
R&D applications				
E-commerce				
Accounting/Finance				
Sales marketing				
Web applications				
Others (…)				

Q 13. What type of cloud model have you adopted or are likely to adopt for cloud computing?

	Already adopted	May adopt in the near future	May adopt in the distant future	No plans to adopt
Internal private cloud				
External private cloud				
Internal open cloud				
External open cloud				
Hybrid cloud				
No idea				

*Internal Cloud-In this case, your firm is fully in charge of your used cloud resources
*External Cloud- In this case, the management of cloud resources is ensured by a cloud service provider
*Private Cloud- In this case, the cloud resources are dedicated to the firm's specific needs
*Public Cloud-In this case, cloud resources are open to the general public or other external organizations
*Hybrid Cloud- This case refers to an environment that mix both private and public cloud service

Q 14. What is the current status of cloud-enabled services in your company?

	Already adopted	May adopt in the near future	May adopt in the distant future	No plans to adopt
IaaS				
PaaS				
CaaS (Container as a service)				
SaaS				

Q15. Please list your main cloud providers (e.g. Google, Oracle, SAP,) and your level of experience with them

	Already using	Aware of and likely to consider	Aware of but not considering in the short term	Not aware
Your main cloud providers (please provide names)				

C- CLOUD COMPUTING ADOPTION BEHAVIOR

Q.16. Please specify the relative importance of the following factors in your decision to adopt cloud computing:

- Overall strategic vision of our company
- Business line pressures (including independence vis-a-vis the IT department)
- Innovation opportunities
- Service supplier pressure on general management and business lines
- Simplification and harmonization
- Reduction of costs

Other (please specify)

Q 17. We would like to know more about how useful you perceive cloud services to be. On a scale of 1–5, where '1' means 'not important at all', and '5' means 'very important', how do the following factors affect your decision to adopt cloud services.

a-Technology

- **Perceived usefulness**

1. Compared to current technologies, cloud computing enables us to accomplish our tasks more efficiently
2. Cloud computing technology will help us to reduce our operational, maintenance, updating and training costs
3. Cloud computing will contribute to the agility of the enterprise

- **Perceived ease of use**

1. Good internet connection and speed of cloud services
2. The ability to use and access cloud tools and my data anywhere
3. Negligible learning time for all employees

- **Compatibility**

1. Cloud computing technology is compatible with our current practices
2. Cloud computing technology is compatible with our firm's core values and goals
3. Cloud computing can easily be integrated into our existing IT infrastructure
4. Our applications are loosely coupled and independent

- **Complexity**

1. Cloud computing is too complex for business operations
2. The skills needed to adopt cloud computing are too complex for the firm's employees
3. The complexity of transferring current systems to a cloud computing platform
4. Uncertainty about the location of data limits the use of cloud computing services
5. The risk of a security breach limits the use of cloud computing services
6. We fully understand the conditions of data use in the cloud (terms of use, local regulations, etc.)

b-Management

- **Top management support**

1. The company's top management provides strong leadership and engages in the process when it comes to information systems
2. The company's top management is willing to take risks in the adoption of cloud computing

- **Adequate resources**

1. Our firm has enough resources to support the development of cloud computing technology
2. Our firm has enough time to develop cloud computing technology
3. Our firm has a budget that is sufficient to develop cloud computing technology
4. Our firm has enough human resources to develop cloud computing technology
5. Cloud computing facilitates the development of a "shadow" IT department

c-Environment

- **Vendor support behaviors**

1. The service level agreement (SLA) is guaranteed by the vendor
2. The vendor would cooperate in returning my data if I want to replace them
3. Our firm would receive adequate compensation for a vendor breach of the SLA
4. We can easily obtain support from cloud computing vendors during our cloud computing implementation
5. We can be trained in cloud computing in appropriate sessions provided by vendors

- **European government policy**

1. The government encourages firms to apply cloud computing
2. There are mediating organizations that support enterprises in the implementation of cloud computing
3. There are enough regulations to deal with legal challenges realted to cloud computing

- **Competitive pressure**

1. Our firm thinks that cloud computing has an influence on competition in their industry
2. Our firm is under pressure from competitors to adopt cloud computing

D- Organizational fit

***Q18.* Compared to your current situation, how would you characterize the impact of cloud computing on the *functionality* (irregularities, deficiencies) of your IT services (access, service delivery, operations, cost among others?)**

	No change	Negative	Mitigated/unclear	Positive
• Access to services (SLA)				
• Operations /processes				
• Interoperability & standards (including between cloud providers)				
• Services liability				
Reversibility, migration from one system to another				
• Control of tasks and services deliverable				
• Agility				
• Procurement				
• Cost				

Q19. Compared to your current situation, how would you characterize the impact of cloud computing on your data management (access, service delivery, operations, and cost among others)?

	No change	Negative (poor fit)	Mitigated (both good and poor fit)	Positive (good fit)
• Access to services				
• Operations /processes				
• Control				
• Risk				
• Legacy /cloud interoperability				
• Cost				

Q20. Compared to your current situation, how would you characterize the impact of your cloud computing practices on the usability (deficiencies vs efficiencies) of your IT services?

	No, or minor changes	Major and growing deficiencies	Major and recurrent deficiencies	Major and growthing efficiencies	Major and recurrent efficiencies
• Data access					
• Data localization					
• Data security					
• Data compatibility					
• Bandwidth					
• Data ownership & IPRs					
• Services reports & delivery					

Q21. Compared to your current situation, how would you characterize the impact of your cloud computing practices on the roles and competences of your IT services?

	No change	Negative	Mitigated	Positive
• Clarity of roles (who does what)				
• Availability of internal competences				
• Balance of competencies (internal vs external)				
• Alignment of competences and formal roles				
• Bottlenecks in tasks and workloads				

Q22. Compared to your current situation, how would you characterize the impact of your cloud computing practices on the control dimensions of your organization?

	No change	Deteriorated (increased rigidity, increased risk)	Mitigated (local rigidities + local flexibilities)	Improved (improved flexibility, decreased risk)
• Control of tasks				
• Services delivery				
• Tasks coordination (internal versus cloud providers)				
• Contractual arrangements				
• Managing contractual risks				

Q23. Could you describe your current governance structure for the cloud? Please specify the type of instruments you have implemented to monitor services delivery by cloud providers?

Governance structure for the cloud

Instruments used, including for data management

Q24. Compared to your current situation, how would you characterize the impact of cloud computing on your organization's culture?

	No change	Negative	Mitigated	Positive
• Formal rules and standards of behavior (formal execution and coordination of tasks, reporting mechanisms)				
• Formal rules and standards of behavior (informal coordination of tasks, reporting mechanisms)				
• Development of cloud culture				

E- Regulation, Data & IPRs
Please consider the following statements:

Q25. "With respect to data issues, we are fully aware of the importance of the legal aspects of data use (especially privacy) in different local contexts" (fully agree … completely disagree)

Q26. "With respect to data issues, we are fully aware of the content of local regulations (especially privacy) and we take it into account when it comes to the use of data in different business contexts"
(fully agree … completely disagree)

Q27. "With respect to data issues, we are fully aware of the IPRs and business issues related to data and we take them fully into account in our applications"
(fully agree … completely disagree)

F- Cloud Future (s) design
This section is oriented towards the design of cloud solutions based on emerging practices and issues.

Q28-Based on your experience, can you foresee an IT infrastructure that is almost or 100% on the cloud? If yes, how?

Q29. Can you foresee full interoperability between cloud solutions and systems (including legacy systems)?

Q30. Do you clearly understand how to move from one system to another?

Q31. How do you foresee the dynamics of cloud systems, especially movements between IaaS, PaaS and SaaS?

PLEASE ADD ANY FURTHER COMMENTS

天行健，君子以自强不息；

地势坤，君子以厚德载物。

一易经

As Heaven maintains vigor through movements,

A gentle man should constantly strive for self-perfection.

As earth’s condition is receptive devotion,

A gentle man should hold the outer world with broad mind.

ÉCOLE DOCTORALE
Sciences de l'homme et de la société (SHS)

Titre : cloud computing et la décision : déterminants, modélisation et impacts

Mots clés : cloud computing, fournisseurs de cloud, l'adoption de cloud, facteurs de la décision

Résumé : Cette thèse cherche à traiter des sujets de l'adoption de cloud et la décision de cloud. Elle analyse des déterminants de l'adoption, discute des services de cloud et compare des fournisseurs de cloud.
Cloud computing a des dimensions à la fois techniques et organisationnelles. Jusqu'à présent, la dimension organisationnelle a reçu peu d'attention, et cloud computing a été essentiellement considéré d'un point de vue technique. Cependant, la "cloudification" des systèmes d'information pose de nombreuses questions économiques et managériales qui doivent être évaluées. Il est donc important d'enrichir notre compréhension des phénomènes liés à la "virtualization" de l'information, à travers un examen de leurs caractéristiques multidimensionnelles.
En général, cette thèse démontre que l'utilité perçue, la facilité d'utilisation perçue, la complexité et la compatibilité sont des facteurs clés de l'adoption de cloud, le savoir-faire informatique joue également un rôle important dans le processus de la décision ; La plupart des petits fournisseurs de cloud ont des performances plus stables et plus efficaces que les grands fournisseurs de cloud, la performance du processeur ayant un impact significatif sur le prix.
Cette thèse contribue beaucoup aux dimensions théoriques et managériales de la recherche sur cloud, mais il y a plus de travail de recherche à faire du point de vue de l'adoption de cloud et de la prise de décision dans le cloud. La recherche future se concentrera sur ces points.

Title : cloud computing and decision-making : determinants, modelling and impacts

Keywords : cloud computing, cloud providers, cloud adoption, decision factors

Abstract : This dissertation addresses cloud computing adoption and decision-making issues. It analyzes adoption determinants, discusses cloud services, and compares cloud providers.
Cloud computing has both technical and organizational dimensions. Until recently the organizational dimension has received little attention, and cloud computing has essentially been considered from a technical perspective. However, the "cloudification" of information systems poses many economic and managerial questions. It is therefore important to enrich our understanding of phenomena related to the "virtualization" of information, through an examination of their characteristics.
Overall, this dissertation finds that perceived usefulness, perceived ease of use, complexity and compatibility are key factors for cloud adoption, IT know-how also plays an important role in the decision process; Most small cloud providers have more stable and better computing performance than large cloud providers, the performance of CPU impact price significantly.
This dissertation contributes a lot to the theoretical and managerial dimensions of cloud computing research, however, there exists more research work to do from the perspective of cloud adoption and cloud decision-making. Future research will focus on the research limitations.

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