ESSAYS ON ANTECEDENTS AND CONSEQUENCES OF CLOUD COMPUTING CAPABILITIES IN ORGANIZATIONS: AN EMPIRICAL ANALYSIS OF FIELD DATA

BY

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DISSERTATION

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ABSTRACT

Cloud computing is widely recognized as a potential disruptive paradigm that changes how IT is consumed and business is conducted in various industries. Managerial and academic literature has shown that cloud computing may benefit firms in various ways such as cost savings, fast project development, and business innovation. Nevertheless, there are many different interpretations and perceptions of cloud computing about how to better prepare for and use it in the information systems (IS) literature. A systematic analysis is necessary to clarify the equivocal issues around cloud computing and guide managers to better understand and utilize cloud computing in practice. This dissertation addresses several important relationships around cloud computing using theoretical models and empirical data as a representation of how the questions about cloud computing may be investigated in the IS literature and how the findings may benefit organizations in using cloud computing. Therefore, the dissertation comprises three connected chapters that address one important antecedent of cloud computing adoption – internal IT modularity within firms and two important consequences – firm performance and strategic alliance formation. It is found that in order to better prepare for cloud computing adoption, firm users can do something themselves by modularizing their internal IT systems. Firms also need to know whether and how cloud computing, after all, can benefit their firm performance or other activities such as strategic alliance formation. The findings show that cloud computing overall and its various specific cloud services may promote firm performance directly or complementarily with internal enterprise resources. Cloud computing and its specific cloud services may also exert different effects on strategic alliance formation. This dissertation systematically addresses the issues around cloud computing in the IS literature and sheds lights

on how such a study can be applied to help managers and decision makers in industries to better understand and use cloud computing to achieve their business goals.

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CHAPTER 1: GENERAL INTRODUCTION

In the past decade, cloud computing has gained its momentum in commercialization. Cloud computing is a novel information technology (IT) consumption model that synthesizes multiple preceding technologies such as networking, grid computing, distributed computing, virtualization, utility computing and service-oriented computing and allows users to provision, consume and dispose of IT resources (including raw resources, system and platform software, and applications) as they need (Armbrust et al. 2010; Marston et al. 2011; Zhang et al. 2010). In theory, organizations no longer need to plan and own their own IT resources. Rather, they simply subscribe to cloud providers and are billed for what IT resources they have consumed. Cloud computing offers organizations with abundant, affordable and easily accessible IT resources from third parties[1], frees organizations from owning and managing IT resources and systems, and eventually enables organizations to focus on their core businesses and innovation (Brynjolfsson et al. 2010). It is widely observable that cloud computing has been successfully utilized by various firms in different industries. Small businesses have used third-party cloud computing resources such as from Amazon Web Services (AWS)[2] to energize and pursue the projects they would have never been able to and compete with the incumbent tech giants on an equal footing IT resource basis. Large enterprises have also shown great interests in cloud computing and tried to use cloud applications and platforms even though they may have considerable internal IT resources (Marston et al. 2011).

[1] Here we assume that cloud computing is provided mainly by third-party cloud vendors (i.e., public clouds), though it can also be provided and owned privately by consumer organizations (i.e., private clouds). See more details about public and private clouds in Mell, P., and Grance, T. 2010. "The NIST definition of cloud computing," *Communications of the ACM* (53:6), p 50.

[2] See the Amazon Web Services website for more details: https://aws.amazon.com

Cloud computing is an umbrella paradigm that contains multiple types of services such as the three basic service layers of Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) (Mell and Grance 2010) and many other extended services such as Knowledge as a Service (KaaS) and Business Process as a Service (BPaaS). Given these many cloud services, organizations may perceive, interpret and utilize cloud computing in various ways. For example, while many startups and small companies appreciate the enablement and convenience of cloud computing, others may think that cloud computing is merely a cost-saving means for them and cannot provide any sustainable competitive advantage. Companies are also very concerned about the risks cloud computing can bring such as IT availability, security and privacy (Zhang et al. 2010). Anecdotes are evident about stories of success and failure. However, there is a lack of research in the information systems (IS) literature to support those observations theoretically and to systematically help and guide companies to be more ready for and better use of cloud computing in the midst of so many different interpretations and understandings.

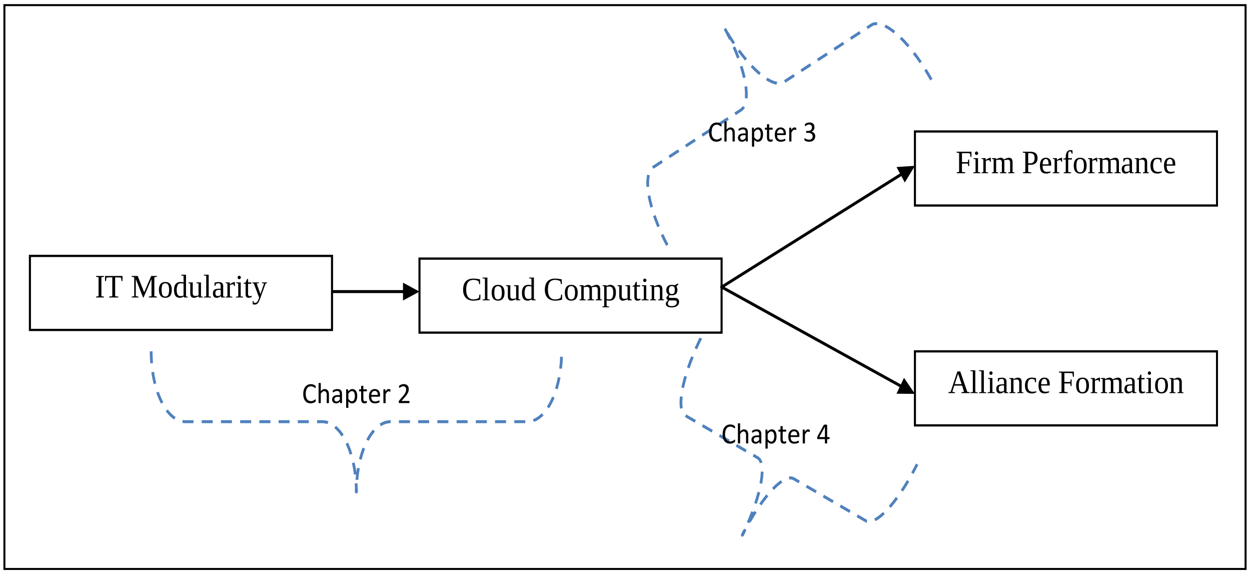
This dissertation addresses several important questions concerning cloud computing. First, it is a twofold issue to address the cloud risks and more generally the usability of cloud computing – from the perspective of cloud providers as well as of cloud users. Cloud providers such as Amazon and Microsoft have been constantly improving their cloud service qualities including minimizing the cloud risks. There are also numerous articles that address how to mitigate those risks in the cloud (A Vouk 2008; Bernstein et al. 2009; Catteddu 2010; Chow et al. 2009; Jensen et al. 2009; Pearson 2009; Santos et al. 2009; Yu et al. 2010). Nevertheless, literature has seldom addressed the potential efforts from the cloud users that can help prevent or alleviate the cloud risks and improve the adoption of cloud computing. Second, even though organizations are more at ease to adopt cloud computing, they need to evaluate whether cloud computing is beneficial for them in terms of firm performance improvement or other types of improvement. Therefore, this dissertation connects one antecedent and two consequences of cloud computing adoption that are important for the audiences to better understand cloud computing and its practical usages in companies. Chapter 2 of this dissertation is dedicated to the study of the IT modularity antecedent and its relationship with cloud computing adoption. Chapter 3 investigates the connection between cloud computing and one of its important consequences to organizations – firm performance. Chapter 4 is organized to study another important consequence of cloud computing adoption – strategic alliance formation. The overall structure and connection of the three chapters in the dissertation can be shown as in Figure 1.1.

The three chapters of the dissertation all utilize theoretical models and empirical data to analyze the connections of the antecedent and consequences of cloud computing. In Chapter 2, a cross-sectional survey dataset containing 457 firms is used to analyze the effect of IT modularity on cloud computing adoption. The empirical analysis reveals that different levels of internal IT modularization within firms help them better adopt different types of cloud computing services. In detail, strategic-level IT modularization such as companywide service-oriented architecture (SOA) implementation may help firms better adopt application-level cloud services such as Software as a Service (SaaS) no matter whether they are small businesses or large enterprises. Non-strategic internal IT modularization such as specific SOA application projects is beneficial for better use of server-level cloud services (i.e., cloud infrastructures and platforms) only for small and medium-sized enterprises (SMEs), not for large firms. Chapter 3 addresses the important question of in what mechanism cloud computing can improve firm performance using cross-sectional and panel data from more than 200 large enterprises that span multiple industries. The findings show that cloud computing as a whole as well as several specific cloud services can improve firm performance measured by Tobin's q. Chapter 4 uses panel data to investigate whether and how cloud computing can help firms to conduct strategic alliance formation. It is found that cloud computing in general and its specific services may exert varied effects on different types of alliance formation.

Through the three empirical chapters, the dissertation signals the importance and possibility of systematically examining cloud computing, and provides and enriches our understanding about cloud computing and its connected constructs in the IS literature. It also offers guidance that can be applied in practice by firms to better prepare for and use cloud computing services to achieve better results. In addition, Chapter 5 serves as a concluding chapter that synthesizes the findings of all there empirical chapters and potential future research streams.

1.1 Figures

Figure 1.1. Overall structure of the dissertation



CHAPTER 2: THE EFFECT OF IT MODULARITY ON ADOPTION OF CLOUD COMPUTING

Abstract

Cloud computing has become a very popular technology that can enable firms to access, utilize and dispose of IT resources cost-effectively and flexibly. Numerous anecdotal cases have illustrated the successful adoption of a variety of cloud services to help firms achieve business goals and strategies. Nevertheless, many times firms, especially those with substantial in-house IT investments, are hesitant to use external cloud services with concerns about the uncertainty, potential costs and risks associated with this new paradigm. Many studies have tried to address the relevant technical or management issues on the side of cloud computing itself, but few have considered whether and how firms can do something within their own organizational borders to reduce the risks and concerns, as well as to be more ready to use cloud services. This paper addresses this literature gap and argues that modularization of the internal IT systems within a firm may play a pivotal role in promoting its use of cloud services. Using data from 457 firms including SMEs and large enterprises, we show that IT modularity aimed for strategic business transformation within firms can help them better adopt application-level cloud services regardless of their firm sizes. IT modularity associated with specific application projects can help better use server-level cloud services for those SMEs, but not for large enterprises. Our theoretical development and empirical analysis of the effect of IT modularity on cloud computing adoption have significant implications for IS theory as well as practice on how firms can be more ready for using cloud computing.

Keywords: modularity, IT modularity, cloud computing, service-oriented, transaction costs, outsourcing, small and medium-sized enterprise (SME), large enterprise

2.1 Introduction

As John McCarthy imagined in 1961 that one day computing power and even specific applications could be sold through the utility business model like water or electricity (Dikaiakos et al. 2009), this long-held dream of computing as a utility has finally come true recently as an integral part of the new paradigm called "cloud computing". This dream could not have been realized without the contribution of several important preceding advances in computer science since the 1960s, namely time-sharing technology, Internet and Web, grid computing, distributed computing, service-oriented computing, and virtualization (Marston et al. 2011; Zhang et al. 2010). Enhanced on top of those technologies, cloud computing evolved into a commercialized IT model in the early years of the 21st century (Marston et al. 2011; Zhang et al. 2010). Cloud computing inherently is a scalable, flexible IT model that emphasizes ubiquitous access to various IT resources based on the pay-per-use or utility-like billing model, not ownership of such resources (Marston et al. 2011; Mell and Grance 2010; Vaquero et al. 2008; Zhang et al. 2010). This IT consumption model has freed firms from the chores and burdens of IT ownership and enabled them to instead focus on their core businesses and competitive strategies. As Brynjolfsson et al. (2010) have argued, cloud computing indeed is not only utility computing, but also has the power to transform how businesses are conducted.

Since the commercialization of cloud computing, many companies started using various cloud computing services such as Software as a Service (SaaS) and there has been some debate on the value of subscribing to cloud computing services over spending on traditional IT resources such as in-house servers and software.

On one hand, many firms value the freedom and flexibility of IT resource/application access, management, and innovation. For instance, Google Document, a SaaS-based word processing and collaborative application, allows a user to collaborate with her colleagues on a common document in real time, no matter what computer device she is using (e.g., a PC, a tablet or a smart phone). She even can continue her editing work after switching to another device without losing any of her previous work. Netflix, a SaaS-based streaming media provider, allows millions of simultaneous users to watch online movies anytime, anywhere with any supported devices, thanks to the massive, scalable IT capacity provided by the well-known cloud provider Amazon. Foursquare, Twitter and Reddit[3], like many other small startups at that moment, successfully utilized the benefits of no or minimum upfront IT capital investments of the cloud services provided by Amazon to promptly engage in providing advanced, innovative applications and services to their customers. The New York Times utilized cloud computing to process its enormous amount of newspaper archives cost-effectively in less than 2 days (NYT TimesMachine 2008).

On the other hand, some firms are concerned about the potential risks in this new IT model (Armbrust et al. 2010), especially firms that already have substantial in-house IT resources. For example, financial service firms such as banks, securities firms and insurance companies are hesitant to use cloud computing because of the significant legal and regulatory challenges, such as issues of financial privacy, customer data protection, and business continuity (Bloomberg 2012). As to cloud availability and business continuity, cloud outages can bring adverse impacts on firms whose businesses are dependent on third-party cloud services such as in the cases of

[3] Foursquare is a local search and discovery service mobile app. Twitter is an online social networking service that allows users to send and receive short messages. Reddit is an entertainment, social networking and news aggregation website where users can submit and share their own content.

Reddit and Airbnb (Amazon Outage 2012)[4]. The IDC survey (2009) summarized the set of concerns that firm users think cloud providers need to address well: 1) security, 2) availability, 3) performance, 4) cost, 5) interoperability standards, 6) avoiding lock-in due to the difficulty of reverting back to in-house systems, 7) integration with in-house IT, and 8) customization.

Therefore, we ask the question – how can firms better adopt and utilize the benefits of cloud computing without fearing the disadvantages? Since the question mainly relates to two sides, it may be addressed from either the perspective of providers or users of cloud computing systems. The mentioned risks and challenges of cloud computing affect cloud providers, cloud users (i.e., those who use services from cloud providers and on top of that to provide their own cloud services to end users) as well as end users (i.e., the consumers who directly use a complete cloud application or service).

Indeed, many prior academic papers have discussed the challenges and risks cloud providers face, mainly from a technical point of view. Data security has been widely recognized as one of the major challenges (Jensen et al. 2009; Motahari-Nezhad et al. 2009; Popović 2010; Subashini and Kavitha 2011; Yu et al. 2010; Zhang et al. 2010; Zissis and Lekkas 2012). Foster et al. (2008) and A Vouk (2008) identify provenance (i.e., the derivation history of a data product) and security as two of the biggest challenges in cloud computing. Pearson (2009) specifically addresses privacy issues in cloud computing. Takabi et al. (2010) focus on discussing the challenges in security and privacy which are categorized into 1) authentication and identity management, 2) access control and accounting, 3) trust management and policy integration, 4)

[4] A few months earlier in 2012, Amazon's cloud service experienced an outage in the East Coast region in US, taking down popular sites like Reddit and Airbnb for several hours.

secure-service management, 5) privacy and data protection, and 6) organization security management. In addition to legal and privacy issues, Khajeh-Hosseini et al. (2010) discuss the challenges that cloud computing brings about in the organizational changes as well as the economic and organizational implications of the utility billing model. Dillon et al. (2010) view cloud computing challenges from two angles: cloud adoption and cloud interoperability. They emphasize the challenge of security and what to migrate in the first category and standard and open API (i.e., Application Programming Interfaces) in the second category. Dikaiakos et al. (2009) and Rimal et al. (2009b) analyze that cloud interoperability, and security and privacy among the most important challenges. Armbrust et al. (2010) have summarized ten important challenges (i.e., obstacles) of cloud computing[5]. Leavitt (2009) generally concurs with Armbrust et al. (2010), adding a concern in related bandwidth costs. Buyya et al. (2009a) summarize even more challenges and some of the additional ones are quality of service (QoS) and service level agreement (SLA), resource metering, pricing and billing, and energy efficiency, and so on. Brynjolfsson et al. (2010) argue that, since cloud computing is beyond just utility computing, the real challenges are complementarities and co-invention, lock-in and interoperability, and security to unleash the full potential of cloud computing.

Seeing those technical challenges and risks, prior studies have focused on addressing them from the perspective of cloud providers (A Vouk 2008; Bernstein et al. 2009; Catteddu 2010; Chow et al. 2009; Jensen et al. 2009; Pearson 2009; Santos et al. 2009; Yu et al. 2010).

[5] 1) availability and business continuity, 2) data lock-in, 3) data confidentiality and auditability, 4) data transfer bottlenecks, 5) performance unpredictability, 6) scalable storage, 7) bugs in large distributed systems, 8) scaling quickly, 9) reputation fate sharing, 10) software licensing.

There is a scarcity of literature that has considered mitigating cloud risks and concerns indirectly from the other side of the issue – the cloud users. That is, whether and how can firm users of cloud computing do anything within their firms to have an easier time to adopt cloud computing, given the present potential and perceived cloud risks and concerns? Is there anything related to firms' internal IT systems on this aspect? Hence, in this paper, we focus on the perspective of cloud users.

Real-world cases show that certain changes in a firm's internal IT systems may indeed help mitigate the risks and uncertainties when using external cloud services.

Mohawk Fine Papers (Computerworld 2012), which manufactures premium paper products, had a need to integrate all kinds of data across its supply chain partners with its ERP system such as ordering, HR systems, planning and scheduling, in a flexible, agile, and cost-effective way. This kind of integration traditionally had used a messaging, point-to-point EDI approach, but this approach required too much IT up-front and expertise for Mohawk. The company then sought an alternative way, a service-based model, to solve this task – they hired a cloud service broker (CSB) called Liaison Technologies to use their expertise in this area for this task. Liaison helped the company build a service-oriented architecture (SOA) in the Amazon cloud and connect various cloud-based integration services with Mohawk's on-premise ERP system. The new model has allowed Mohawk to quickly set up new business relationships while minimizing the costs and technical hurdles, and to produce new revenue opportunities and millions of dollars in cost savings. The IT department of Mohawk now can focus on more value-added tasks such as developing new business models and connecting with new business partners rather than creating and maintaining the connections. The low cost per integration and the rapid turnaround have given the company the flexibility to create new business relationships and build business processes on a trial basis as well as to tackle smaller projects that would have been impossible before. The company has a vision regarding this model that monolithic enterprise applications will disappear eventually and an ecosystem of cloud services will be interoperating with other workflows and processes that can be anywhere.

Forrester Vice President Jeffrey Hammond (SearchSOA 2013) points out that the new major challenges of today for businesses are to be agile, to respond to customer feedback and act on it quickly, to provide a desirable user experience, and to provide a flexible infrastructure that supports future applications. He argues that more and more smaller projects will be examined in order to pursue such needs. The small project experimentation trend reinforces the usefulness of the loosely-coupled, modularized SOA concept. In this approach, companies publish their changes and updates for modular components early and independently, rather than grouping them into major releases. He calls this a 'continuous delivery' model in enterprise development. McKendrick (ZDNet 2009) envisions the emergence of the loosely coupled companies which may exist purely as an aggregator of third-party services. Most of the services will be SaaS which can reside anywhere in a private cloud, a public cloud, a community cloud, or a hybrid cloud[6]. He predicts this entrepreneurial spirit will be embraced not only by startups but also by even the largest and most progressive companies to do business in the virtual, componentized way. Mohan Sawhney, a professor of Business Administration at Kellogg, Northwestern, believes that the most efficient companies are those as "orchestrators" of available services,

[6] See more details about the cloud deployment models in Mell, P., and Grance, T. 2010. "The NIST definition of cloud computing," *Communications of the ACM* (53:6), p 50.

rather than actual producers (ZDNet 2009). Cloud computing promotes the model of component delivery and the emergence of the phenomena of corporation-as-service-orchestrator (ZDNet 2009).

These cases illustrate that firms, as cloud users, may adopt cloud computing more easily if they modularize their internal IT systems more (e.g., through a service-oriented architecture). IT modularity has been endowed with new meanings with the advent of cloud computing.

Modularity refers to the design principles for a complex system consisting of components or units that can be designed independently yet function together as an integrated whole (Baldwin and Clark 2003). Modularity as a broad concept has been extensively studied in IS literature. Many papers have emphasized the importance and benefits of modularity in various industries. Modularity can reduce system complexity (Baldwin and Clark 2000; Langlois 2002; Parnas 1972; Simon 1991), promote innovation by allowing freedom in module design, and mix and match of modules (Argyres and Liebeskind 1999; Baldwin and Clark 2000; Ethiraj and Levinthal 2004; Langlois 2002), as well as flexibility and agility (Baldwin and Clark 2003; Sanchez and Mahoney 1996; Schilling 2000; Worren et al. 2002).

Anecdotal cases also testify the effects of modularity. Amtrak (InformationWeek 2006) was very concerned with the limitations and rigidity of its point-to-point integrations between its mainframe-based host systems and applications such as call centers, ticket reservation system and website. The legacy systems made it difficult and costly to initiate business process changes in an agile and flexible manner. Business-to-business (B2B) connections were also difficult.

Some travel sites even gave up connecting to Amtrak's system after unsuccessful tries of several months. The point-to-point integration incurred a lot of redundancies and maintenance overhead. Seeing the difficulties, Amtrak considered using a service-based middleware to hide the complexity of its mainframe systems, reduce unnecessary costs and rigidity, and improve flexibility and agility. By using a common set of Web services under the service-oriented architecture (SOA)[7] which is a specific form of modularization, Amtrak became more adept at exchanging information between its customer distribution channels and back-end systems, and in turn, became more responsive to customer needs.

City University London (IBM 2010) conducted most of its annual registration process for over 8,500 new students manually. This involved tremendous paperwork and it was very time-consuming and costly. Staff and students' time was wasted in the tedious registration process and couldn't be used for more valuable activities. The University decided to use a module-based architecture that uses IBM WebSphere Process Server to automate the entire process. The project was a huge success. Student registration time was reduced by more than 95%. Paperwork was essentially eliminated and the University experience for the new students was improved. Total financial cost savings was approximately £20,000 per year. The modularized architecture not only enhanced the registration experience for staff and students but also enabled new opportunities and innovations for future business process improvements for the University. For example, student demographics could be easily analyzed using data mining techniques to help meet regulatory requirements and gain appropriate government funding.

[7] SOA is an approach to reorganize IT infrastructures and applications into interconnected services (Papazoglou 2003).

Whereas prior studies have focused on modularity in reducing complexity, enhancing innovation, flexibility and agility, as aforementioned, there is no much work that has been done in studying IT modularity as an enabler of cloud computing adoption. Given the present risks and concerns in cloud computing, our paper tries to address this interesting and important research question: Are firms more likely to adopt cloud computing if they modularize their internal IT systems?

The purpose of this study is to empirically examine the relationships between a firm's internal IT modularity and adoption of cloud computing. IT modularization in an enterprise, especially those with substantial in-house IT assets, may help it adopt and utilize cloud computing. Using data from 457 firms including SMEs and large enterprises across various industries, we show that for both SMEs and large enterprises, internal IT modularity aimed for strategic business transformation can help a firm to better adopt application-level cloud services (i.e., SaaS applications) while a modularization approach in specific project development and delivery may instead hinder the adoption of application-level cloud services. We also show that SMEs and large enterprises may experience different results when using IT modularity as a strategy to promote their adoption of server-level cloud services (i.e., Infrastructure as a Service or IaaS, and Platform as a Service or PaaS). The theoretical derivation and empirical analysis of the effect of IT modularity on adoption of cloud computing have a significant contribution to the IS literature. Our study offers a new perspective of how to enable enterprises with IT legacies to use cloud computing without worrying too much about its risks.

In the following sections, we first present a theoretical framework based on which our hypotheses are derived. We argue that this relationship is driven by various transaction cost reductions and relevant effects such as outsourcing that augment the benefits and reduce the risks of cloud computing offered by IT modularity. We then elaborate how we collect the relevant data, construct the measures for the variables, as well as build the estimation models we use in our analysis. We then go on with presenting our empirical results and robustness checks. Finally, we present the main findings, implications and contributions to the research and managerial aspects, as well as limitations and work that can be done in the future.

2.2 Theoretical Framework and Hypotheses

In this section, we present the structure of our arguments and theoretical support for the link between IT modularity and adoption of cloud computing. The logical components of the argument for IT modularity and adoption of cloud computing can be illustrated in Figure 2.1: IT modularity is associated with adoption of cloud computing by the theory of TCE.

2.2.1 Cloud computing and its taxonomies

As a still-evolving paradigm, cloud computing may have many different definitions, depending on what perspective a person emphasizes. However, there is a fairly comprehensive definition that covers the essence of cloud computing given by Mell and Grance (2010, p. 6), which says: "A model for enabling 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 definition largely agrees with the one proposed by Vaquero et al. (2008) consolidating various definitions of cloud computing.

Cloud computing has the following beneficial characteristics (Marston et al. 2011; Mell and Grance 2010; Vaquero et al. 2008; Zhang et al. 2010): 1) agility and flexibility, 2) cost savings and lower barriers to entry for IT resources, 3) device and location independence, 4) virtualization, 5) multi-tenancy, 6) on-demand self-service, 7) shared resource pooling, 8) scalability and elasticity, 9) loosely coupled architectures, and 10) measured and pay-per-use service.

The services provided by cloud computing can be grouped into several conceptual layers which are called service models. Mell and Grance (2010) summarizes the three basic and fundamental service models as Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS).

SaaS provides cloud consumers (including end users and cloud users) with the capability to use the provider's ready-for-use applications running in the cloud (Mell and Grance 2010). It is the most visible layer to the end users of the cloud (Youseff et al. 2008). The customer relationship management (CRM) application from Salesforce.com, Facebook and Gmail are three well-known SaaS application examples. An end user, for example, a Gmail user, need not develop or install any software application herself on her own computer. Instead, she just needs a web browser and Internet access to visit the SaaS application of Gmail online, sign in with her username and password, and use the email application as she may have used any such application installed on her local computer.

PaaS provides cloud users with the capability to deploy user-created or acquired applications in the cloud using the programming languages, the computing platform and a set of well-defined APIs supported by the cloud provider (Mell and Grance 2010). Google App Engine is an example of this category. It allows developers to build and run applications on Google's cloud infrastructure.

IaaS provides cloud users with the capability to provision processing, storage, networks, and other fundamental infrastructure resources where the consumer can deploy and run any software including operating systems and applications (Mell and Grance 2010).

More concisely, the above three basic service models can be classified into two major groups: application-level services and server-level services because the two groups have an essential difference: application-level services typically provide end cloud products and services to be consumed by end users directly (though application-level services might still be used to enhance and create another new service such as in a mashup application), while server-level services typically only provide foundational hardware or software resources to be further used by cloud users to build ready-for-use cloud products or services. The application-level services mainly include SaaS and the server-level services mainly include PaaS and IaaS. In other words, the application-level cloud services are more transparent for firms and users to use comparing to the server-level cloud services because the firms and users need not do any development, major change or investment to adopt the application-level cloud services, as demonstrated in the Gmail case. In many cases, a simple web interface and a network connection are all that is required to use application-level cloud services. On the contrary, server-level cloud services usually demand firms and users to have a deep understanding of the technologies to acquire and develop their own applications in the cloud.

In addition to the cloud service models, cloud computing can be deployed differently following several models. Mell and Grance (2010) summarize the deployment models as private cloud, community cloud, public cloud, and hybrid cloud. A private cloud is operated solely for an organization and typically owned by that organization as well. The organization enjoys the total ownership of the cloud. A community cloud is a collaborative endeavor by several organizations and typically they collectively own the community cloud. A public cloud is made available for public access and use. It is typically owned by a cloud provider whose main business is to sell the cloud services to the public on a pay-as-you-go basis. An example is Amazon Web Services (AWS)[8]. A hybrid cloud is a composition of two or more aforementioned cloud deployment models.

2.2.2 IT modularity

Simon (1991) proposes the early notions of modularity such as nearly decomposable systems and loosely coupled components in addressing the architecture of complex systems. Emerging largely due to the successful practice of module-based design in managing complex technologies in the computer industry, the explicit term of modularity is defined as a general set of design

[8] Amazon Web Services is a set of public cloud services provided by Amazon. For details, see https://aws.amazon.com

principles for composition of a complex system of small subsystems or units that can be designed independently yet function together as an integrated whole (Baldwin and Clark 2003). The subsystems or units are called modules. To achieve a modular design, Baldwin and Clark (2003) suggest information be partitioned into visible design rules and hidden design parameters. The hidden design parameters are decisions within a local module – they do not affect the design beyond it. The visible design rules are decisions that affect subsequent design decisions and fall into three categories: architecture, interfaces, and standards.

2.2.2.1 IT infrastructure modularity

Byrd and Turner (2000, p. 172) define IT infrastructure as: "The shared IT resources consisting of a technical physical base of hardware, software, communications technologies, data, and core applications and a human component of skills, expertise, competencies, commitments, values, norms, and knowledge that combine to create IT services that are typically unique to an organization. These IT services provide a foundation for communications interchange across the entire organization and for the development and implementation of present and future business applications." This is a definition consisting of two components from prior literature: the technical component (Duncan 1995) and the human component (Broadbent 1998; Byrd and Turner 2000). However, we focus on the technical component of IT infrastructure in this study.

IT infrastructure modularity is often discussed as one of the dimensions of the IT infrastructure flexibility construct (Byrd and Turner 2000; Chung et al. 2005; Duncan 1995; Fink and Neumann 2009). Byrd and Turner (2000) show that the technical component of IT infrastructure flexibility comprises two distinct factors: integration and modularity, each of which in turn has two sub-factors. Integration consists of IT connectivity and IT compatibility (Duncan 1995) while modularity consists of application functionality and data transparency (Dakin 1993; Gibson 1994). Application functionality is about the ability to add, modify, and remove the modules of software applications with little or no widespread effect on the applications collectively. Data Transparency is about the free retrieval and flow of data between authorized personnel in an organization or between organizations regardless of location (Dakin 1993; Gibson 1994).

2.2.2.2 IT architecture modularity

Tiwana and Konsynski (2010, p. 288) define IT architecture as "the overarching structure and properties of the relationships among the systems and applications in an organization's IT portfolio", and IT architecture modularity is "the degree to which an organization's IT portfolio is decomposed into relatively autonomous subsystems". The subsystems are atomic, fine-grained units of functionality which can be software components, modules, objects or services, and they can be easily mixed and matched with other modules to construct a new process (Sanchez and Mahoney 1996). Ulrich (1995, p. 422) defines a modular architecture includes "one-to-one mapping from functional elements to physical components of the product, and specifies decoupled interfaces between components".

2.2.2.3 IT modularity consolidated

Considering the previous literature regarding modularity and IT modularity, we define IT modularity as a general set of design principles for composition of a complex IT system (in the sense of infrastructure or architecture) from small autonomous subsystems or modules that can be designed independently yet function together as an integrated whole in the context of either IT infrastructure or IT architecture, which reflects the degree to which a firm's IT portfolio is decomposed into relatively independent, reusable subcomponents.

2.2.3 Firm size

Companies may be generally divided into two major types according to their personnel size: small and medium-sized enterprises (SMEs) and large enterprises. SMEs (or small and medium-sized businesses, SMBs) are companies whose personnel numbers fall below certain limits (Wikipedia, Small and medium enterprises). Here we adopt the standard from Forrester Research Inc. that an SME is a company whose number of employees is between 2 and 999 inclusive. A large enterprise is a company whose number of employees is 1,000 and more.

There are certain significant differences between SMEs and large enterprises. Prior literature finds differences between SMEs and large enterprises when they adopt IT systems or applications. Themistocleous et al. (2005) find that SMEs and large enterprises have different reasons when deciding to adopt an enterprise resource planning (ERP) system. Structural and organizational reasons[9] are the major ones for SMEs when they consider ERP adoption while organizational reasons are the major ones for large organizations. As to the decision process regarding the adoption of an ERP system, an SME is more affected by exogenous reasons than business-related factors, while a large enterprise is more interested in managing process integration and data redundancy/inconsistency through ERP implementation. Laukkanen et al. (2007) find significant differences between small, medium-sized and large enterprises regarding

[9] Structural reasons are those related to the need for managing and coordinating complicated business activities. Organizational reasons are those related to the organizational changes brought by the ERP implementation. (Themistocleous et al. 2005)

the objectives and constraints of ERP system adoption. Small enterprises experience more knowledge constraints while large enterprises are challenged by the changes imposed by ERP adoption. Large and medium-sized enterprises are more proactive in ERP adoption than small enterprises. While all types of companies regard business development as the major objective for ERP adoption, medium-sized enterprises take it most seriously.

Daniel and Grimshaw (2002) compare the reasons of adopting electronic commerce (e-commerce) by small and large companies in the UK. They find that small businesses are more driven by the e-commerce capabilities of responding to competitors, providing enhanced customer services and improving relations with suppliers while large enterprises are only more interested in improving operational efficiency. In addition, small businesses believe that they have achieved greater benefits from their e-commerce services than the large enterprises. Karlsson and Olsson (1998) find that regional environment plays different roles in product innovation in enterprises of different size. Counter-intuitively, their empirical results show that large enterprises are more dependent upon their regional environment than SMEs for an early adoption, that is, they need the resource-rich environment offered by the core urban regions. SMEs prefer peripheral regions that are able to provide an innovative environment. Sun and Cheng (2002) investigate the reasons behind, practices and effects of ISO 9000 certification and Total Quality Management (TQM) implementation in Norwegian SME and large manufacturing companies and find significant differences between SMEs and large firms in implementing ISO 9000 certification and TQM. For example, the impetus for the SMEs to implement ISO 9000 and TQM is mainly from external pressure such as market and customer demand rather than internal initiation. SMEs are more likely to use casual, people-oriented approaches in TQM implementation while large enterprises are more structured, organized, and process-oriented. Different facets of TQM contribute differently in SMEs and large enterprises. Spanos et al. (2001) study the changes in competitive strategy, structure and management processes that Greek firms confronted when Greece was about to join the Economic Monetary Union (EMU). They find that firm size has a significant impact on the degree and direction of the changes in the three dimensions. SMEs seem to be less able and/or less willing to implement change probably because of size-related disadvantages.

Specifically in cloud computing adoption, firm size may also play an important role. In other words, SMEs and large enterprises may have quite different considerations, attitudes and strategies regarding cloud services, and subsequently different levels of acceptance and usage of cloud services. Talukder and Zimmerman (2010) point out that the economic benefits and costs of using cloud services may vary depending on the firm size and its extant IT resources and overheads. SMEs typically have less of a burden from legacy IT resources, internal processes, IT staffing and technical skill base than large enterprises. At the same time, SMEs do not have the advantage of large enterprises in terms of access to capital and the ability to leverage existing human, software and hardware resources. With cloud computing, the disadvantage of the lack of existing IT resources diminishes substantially for SMEs, while the advantage of no legacy burden still holds for them. This may make cloud computing extremely attractive to SMEs. Cloud computing frees SMEs from having to access venture capital funds to obtain the necessary IT infrastructure to pursue their perceived business opportunities – they only need to pay on a pay-as-you-go basis and the cloud resources are highly scalable. Kushida et al. (2010) draw similar conclusions. They claim that cloud computing dramatically lowers the entry costs for new players because of its utility-style billing model. Cloud users are endowed with a radically increased capacity to innovate, experiment, and quickly scale up or scale down their computing operations. Initial startup costs for SMEs are considerably lowered. They point out that, in Silicon Valley, venture capitalists are increasingly mandating new startups to use cloud computing for their initial computing needs instead of making their own data centers. They also point out that large enterprises are highly sensitive to data security. Therefore, generally speaking, large enterprises are less willing than SMEs to have their data in an external cloud. The benefits of cloud computing to SMEs and startups are significant because costly upfront capital investments can be shifted into scalable operational expenses. SMEs typically are less concerned about the degree of service level agreement (SLA) and security offered by a cloud provider than large enterprises. Consequently, they summarize that the hurdles for cloud computing adoption by large enterprises are still high while SMEs face a greater set of immediate benefits with lower hurdles for adoption.

2.2.4 IT modularity and adoption of cloud computing

In this section, we argue that IT modularity can reduce asset specificity, coordination costs, and opportunism in terms of the theory of transaction cost economics (TCE), and hence alleviate some risks associated with cloud computing. In addition, IT modularity can promote vertical de-integration and outsourcing which are constructs relevant to the theory of TCE.

Williamson (1981) states that the determinants of transaction costs are frequency, specificity, uncertainty, bounded rationality, and opportunistic behavior. Transaction costs can be divided into three broad categories: 1) search and information costs, 2) bargaining and contracting costs,

3) policing, enforcement and maintenance costs (Ciborra 1996). When the external transaction costs are higher than the bureaucratic costs (i.e., internal transaction costs), the company will grow. If the bureaucratic costs are higher than the external transaction costs, the company will be downsized by outsourcing. TCE focuses on the risk of opportunism such as lock-in (i.e., hold-up), below-peak effort, or the misappropriation of proprietary information (Teece 1977; Williamson 1983). Asset specificity is the most influential attribute of the transaction (Rindfleisch and Heide 1997). According to McGuinness (1994), asset specificity is defined as the extent to which the investments made to support a particular transaction have a higher value to that transaction than they would have if they were redeployed for any other purpose. Williamson (1985) argues that transaction-specific assets (e.g., specialized physical and human investments for a task) are valueless in redeployment for another task.

Baldwin (2008) points out transactions are more likely to be located at modules' boundaries than in their interiors. Modularizations create new module boundaries with (relatively) low transaction costs. By hiding areas with dense and complex transfers within local modules (i.e., transaction-free zones), the transaction cost can be significantly eased. Modules, by definition, are separated from one another by thin crossing points – the boundaries of modules. The efforts for modularization can be used to reduce frictional and opportunistic transaction costs. Modularization makes transactions feasible where they were previously impossible or highly costly, so firms desiring to transact may modularize the task network at the point of their transaction.

Modular systems lower the transaction costs of information about the parts available for a firm and facilitate economies of scale in assembling the package for a consumer (Langlois and Robertson 1992). Kumar and Van Dissel (1996) claim that software characteristics such as reusability and modularity, by hiding technical details within modules, may reduce transaction risk which is the cost associated with the exposure to being exploited in the relationship. Transaction risk could be a direct cause of the risk of opportunism and consequent conflict in the inter-organizational systems alliance. Therefore, cloud users can lessen their worries about opportunistic activities that might be conducted by cloud providers by making their internal IT systems modularized.

Argyres and Bigelow (2010) argue that in the situation with a dominant or several major standards, modularity is associated with vertical de-integration because of the highly-standardized components when they study the vertical integration phenomena in the early US auto industry. Sanchez and Mahoney (1996) indicate that a modular product architecture already implies the engineering interfaces to be standardized. Shared standards reduce specificity and provide a form of embedded control that reduces search, monitoring, and enforcement costs. Standardized interfaces help structure the technical dialogue between component design engineers, hence reducing the need for unstructured dialogue and reducing the total amount of product-specific dialogue (Argyres and Liebeskind 1999; Monteverde 1995). By reducing the required communication, modular architectures also mitigate the hazard of proprietary information being leaked to another component designer (Teece 1996). Therefore, modular architectures help reduce asset specificity. By reducing asset specificity and leakage concerns, increasing product architecture modularity promotes greater use of a market-based mechanism for governing the transactions between component designers at the expense of vertical integration (Shelanski and Klein 1995; Williamson 1985). Component standardization by definition reduces asset specificity and leakage hazards, thereby reducing the sum of production and transaction costs (Riordan and Williamson 1985). Similarly, the issues of security and privacy in public clouds may be mitigated by IT modularity. Clemons et al. (1993a) argue that IT can reduce coordination costs without increasing the associated risks, which lead to more outsourcing and less vertical integration. Sanchez and Mahoney (1996) suggest that the ability of standardized interfaces between components in a product design is to embed coordination of product development processes. Through such mechanism, product design modularization can facilitate organization design modularization and coordination of activities via an information structure so that overt, excessive managerial authority costs can be significantly reduced. Gomes and Joglekar (2008) empirically show that an increase in task modularity is associated with transactional efficacies such as reduced coordination effort and shorter completion time, *ceteris paribus*. As a result, IT modularity may reduce the coordination costs between an enterprise's internal IT systems and a public cloud so that the enterprise can more easily move its IT components to the external cloud. The terminology of outsourcing is described as buying a good or service from another company rather than making or doing it yourself (Womack et al. 1990). Halldorsson et al. (2007) note that modularization reduces transaction costs and may encourage firms to outsource certain components to be developed and manufactured by qualified suppliers. Hoetker (2006) claims that a firm will more likely consider external suppliers when designing a modular product because the transaction costs of communication and opportunism are reduced. The theory of transaction cost economics (TCE) suggests that the advantages of long-term and internal suppliers become less important in the presence of product modularity. Product modularity may reduce the risk of opportunism by making a firm easier to switch suppliers hence less vulnerable to lock-in (i.e., hold-up) by a particular supplier. Similarly, IT modularity may help a firm tackle the challenges of service availability and vendor lock-in in current clouds.

Schilling and Steensma (2001) notice that modular designs facilitate outsourcing via contracts and/or alliances. They clarify that a standard interface makes assets nonspecific. Mikkola (2003) argues that outsourcing can only be realized when a system can be modularized with well specified and standardized interfaces for the modules. If one of the purposes of outsourcing is to reduce transaction costs, then modular product architecture designs can be used for such a goal in the context of mass customization (Mikkola 2007). Voss and Hsuan (2009) study the service architecture and note that a modular architecture enables a firm to consider outsourcing some of its services or service processes to others (or to be a supplier of services to others). Effective service outsourcing requires clear knowledge of both the process architecture of services and the interfaces between them. This has a direct implication on the association of IT modularity and cloud computing adoption. Specifically, if a firm can modularize its IT assets as services, it will have an easier time to outsource some of its services to a third-party cloud provider.

The relationship between modularity and outsourcing are well-studied in the context of the auto industry. Camuffo (2004) observes that modularization and outsourcing are becoming increasingly inseparable particularly when producing a “world car”. Ro et al. (2007) find a significant impact of modularity on outsourcing, product development, and supply chain coordination based on the interview results from automakers and suppliers across four years. Fixson et al. (2005) say that a modularization of the product architecture may contract the boundary of a firm and thus result in the outsourcing of components and processes. Griffith et al. (2009) study the effects of two important aspects of TCE, asset specificity and uncertainty, on supply concentration and degree of supplier involvement in offshore outsourcing activities of new product development (NPD) in technology intensive markets. They argue that NPD offshore outsourcing uses market exchange rather than internalization to reduce transaction costs and resource dependence, and enhance efficiency and effectiveness. As Mikkola and Skjoett-Larsen (2003) indicate, one of the main reasons for outsourcing is to shift initial investment costs and the risk of demand uncertainty to a supplier. They claim that when the interfaces become standardized and specified for the product components, the components become loosely coupled modules, and outsourcing of the component design and/or manufacturing tasks can then be possible. Mikkola (2003) emphasizes that a central focus on modularization strategies is to standardize and specify the interfaces of the components in a system well. Companies can achieve explicit financial gains by outsourcing non-core activities as outsourcing reduces the unit costs and investments needed to produce them quickly, and by doing so, companies free their scarce capital to be directed to where they hold a competitive advantage. This is exactly what many companies are doing with cloud computing adoption even with concerns about the cloud risks: they first put their non-core functions or applications into public clouds, which can take advantage of the clouds' capabilities and save IT costs, but at the same time, not let the cloud risks impact their core businesses before they figure out how to deal with the risks. TechTarget (2016) suggests that SaaS probably should be the first to look to comparing to IaaS when firms consider moving their existing non-core applications to cloud because SaaS offers a significantly larger offloading of IT workloads such as server management, security handling, and application patching and upgrade to the cloud vendors. It points out that cloud-based email and collaboration applications such as Gmail and Office365 are so mature and widely used that they are not risky to use, and in fact, they become must-haves for many firms. Particularly for a modularized ERP system, putting some ERP components in the cloud can make the entire ERP system more easily and frequently updated and the data more smoothly flow across different components to be integrated for analytics. In a modular system, component outsourcing enables the firm to purchase components from multiple suppliers hence decreasing switching costs (Sanchez 1995). This is a good indicator of how cloud users can use public clouds to transfer their IT utilization risks and costs to cloud providers, which is a major advantage championed by Armbrust et al. (2010) for cloud computing and of how IT modularity can facilitate the use of multiple cloud providers' services to increase availability and reduce the risk of vendor lock-in.

Tiwana (2008) finds that increasing interfirm modularity lowers the need for interfirm knowledge sharing in knowledge-intensive alliances. Interfirm modularity is the looseness of coupling between the outsourced project and outsourcer's technological portfolio with which it has functional, procedural, or informational interdependencies (Sanchez and Mahoney 1996). Interfirm modularity is higher if the outsourced project's relationship with the outsourcer's technological portfolio has a weaker coupling, lower interdependence, and comprehensiveness of their ex-ante interface specifications. Clemons and Hitt (2004) note that modularity can help reduce the risk of poached information. By making information modular, a firm may distribute different components to different suppliers, which makes it less likely for any single supplier to reconstruct the complete set of information that has economic value. This has a direct implication on how IT modularity can help mitigate the concerns of privacy, security, and data ownership in cloud computing. More IT modularity may lower such risks because of the knowledge-sharing reduction and poached information prevention effects.

Fremantle et al. (2002) find that service-orientation makes it possible to create modular, accessible, well-described, implementation-independent and interoperable services. Janssen and Joha (2008) find that Internet and SOA improve interoperability and reduce transaction costs hence allowing firms to focus on their core competencies. Some articles indicate the synergy between service-oriented computing and cloud computing. Tsai et al. (2010) argue that SOA is a service-based architectural pattern of how to create, organize and reuse computing components, and cloud computing is an enabling technology that provides a flexible platform upon which SOA solutions can be built, therefore they will complement and support each other. Wei and Blake (2010) suggest that service-oriented computing and cloud computing have a reciprocal relationship because the former provides the computing of services and the latter provides the services of computing. They discover that putting the two paradigms together, some challenges of one might serve as an opportunity for the other and identifies such opportunities as service discovery through federated clouds, agent-based ontology generation from co-located data, and rapid service deployment. Mircea (2010) says to migrate toward cloud computing in the higher education sector, a well-defined strategy that supports cloud computing capabilities should be present. By providing the necessary infrastructure for cloud complementation, a service-oriented architecture at the institutional level may ensure the success of such a strategy implementation. Namjoshi and Gupte (2009) have verified that SOA helps rapid identification, modeling, implementation and monitoring of services for the Travel Reservation Software as a Service (TRSaaS) application in the Amazon cloud. Sedayao (2008) has developed a prototype and verified that with SOA and cloud computing, it is easy to build a robust and highly distributed application composed of unreliable parts. SOA techniques can be used to build reliable services on cloud computing infrastructure.

In the software industry, there has been a new trend called “DevOps” since 2009 for agile, flexible and harmonious software development and deployment that involve collaboration and communication of all relevant parties such as developers and IT system operators (Swartout 2014). The term is a clipped compound word of development and operations. In alignment with such trend, software firms have started modularizing their software development processes to ensure better, faster and easier software delivery and deployment. For instance, Docker (NYT Docker 2015), a software startup in San Francisco, uses the concept of containers of code in their software development. By modularizing codes and applications into containers, applications can be easily and effortlessly deployed and moved across different IT systems. This approach reduces significant code rewriting efforts when the codes are moved across different platforms. The concept of containers of code fits with cloud computing excellently and makes cloud computing a preferred deployment environment. It is indicative that modularization of programs can help firms choose cloud computing platforms to implement and run those programs. More broadly speaking, the use of cloud infrastructure has become a critical choice to support the idea of DevOps.

Therefore, we posit that more modularity in a firm’s internal IT assets may facilitate adoption of cloud computing by reducing various transaction costs and promoting outsourcing (See Figure 2.1).

Since cloud computing can be grouped into two major types: server-level cloud services (i.e., IaaS and PaaS) and application-level cloud services (i.e., SaaS), it is necessary to test this proposition for both types of cloud computing. As we have argued in the previous cloud computing and its taxonomies section, application-level cloud services may present quite different ease of use and use characteristics than server-level cloud services. As most of the application-level cloud services are aimed for cloud end users to use them directly and conveniently regardless of any type of end users (either an SME or large enterprise in our study), it is likely that IT modularity is beneficial for adoption of application-level cloud services regardless of firm size, even though internal IT modularity is not a necessary prerequisite for firms to use such applications. Instead, we hypothesize internal IT modularity is a sufficient condition for both SME and large enterprises to use external application-level cloud services.

So far, we have discussed IT modularity as an overall concept and its effect on adoption of application-level cloud services. In practice, IT modularity can be created in a firm's internal IT systems on various scales, depending on the particular business needs and considerations of that firm. Generally speaking, the needs and considerations can be grouped into two main levels: those from business strategies and those from other non-companywide, non-strategic activities such as certain modularized projects development and deployment in a department in the firm. The former can be named IT modularity in strategic business transformation while the latter can be named non-strategic IT modularity implementation. IT modularity is suitable for both types of use. As a result, a firm may consider starting to modularize its internal IT systems from a top-down (starting from considering strategic business transformation) or a bottom-up (starting from considering project development management) perspective (Walker 2007).

The two types of IT modularization have quite distinct impetuses and effects. Like many other new technologies, oftentimes IT modularity is first embraced by the impulsive curiosity from the practitioners in a firm who want to explore and grasp its perceived value (Walker 2007). This type of grassroots, bottom-up approach typically is only limited to a certain small scale – for example, a small set of projects within a certain department or unit in a firm initiated by the department manager or project manager. As a result, when choosing which projects to be modularized and how to be modularized, the managers often don't have a bigger picture or strategic thinking from the overarching perspective of the firm. These modularizations are hence often isolated and there is no guarantee that the relevant IT resources have been optimized for reusability and efficiency by the entire firm. On the other hand, IT modularity can be implemented using a top-down approach, with companywide or even industry-wide business strategies and goals borne in mind. In such cases, business drivers, such as customer satisfaction, quick response to changing market conditions, and creating a flexible, on-demand business, are often the impetus to implement the business transformation enabled by IT modularity in the form of SOA (Cherbakov et al. 2005; Walker 2007). This higher-level, overarching perspective usually comes from the most senior executives who are responsible for and have a clear picture of the overall strategies and goals of the firm. It is more likely that this top-down approach will help implement IT modularity in a much more systematic and broader way than the bottom-up approach. Hence, IT modularity in strategic business transformation is much more influential companywide than non-strategic IT modularity and may involve a variety of enabled tactics to fulfill the overall strategies and goals. For example, outsourcing may be simplified and more used since IT modularity with open standards makes applications more easily be outsourced to an external third-party provider (Walker 2007). Incorporating third-party products and enhancing B2B (business to business) transactions are two other exemplary tactics that can be achieved by strategic IT modularization of SOA (Walker 2007) since SOA provides standardized interfaces for the services from different firms to be conveniently connected and integrated. Therefore, IT modularity in strategic business transformation may enable a firm to use more external third-party applications while ad-hoc, non-strategic IT modularity in local, firm-specific projects may instead hinder strategic outsourcing of such internal IT projects to external application providers or integration with business partner's applications.

Therefore, we argue that IT modularity in strategic business transformation may help promote adoption of application-level cloud services while non-strategic IT modularity may hinder adoption of application-level cloud services. The relevant hypothesis is as follows:

Hypothesis 1A (H1A): IT modularity in strategic business transformation is positively associated with adoption of application-level cloud computing for both SMEs and large enterprises combined.

Hypothesis 1B (H1B): Non-strategic IT modularity is negatively associated with adoption of application-level cloud computing for both SMEs and large enterprises combined.

As server-level cloud services are more complicated in nature comparing to application-level cloud services, and require more specific IT knowledge, know-how and skills to acquire, develop and deploy applications based on those services, we suspect that they will show different patterns for SMEs and large enterprises as the two types of firms usually have different levels of IT resources, capabilities and concerns. In addition, as Talukder and Zimmerman (2010) have observed, firm size may play an important role in whether and how much a company will adopt a certain cloud computing service, it is helpful to test the proposition for SMEs and large enterprises separately for server-level cloud services. IT modularity in strategic business transformation may enhance the use of external server-level cloud services (i.e., IaaS and PaaS) by using more external cloud platform and computing capacity rather than acquiring them in-house. Non-strategic IT modularity may also enhance the use of external server-level cloud services because the firm can either more cost-effectively develop such firm-specific projects using external server-level cloud services than develop them in-house, or develop and deploy other related projects using such cloud services.

Therefore, we have the following hypotheses:

Hypothesis 2A (H2A): IT modularity in strategic business transformation is positively associated with adoption of server-level cloud computing for SMEs.

Hypothesis 2B (H2B): Non-strategic IT modularity is positively associated with adoption of server-level cloud computing for SMEs.

Hypothesis 3A (H3A): IT modularity in strategic business transformation is positively associated with adoption of server-level cloud computing for large enterprises.

Hypothesis 3B (H3B): Non-strategic IT modularity is positively associated with adoption of server-level cloud computing for large enterprises.

2.3 Research Design and Methodology

2.3.1 Data

A cross-sectional data source from Forrester Research Inc.[10] is used in empirical testing. It is a comprehensive online survey of adoption trends in software technology conducted by Forrester to more than 2,000 companies ranging from very small businesses and startups (i.e., 2-10 employees) to global enterprises (i.e., 20,000 or more employees) in North America (US and Canada) and Europe (UK, Germany and France) during the fourth quarter of the year of 2008 (December 2008-February 2009)[11]. All respondents were screened for significant involvement in IT decision-making as well as IT purchasing processes and authorization. In the Forrester Q4 2008 Software Survey dataset, the questions are about budget, information and knowledge management, packaged application, platform and infrastructure, custom software development, and sources and influences. The dependent variables about both application-level and server-level cloud computing, the independent variables about IT modularity, and the control variables can all be identified and linked to specific survey questions in the single dataset.

Specifically to our study and hypotheses, the final data sample derived from the Forrester Q4 2008 Software Survey dataset contains 457 firms including 189 SMEs and 268 large enterprises. The final data sample is reasonably representative in the firm numbers across all different industries included in the survey, which can be seen in Figure 2.2, 2.3, and 2.4 for the pooled firms, SMEs only, and large enterprises only respectively. In addition, comparing to the distribution of firms in the entire Forrester Q4 2008 Survey dataset (see Figure 2.5), the final samples are in the similar distribution pattern, which indicates that they are a good reflection of

[10] Forrester Research Inc. is an independent technology and market research company that provides advice on existing and potential impact of technology to its clients and the public.
[11] The dataset is thereafter called "Forrester Q4 2008 Software Survey" in this paper.

firms in the large population represented by the comprehensive survey containing 2,227 firms in total.

2.3.2 Variables

2.3.2.1 Dependent variables – cloud computing adoption

Our constructs of cloud computing adoption on server level and application level, the two dependent variables *PerVirSer* and *PerSaaS*, are measured by the percentage values of virtual server and SaaS usage in the relevant survey questions respectively (see the dependent variables in Table A.1 in Appendix A), according to the prior literature about the taxonomy of cloud computing (Hoefer and Karagiannis 2010; Mell and Grance 2010; Youseff et al. 2008). The detailed method used to identify the relevant keywords for cloud computing can be found in Appendix A.

2.3.2.2 Independent variables – SOA as a typical representation of IT modularity

Our constructs of IT modularity, the independent variables, are based on the prior literature of how IT modularity is measured (Byrd and Turner 2000; Chung et al. 2005; Duncan 1995; Fink and Neumann 2009; Tafti et al. 2013; Tiwana and Konsynski 2010). Many prior constructs of IT modularity are discussed as an important dimension of IT flexibility. Since IT modularity generally can be discussed within the context of IT infrastructure flexibility and of IT architecture flexibility, we reference how it can be measured from the prior literature on both concepts to find the relevant keywords. The relevant literature reveals that IT modularity in both infrastructure and architecture represents the following characteristics: 1) service-oriented or services-based 2) module, 3) loosely-coupled, 4) object-oriented, 5) reusable and reusability, 6) standard, 7) open source, 8) enterprise service bus, and/or 9) component and componentization (Byrd and Turner 2000; Chung et al. 2005; Duncan 1995; Fink and Neumann 2009; Tafti et al. 2013; Tiwana and Konsynski 2010). Using the consolidated nine keywords for IT modularity from the prior literature (see Appendix A for details about the keywords), we searched the entire survey for the relevant survey questions. After carefully investigating the content of each of the matched survey questions, we found that only the questions related to service-oriented architecture (SOA) are pertinent to the construct of IT modularity in the survey.

Correspondingly, as shown in Table A.1, there are two such constructs that can be found in the survey representing IT modularity from the two distinct levels. *BizTranSOA* is a dummy variable that indicates whether a firm has used SOA for its strategic business transformation. *ProjSOA* is an integer measure ranging from 0 to 4 that indicates the magnitude of how much SOA a firm has used in solution delivery projects for both new applications and changes to existing applications.

The SOA paradigm itself has been studied extensively in the information systems literature (Erl 2008; Foster 2005; Gu et al. 2005; Huhns and Singh 2005; Krafzig et al. 2005; Papazoglou 2003; Papazoglou et al. 2008). Service-oriented architecture (SOA) is defined as (Papazoglou 2003, p. 3): “A way of reorganizing a portfolio of previously siloed software applications and support infrastructure into an interconnected set of services, each accessible through standard interfaces and messaging protocols.” The succinct definition of SOA itself reveals that SOA is a typical modularized architecture based on the self-contained modules of services which are business functions implemented in software and wrapped with standard interfaces (Huhns and Singh

2005; Papazoglou 2003). The module encapsulation concept in SOA is from the principles of modularity in software engineering which make programs into modules, objects, and components (Baldwin and Clark 2003). The major difference between SOA modularity and conventional software modularity is that services in SOA represent complete business functions which are reusable in new transactions at the level of the firm or even across firms rather than of a single program or application in the firm (Papazoglou 2003).

Tafti et al. (2013) identify services-based IT architecture as a representative proxy for modular architecture and consider whether a services-based IT architecture has been widely deployed within the firm. The relevant survey question is: "Has your IT department developed and deployed a company-wide services-based IT architecture?" Tiwana and Konsynski (2010) identify SOA as the typical modular IT architecture.

From the rich SOA literature about its definition and features, we believe that SOA is a typical representation of IT modularity in our study.

2.3.2.3 Control variables

Eleven control variables spanning a firm's decisions and perceptions towards IT (Web services for new custom applications, technical goals, preferred deployment option for a major application, reasons for having no interest in SaaS, and factors that affect a firm's decision to adopt SaaS), organizational characteristics (firm size – an SME or a large enterprise, and spending in IT in a firm), as well as industry characteristics (industry categories) are used to account for rival explanations of cloud computing adoption.

Among the decisions and perceptions towards IT of a firm, we control for SOAP (Simple Object Access Protocol) or REST (representational state transfer)[12] based Web services used for new custom applications. A Web service is a special type of service that is designed to communicate over the Internet. It uses Internet standards and protocols such as hypertext transfer protocol (HTTP) to expose its features over the Internet, and it can be implemented via an interface that is written in open Internet standards such as extensible markup language (XML) (Papazoglou 2003). Custom applications are software applications developed or customized for a specific user or a group of users within an organization, therefore, they are typically very asset-specific in terms of TCE and can become very idiosyncratic and strategic resources for the firm. On the other side, it can be very hard and costly to maintain and upgrade due to its rigidity and non-standard implementation. However, building new custom applications as Web services may help solve these problems and make the custom applications more valuable in terms of flexibility and usability. A firm can publish its Web service based custom applications over the Internet to be discovered and used by other firms.

We also control for a firm's initiative towards outsourcing internal applications to external third parties – how important it thinks the goal of outsourcing some/more enterprise applications to off-premise providers or to external SaaS. The more important the firm thinks outsourcing is, the more likely it is that they will use external cloud services. Originally, the relevant survey question (see Table A.1 for *ImGoal_Out*) contains a set of sub-questions that detail the different

[12] SOAP (Simple Object Access Protocol) is an open-standard, extensible markup language (XML) based Web service interface specification for exchanging information among Web services. REST (representational state transfer) is an alternative Web service interface specification for Web services. Even though the architectural style of REST does not enforce open-standard use, most implementations of REST use standards like XML. For more details, see https://en.wikipedia.org/wiki/Web_service

subtle aspects of the primary question, therefore, it is very likely that some of the sub-questions are correlated, so we first generate each measure for each sub-question, then use principal component analysis (PCA) to merge the highly correlated sub-questions and form fewer measures. After further consideration of the merged measures about their relevance to our study and multicollinearity analysis (VIF) after regression analysis, we find that the construct for a firm's initiative towards outsourcing (*ImGoal_Out*) is relevant and should be kept in the model. Similarly, we control for using SaaS as the preferred deployment option for a major application (*PDepSaaS*), having no interest in SaaS because of the SaaS quality concerns (*NoSaaS_Qual*) on SaaS performance (e.g., downtime, speed), SaaS security and SaaS integration with internal systems, as well as the factor of SaaS being a flexible and agile IT model that a firm thinks important when considering adopting SaaS (*AdSaaS_FlexAgi*). Similarly to how the construct of *ImGoal_Out* is finalized, these three controls are from the relevant survey questions with dimensional reduction using PCA and construct relevance investigations after regressions. The three controls are all about a firm's attitude towards using external SaaS applications, so they may be directly linked to more adoption of SaaS and indirectly linked to more adoption of server-level cloud services. See Table A.1 for more details for how the constructs are formed.

Among the organizational characteristics, we control for firm size (i.e., SME or larger enterprise) as well as IT spending. The control for firm size (*ENT*) is a dummy with 0 indicating an SME and 1 a large enterprise. We see it as a relevant control in the model because as we have discussed in the previous section of firm size, SMEs and large enterprises may display quite distinct reasons, acts and effects towards technology adoption (Daniel and Grimshaw 2002; Karlsson and Olsson 1998; Laukkanen et al. 2007; Spanos et al. 2001; Sun and Cheng 2002). As specifically to cloud computing adoption, Talukder and Zimmerman (2010) point out that cloud computing might appear much more attractive to SMEs than to large enterprises because SMEs usually have no much burden on the internal legacy IT systems and cloud computing diminishes SMEs' disadvantage of lacking extant internal IT resources. Furthermore, the benefits of strategic flexibility, cost reduction, software availability, skills and staffing and energy efficiency may appear more attractive to SMEs as well. On the contrary, large enterprises usually are more concerned with data security and cloud quality and performance issues (e.g., stricter service level agreements (SLAs)) (Kushida et al. 2010). The control for IT spending in a firm (*ITSpend_ln*) has the value of how many US dollars the firm has spent on IT in the year of 2008. IT expenditure is a widely used control in many IS empirical studies. For example, Tafti et al. (2013) control IT expenditure as a proxy for overall information intensity of a firm's operations in their empirical models studying IT-enabled flexibility on the formation and market value of alliances. In our model, it is also likely that IT expenditure will affect a firm's financial ability to develop more internal applications and the log of the IT spending value is used.

Finally, among the industry characteristics, we control for which industry a firm is in as in many IS articles to account for differences in IT modularization level across industries. Similar to Tafti et al. (2013) and Tiwana (2008), we use four industry dummy variables – Manufacturing (*Ind_Man*), Retail & Wholesale (*Ind_RnW*), Various Services (*Ind_Ser*), and Public Sector (*Ind_Pub*). The constructs of the four variables come from a relevant industry type question in the survey. Originally in the survey question there were seven types of industry, after initial regression analysis and mapping with the 2012 NAICS[13] industry categorization using the leading digit in the NAICS codes, we reduced the seven industry types to four. Basically, 1)

[13] For more details, visit http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2012

Services, 2) Media, Entertainment, & Leisure, 3) Utilities & Telecom and 4) Finance & Insurance can be merged into a single large group – services.

The construct correlations and descriptive statistics for the entire final sample (457 firms including both SMEs and large enterprises) are summarized in Table 2.1. Factor analysis and multicollinearity check (after regression) are used to confirm the sufficient discriminant validity.

Table 2.2 and 2.3 show summary statistics and correlations for SMEs only (189 firms) and large enterprises only (268 firms) respectively with redundant/irrelevant controls removed[14]. Factor analysis and multicollinearity check (after regression) are used to confirm the sufficient discriminant validity.

2.3.3 Estimation models

In the first step, we use two similar ordinary least squares (OLS) models with interaction terms of SOA and firm size (SME or large enterprise) to test whether SMEs and large enterprises can be pooled together for the regressions for the adoption of server-level cloud services (virtual server) and application-level cloud services (SaaS) respectively as shown below.

OLS model 1:

$$PerVirSer = \beta_0 + \beta_1 BizTranSOA + \beta_2 ProjSOA + \beta_3 ENT + \beta_4 BizTranSOA \times ENT + \beta_5 ProjSOA \times ENT + \boldsymbol{\beta_c X_c} + \varepsilon \qquad (1)$$

[14] For the regressions on server-level cloud adoption separately for SMEs and large enterprises, some of the control variables used in the regression on application-level cloud adoption for SMEs and large enterprises combined are no longer valid, hence removed. For example, the control variables pertaining to SaaS are irrelevant to server-level cloud adoption, and the dummy variable of firm size is also redundant for the regressions separately for SMEs and large enterprises.

OLS model 2:

$$PerSaaS = \beta_0 + \beta_1 BizTranSOA + \beta_2 ProjSOA + \beta_3 ENT + \beta_4 BizTranSOA \times ENT + \beta_5 ProjSOA \times ENT + \boldsymbol{\beta_c X_c} + \varepsilon \quad (2)$$

Please note, the term of $\boldsymbol{X_c}$ in the above two models represents all the control variables in Table A.1.

After the regressions, we use a Chow test to tell if the data can be pooled together when the Chow test is not significant at 5% or the data must be split into two separate datasets for SMEs and large enterprises when the Chow test is significant at 5%.

According to our previous arguments about that the application-level cloud services may appear similar to both SMEs and large enterprises while the server-level ones may appear quite different for them on various aspects, we predict that in Model 1, the Chow test would be significant, and it would be insignificant in Model 2.

Following the logic, we next use a simplified model for the hypotheses related to server-level cloud service adoption as follows:

OLS model 3:

$$PerVirSer = \beta_0 + \beta_1 BizTranSOA + \beta_2 ProjSOA + \boldsymbol{\beta_d X_d} + \varepsilon \quad (3)$$

Please note, the term of $\boldsymbol{X_d}$ in the above model represents only the relevant control variables in Table A.1 for server-level cloud service adoption which are *WSCApp*, *ImGoal_Out*, *PDepSaaS*, *ITSpend_ln*, and the industry controls *Ind_Man*, *Ind_RnW*, *Ind_Ser*, and *Ind_Pub*.

2.4 Results

2.4.1 Chow test results

We first did regressions on the entire final sample of the pooled data of SMEs and large enterprises (457 firms in total) for Model 1 and Model 2 and followed with two Chow tests to determine whether the pooled data can be used for the regressions or not. We find that, for server-level cloud services, the Chow test is significant at the 5% level (Prob > F = 0.0166)[15], therefore firm size differentiates the behavior of the SMEs and the large enterprises and the data should be separated for the two types of firms and Model 3 should be used for SMEs and large enterprises separately (see the columns of Model 3 in Table 2.4). For application-level cloud services, the Chow test is insignificant even at the 10% level (Prob > F = 0.2432), so the pooled data can be used for Model 2 (see the column of Model 2 in Table 2.4). These test results reflect our earlier arguments about that firm size may play a different role in the two different types of cloud computing adoption – firm size does not matter for application-level cloud adoption while it matters for server-level cloud adoption.

2.4.2 General results

Table 2.4 presents results for all the hypotheses in our study. For Model 2, Hypothesis 1A, which predicts that IT modularity in strategic business transformation is beneficial for application-level cloud computing adoption for SMEs and large enterprises is supported (β = 2.836, t = 1.99, p <

[15] Details of the regression and the Chow test results can be found in Table A.2 in Appendix A.

0.05). Hypothesis 1B, which predicts that non-strategic IT modularity may have a negative effect on application-level cloud computing adoption for both SMEs and large enterprises, is also supported ($\beta = -1.173$, $t = -1.82$, $p < 0.10$). In the controls, the goal of outsourcing is positive and significant ($\beta = 1.074$, $t = 2.78$, $p < 0.01$), indicating that any type of firm will consider using more application-level cloud (i.e., SaaS) if it has a clear goal of outsourcing its application to external providers. Three controls that directly linked to SaaS are also significant. SaaS as the preferred deployment method for a major application is positive and significant ($\beta = 8.959$, $t = 3.29$, $p < 0.001$). Concerns on SaaS downtime, speed, security and privacy, and integration issues are negative and significant ($\beta = -0.472$, $t = -2.20$, $p < 0.05$). The various benefits of SaaS applications in flexibility and agility are positive and significant ($\beta = 0.791$, $t = 3.29$, $p < 0.001$). We can observe that, among the three SaaS factors, SaaS as the preferred deployment method for a major application has the largest positive coefficient, which may indicate that it has the strongest influence on adoption of SaaS applications. As expected, the coefficient on the dummy variable of firm size – SME or large enterprise is not significant ($\beta = -2.085$, $t = -1.01$, $p = 0.31$) so that the pooled data of SMEs and large enterprises were used for Hypothesis 1A and Hypothesis 1B. It is a bit counterintuitive that IT expenditure has a small, negative (yet significant) effect ($\beta = -0.431$, $t = -2.24$, $p < 0.05$) on adoption of application-level cloud services, which is opposite to the general finding in IS literature when investing the relationship of IT and other paradigms[16]. This might indicate the essential billing model difference between SaaS and conventional IT applications. SaaS typically uses a pay-per-use metering and billing model, unlike the traditional license one. As Kushida et al. (2010) point out, cloud computing converts a firm's capital investments in IT into scalable operational expenses. It is challenging

16 For example, in the paper by Tafti et al. (2013), the IT expenditure as a control is found positively associated with joint-venture formation, though not significant in other types of alliances such as arm's-length and collaborative.

for firms to adapt to and correctly account for this novel billing model (Ruiz-Agundez et al. 2011). The negative IT expenditure might reflect this challenge in that a large portion of the total IT expenditure had been absorbed by daily operational IT costs rather than stated as the explicit IT capital expenditure. Another possible explanation is that, since as many have claimed that SaaS is more cost-effective than traditional internal application purchase (Marston et al. 2011; Mell and Grance 2010; Vaquero et al. 2008; Zhang et al. 2010), a lower IT expenditure can be actually associated with more SaaS usage. The coefficients for the industry controls are not significant, which may indicate that which industry a firm is in does not influence much on its use of application-level cloud computing.

For Model 3, two sets of separate results are shown for SMEs and large enterprises respectively. Hypothesis 2A, which predicts IT modularity used for strategic business transformation is positively associated with server-level cloud service adoption for SMEs, is insignificant and not supported ($\beta = 1.637$, $t = 0.74$, $p = 0.46$) even though the coefficient is positive as predicted. Hypothesis 2B, which predicts IT modularity used for non-strategic local projects is positively associated with adoption of server-level cloud computing is supported ($\beta = 2.050$, $t = 2.05$, $p < 0.05$). Considering the two collectively, it may indicate the fact that SMEs generally lack internal server-level IT resources (i.e, IT infrastructure and platform resources), so they tend to use more of such external resources when developing and deploying modularized application projects. As the scope of IT modularity for business strategy transformation is much wider than the one in local projects, it requires more than using raw resources of server-level cloud computing to develop its own applications. Instead, oftentimes it involves transformations and reinventions on various levels in a firm such as in business processes and practices of B2B transactions and outsourcing (Walker 2007). Another factor that may contribute to the insignificance of strategic IT modularity use is that SMEs usually inherently lack a systematic management and many activities are initiated in an unplanned manner so that strategic IT modularization is not a point of emphasis. Two controls have significant effects on server-level cloud adoption for SMEs. Custom applications developed as Web services have a strong significant, negative effect ($\beta = -6.371$, $t = -2.16$, $p < 0.05$), which may indicate that Web service can enable the rigid, asset-specific custom applications within a firm to become valuable, accessible strategic IT resources published and offered on the Internet to other firms. Therefore, it is more about offering IT resources from the inside, rather than accessing more server-level IT resources from the outside. Again, the goal of outsourcing is positively and significantly related to server-level cloud service adoption ($\beta = 1.739$, $t = 1.91$, $p < 0.10$). IT expenditure is no longer significantly (though positively) associated with server-level cloud service adoption, which indicates that using IaaS and PaaS diminish an SME's worry on the costs of IT as they provide a flexible, per-per-use billing model. The industry controls' coefficients are not significant which may indicate that SMEs across different industries seem to have a similar attitude towards usage of server-level cloud services.

The regression about Model 3 for large enterprises is not significant overall (F test = 0.53, Prob > F = 0.8550). Hypothesis H3A, which predicts IT modularity used for strategic business transformation is positively associated with server-level cloud service adoption for large enterprises, is not supported ($\beta = 1.520$, $t = 1.37$, $p = 0.17$) though the coefficient is positive as predicted. Hypothesis H3B, which predicts IT modularity used for non-strategic local projects is positively associated with adoption of server-level cloud computing for large enterprises, is neither supported ($\beta = -0.672$, $t = -1.19$, $p = 0.24$) and the coefficient is negative. A possible implication is that since large firms usually possess sufficient internal computing resources, they are not so keen to try external server-level cloud resources with potential new risks that need to be handled. All controls are non-significant as well. In other words, large enterprises seem to be indifferent in server-level cloud service adoption when modularizing their internal IT systems either strategically or non-strategically. Though this is a bit surprising to us initially, we think that it also reflects the fact that large companies are still quite hesitant to use external cloud computing due to their serious concerns about the perceived risks and uncertainties associated with server-level cloud computing. Unlike SMEs, large companies usually have a lot of things other than IT accessibility to consider. For example, a financial service firm must consider the significant enforced legal and regulatory requirements before it can use any server-level cloud services for its important businesses and services (Bloomberg 2012). Financial privacy issues, customer data protection issues, and business continuity issues are several salient challenges that a financial service firm must address before considering a major server-level cloud use (Bloomberg 2012). Large companies may also have much more leeway than SMEs to postpone their decisions toward server-level cloud computing adoption because they may already have considerable existing in-house IT resources including legacy systems. The sufficient internal IT resources may delay the firms' consideration of external server-level cloud use. Legacy systems may deter the use of more novel technologies such as server-level cloud computing because of the issue of incompatibility. Large enterprises may also be less flexible and agile than SMEs due to their size. It is common to observe that large companies may react in a slower manner than SMEs to the changes in the business environment (Chen and Hambrick 1995). Incumbent corporate culture, inertia to changes, preset business strategies, routine senior management as well as complexity of changes may all contribute to the reluctance of using server-level cloud computing.

2.4.3 Tests for common method bias

Because all variables for the OLS models in our study come from the same data source – the Forrester Q4 2008 Software Survey dataset, the issue of common method variance (CMV) or common method bias may exist. Common method bias refers to the amount of spurious correlation among variables due to the same method used in data collection such as a self-report survey (Craighead et al. 2011; Malhotra et al. 2006). The existence of common method bias may render the conclusions erroneous or misleading by intermingling the actual phenomenon of interest with measurement artifacts that leads to either inflated or deflated results (Craighead et al. 2011; Malhotra et al. 2006). To address the problem of common method bias, various methods have been introduced which can be grouped into two major categories: statistical and post hoc remedies, and procedural methods (Podsakoff and Organ 1986). The former includes methods that can be applied using statistical knowledge after the variables have already been measured in the single source data. The latter includes methods that can mitigate or avoid such biases at the beginning of data collection. Since our Forrester Q4 2008 Software Survey dataset is a secondary data source conducted by the third-party company Forrester before our study is done, it is not possible for us to adopt the procedural methods to address common method bias. Therefore, we focus on the statistical and post hoc methods that can help us to address the common method bias in our study.

In the statistical and post hoc category, there are a lot of different methods that one can utilize to address common method bias. For example, some widely used methods are traditional MTMM procedure, CFA-based MTMM technique, Harman's single-factor test, as well as Lindell-Whitney marker-variable technique (Lindell and Whitney 2001). Specific to IS research, Malhotra et al. (2006) conduct a series of comparison among the various statistical and post hoc CMV methods to evaluate their capabilities as well as their differences. First they find that actually the issue of CMV is not as serious as researchers imagined before in IS research. In other words, CMV, though present, is not substantial in IS study. Furthermore, they find that, in terms of the ability to detect CMV, various methods perform similarly without significant difference.

Considering the factors, we decide to use Harman's single-factor test as well as marker-variable technique to address the potential common method bias issue in our study because these two methods are the most widely used ones in social research.

There are two ways to do a Harman's single-factor test: using exploratory factor analysis (EFA) or confirmatory factor analysis (CFA) (Podsakoff and Organ 1986). We choose to perform Harman's single-factor test with EFA setting in our study because it is widely known as an efficient method to detect CMV and easy to implement. In this method, if a single factor emerges or a first factor explains the major variance in the variables, CMV is regarded as extant in the data.

Harman's single factor tests with EFA are performed for all regressions presented in Table 2.4. For Model 2, we did the single-factor test with orthogonal varimax rotation and did not find such a single factor emerged (chi2(78) = 2658.80 Prob>chi2 = 0.0000). For Model 3 for SMEs only, we did not find such a single factor emerged either (chi2(36) = 6621.60 Prob>chi2 = 0.0000). For Model 3 for large enterprises only, we did not need to perform such a test since the overall regression is not significant.

Lindell-Whitney marker-variable technique (Lindell and Whitney 2001) uses a so-called marker variable that is theoretically unrelated to the principle constructs to adjust the correlations among principle constructs. Any high correlation between the marker variable and any of the principle constructs is an indication of possible common method bias (Tiwana 2008). For robustness, we used two different marker variables (one dummy marker variable indicating whether the firm is in North America or not, and the other numeric marker variable indicating the age of the survey respondent) to repeat the tests for Model 2 and Model 3 for SMEs only[17]. We found that there is no high correlation (i.e., absolute value >= 0.80 according to Bagozzi et al. (1991)) in the tests. Collectively with the results from the Harman's single factor tests and Lindell-Whitney marker-variable tests, we can conclude that common method bias is not a serious problem in our study.

2.5 Conclusion and Discussion

2.5.1 Main findings and research implications

To our knowledge, this is the first study that seeks to theoretically link IT modularity with cloud computing and to empirically examine their relationship for two distinct type of firms – small

[17] Details of the Lindell-Whitney marker-variable test results for Model 2 and Model 3 for SMEs only can be found in Table A.3 in Appendix A.

and medium-sized enterprises (SMEs) and large enterprises. On one hand, we find that SMEs and large enterprises display very similar behaviors towards application-level cloud adoption (i.e., SaaS applications). This reflects the fact that SaaS, the highest layer in the fundamental service model of cloud computing (Mell and Grance 2010), is the most ready-for-use and function-rich one comparing to the other two – PaaS and IaaS. No matter a firm's size is and what industry the firm is in, it can always find some SaaS applications that are right for it. We find that a firm's internal IT modularity on the strategic business transformation level has a positive effect on its SaaS application adoption. We argue that this occurs because 1) IT modularity, in general, reduces various transaction costs and risks, promotes outsourcing and alliances (Tiwana 2008) and 2) IT modularity used for strategic business transformation, in particular, covers an extensive scale of deep changes and deployments in a firm many of which relate to not only raw computing capacity but also higher-level business process, functionality, and application (Walker 2007). We also find that a firm's internal IT modularization on non-strategic, localized project development and deployment has a negative effect on adoption of external application-level cloud services. This may reflect the fact that many such cases are impromptu and short of an overall plan, and involve specific technique-oriented endeavors (Walker 2007). The differences between such strategic and non-strategic uses of IT modularity reflect the notions of top-down and bottom-up approaches mentioned by Walker (2007). In addition, we find that no matter for SMEs or large enterprises, firms seem to have a more similar perception towards the benefits and risks of SaaS comparing to PaaS and IaaS. These findings complement and enrich the arguments about the benefits, costs and risks of cloud computing as an overall concept for firms of different size (Kushida et al. 2010; Talukder and Zimmerman 2010). We find that less internal IT expenditure is associated with more use of SaaS applications, reinforcing the argument of the superior pay-per-use metering and billing model and the associated economics brought by SaaS (Kushida et al. 2010) comparing to the traditional license-based charging model for software.

On the other hand, we find that SMEs and large enterprises display distinctly different behaviors towards server-level cloud adoption (i.e., PaaS and IaaS raw computing resources). SMEs are sensible to use server-level cloud services if they implement non-strategic, localized modularization for their IT projects. While strategic modularization across an SME firm may encourage more use of application-level cloud services, it may not have a significant effect on server-level cloud services. This again may enhance the idea of that strategic modularization is far more than raw IT resource renovation and is primarily relevant to application-level cloud services. Interestingly, we also find that, if SMEs develop more new custom applications using Web service themselves, they will tend to use less external server-level cloud services. Custom applications, designed for specific needs and uses within an SME, are idiosyncratic and asset-specific IT assets for the firm. However, they can become very inflexible and costly to maintain as well, rendering them to be much less valuable to other usages or to business partners. This becomes a serious problem especially in the present business environment that emphasizes responsiveness to fugitive opportunities and resilience to changes and challenges (Prahalad and Krishnan 2008). Web service can renovate these rigid IT assets to become real strategic resources, not only for the SME itself but also ready to be utilized by other firms and business partners. Web service for new custom application development is more about offering IT capability to others, rather than acquiring IT capability from others, thus implying less use of external server-level cloud services for an SME. Again, the goal of outsourcing is important in promoting the use of server-level cloud. Industry type does not imply any significant difference on how much an SME will use server-level cloud services. Contrastingly, both strategic and non-strategic IT modularity do not present any significant effect on server-level cloud adoption for large enterprises. This phenomenon indicates the complication of the factors that could affect large enterprises' decision to use external server-level cloud services. As Kushida et al. (2010) and Talukder and Zimmerman (2010) argue, since SMEs have a more urgent need for ample affordable IT resources and have much fewer factors to considerate and worry about than most of the large enterprises, they tend to use more server-level cloud computing. Large enterprises usually have to consider many more factors when adopting cloud computing, they may try it on a trial basis and first use SaaS applications. As to the more deepened server-level cloud computing (i.e., PaaS and IaaS), they are quite reluctant to use as they are concerned with the deeper data ownership, security and privacy issues, reputation, and regulation requirements that will affect the ways they deal with their sensitive data. They also typically have quite sufficient internal IT resources already which make them less driven to use external sever-level cloud resources.

2.5.2 Managerial implications, limitations and future work

Cloud computing, as an appealing new IT consumption model, is getting more and more acceptance by companies. It can help a firm to achieve not only cost savings, but also flexible, agile business innovations. Even though cloud user firms cannot address the risks of cloud computing directly like what cloud providers are trying to accomplish, they, at least, can do something inside their own firm borders to help mitigate the possibility of such risks and uncertainties, that is, to modularize their internal IT systems in two different ways – strategic or non-strategic, depending on what kinds of cloud services the firms want to use.

In a firm, regardless of its size, strategic internal IT modularity should be considered by managers as an important factor to help increase adoption of cloud-based SaaS applications in the near future. Decision makers in both SMEs and large enterprises who are still doubtful on the pay-per-use metering and billing model of SaaS should now be less concerned according to the evidence that SaaS is a more cost-effectively model than the traditional license-based software billing model. A thorough study on the benefits and the risks of SaaS is also important for the managers before they decide to adopt SaaS applications. Non-strategic, localized IT modularity for project development and deployment should be considered as a helpful factor for managers in SMEs to adopt cloud-based IaaS and PaaS computing resources rather than SaaS applications. Managers in SMEs can also consider using Web service to make their internal new custom applications more attractive and valuable for their business partners and other third-party firms to use, though this is not related to being ready for adoption of external cloud services, but to offering own services to others.

As a first attempt at the relationship between IT modularity and cloud computing adoption, this study is not without limitations that can be addressed in future work. Due to the cross-sectional, self-reported survey data, especially when narrowed down to our specific research questions, we cannot identify many of the firms' identity such as name and other information that may have enabled us to link the survey to other publicly available financial data sources. One resulting limitation is that some possible controls such as firm age (Tiwana 2008) and industry concentration and regulation (Tafti et al. 2013) cannot be obtained and thus are not included in the models so plausible alternative explanations may not have been accounted for. Even though service-oriented architecture (SOA) is a typical, widely accepted proxy of IT modularity, we would have extended the representation of IT modularity into other constructs if the data were allowed us to do so. As to the robustness of our results, we would like to reexamine them using a longitudinal dataset if possible. As Sanchez and Mahoney (1996) indicate the link between product modularity and organizational modularity, we can examine other types of modularity such as organizational modularity to see if they have any effect on adoption of cloud services. Due to the novelty of cloud computing in 2008, many firms still did not use cloud computing at all according to their answers in the survey, this may cause some distortions in the results, therefore, caution should be taken when generalizing our results.

2.6 Figures and Tables

Figure 2.1. Logical structure of theoretical framework: IT modularity and adoption of cloud computing

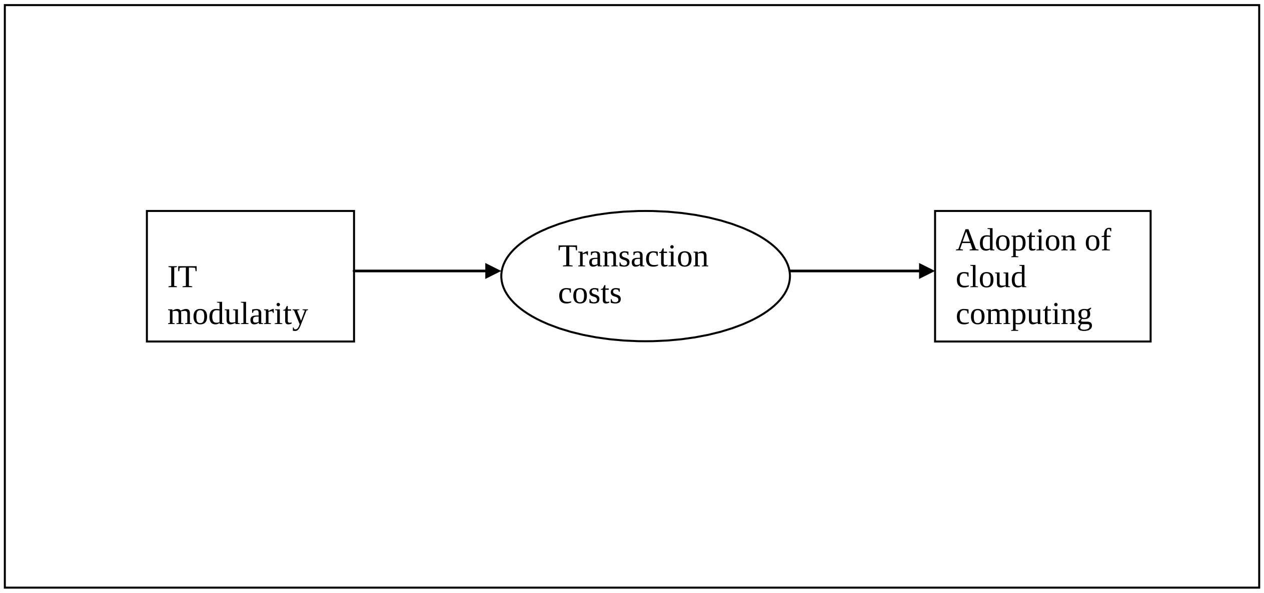


Figure 2.2. Final sample representativeness – SMEs and large enterprises combined

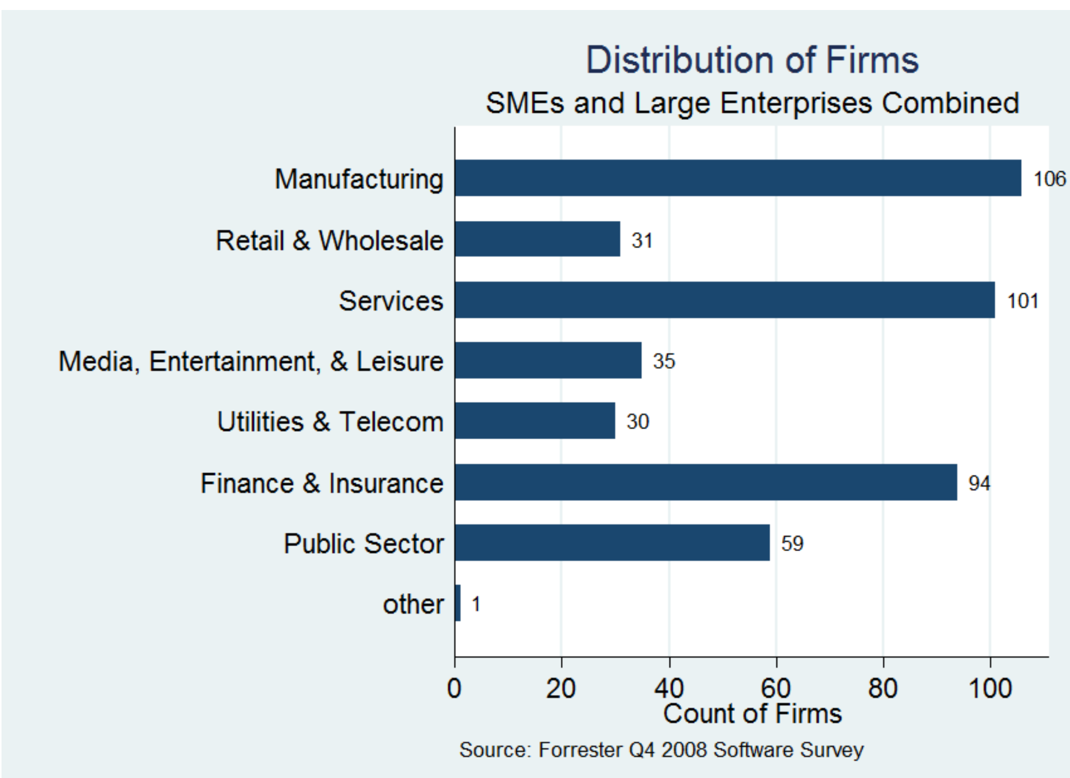


Figure 2.3. Final sample representativeness – SMEs only

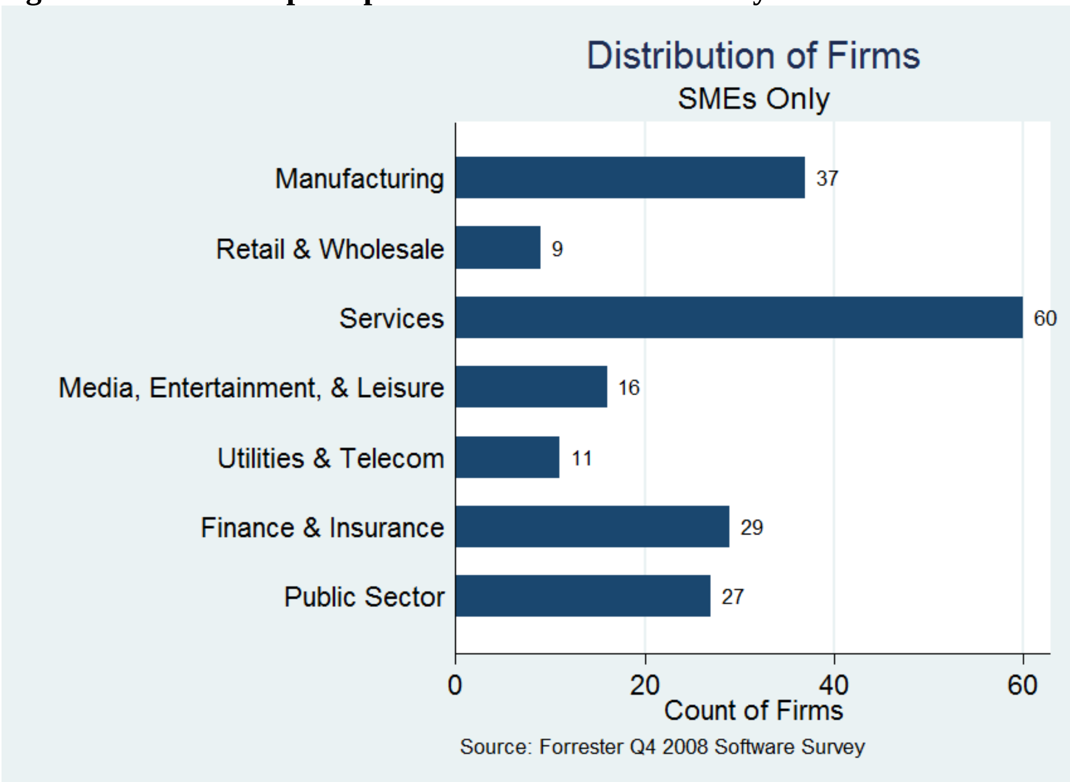


Figure 2.4. Final sample representativeness – large enterprises only

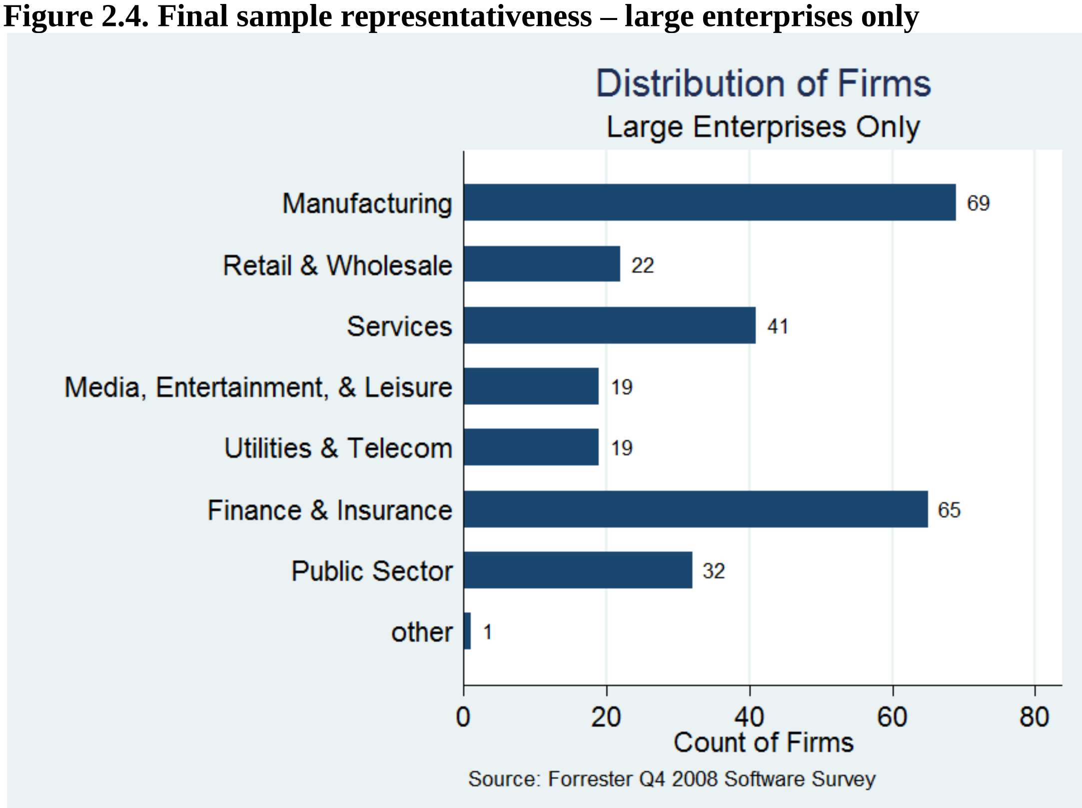


Figure 2.5. Firm distribution of the entire Forrester Q4 2008 Survey dataset – SMEs and large enterprises combined

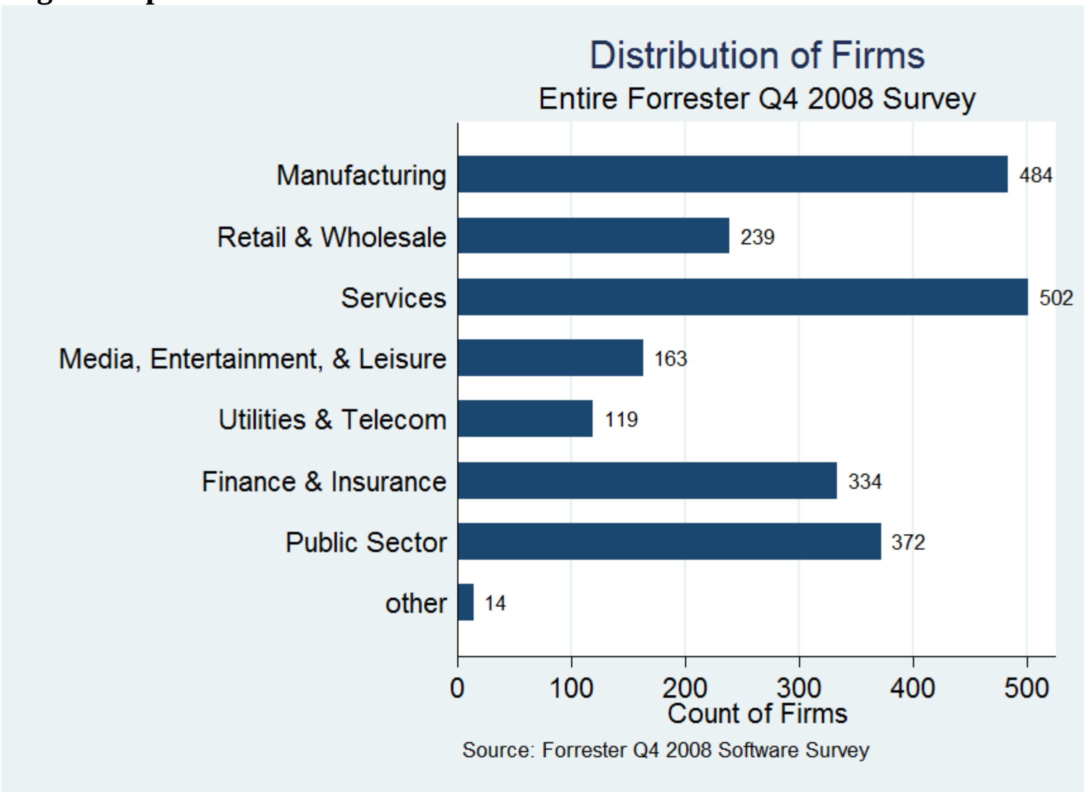


Table 2.1. Correlations and summary statistics for SMEs and large enterprises combined

	Mean	S.D.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) App-level cloud	4.58	8.94	0.00	75.00	1.00						
(2) Strategic SOA	0.26	0.44	0.00	1.00	0.03	1.00					
(3) Non-strategic SOA	1.95	0.91	0.00	4.00	-0.02	0.23	1.00				
(4) Web ser cust app	0.13	0.34	0.00	1.00	-0.06	-0.01	0.08	1.00			
(5) Goal outsourcing	-0.00	1.07	-2.18	5.67	0.23	-0.04	-0.01	-0.10	1.00		
(6) Pref deploy SaaS	0.02	0.15	0.00	1.00	0.25	0.00	-0.02	-0.06	0.24	1.00	
(7) SaaS qual concerns	-0.00	1.85	-0.56	12.75	-0.13	0.00	-0.01	-0.09	-0.08	-0.05	1.00
(8) SaaS flexibility	0.00	1.70	-0.52	11.74	0.24	-0.02	-0.01	-0.02	0.19	0.26	-0.09
(9) Firm size	0.59	0.49	0.00	1.00	-0.13	0.01	-0.12	0.04	-0.14	-0.13	-0.03
(10) IT expenditure	15.13	2.88	8.32	24.12	-0.17	0.10	-0.06	0.06	-0.17	-0.10	-0.00
(11) Ind-Manufact	0.23	0.42	0.00	1.00	0.09	-0.01	0.03	-0.08	0.09	0.02	0.06
(12) Ind-Retail&Wh	0.07	0.25	0.00	1.00	-0.04	-0.06	-0.01	-0.03	-0.03	0.01	0.04
(13) Ind-Services	0.57	0.50	0.00	1.00	-0.02	0.09	0.06	0.11	-0.08	-0.07	-0.06
(14) Ind-Public sect	0.13	0.34	0.00	1.00	-0.06	-0.07	-0.12	-0.04	0.03	0.07	-0.01

	Mean	S.D.	Min	Max	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(8) SaaS flexibility	0.00	1.70	-0.52	11.74	1.00						
(9) Firm size	0.59	0.49	0.00	1.00	-0.06	1.00					
(10) IT expenditure	15.13	2.88	8.32	24.12	-0.05	0.69	1.00				
(11) Ind-Manufact	0.23	0.42	0.00	1.00	0.08	0.07	0.09	1.00			
(12) Ind-Retail&Wh	0.07	0.25	0.00	1.00	-0.04	0.07	-0.01	-0.15	1.00		
(13) Ind-Services	0.57	0.50	0.00	1.00	-0.04	-0.08	-0.04	-0.63	-0.31	1.00	
(14) Ind-Public sect	0.13	0.34	0.00	1.00	-0.01	-0.03	-0.05	-0.21	-0.10	-0.44	1.00

N = 457 firms. Dependent variable is application-level cloud adoption.

Table 2.2. Correlations and summary statistics for SMEs only

	Mean	S.D.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Server-level cloud	5.39	13.02	0.00	90.00	1.00						
(2) Strategic SOA	0.26	0.44	0.00	1.00	0.10	1.00					
(3) Non-strategic SOA	2.08	0.98	0.00	4.00	0.16	0.21	1.00				
(4) Web ser cust app	0.12	0.32	0.00	1.00	-0.13	-0.03	0.11	1.00			
(5) Goal outsourcing	0.17	1.06	-1.62	4.60	0.10	-0.11	-0.08	-0.02	1.00		
(6) Pref deploy SaaS	0.05	0.21	0.00	1.00	-0.06	-0.02	-0.12	-0.08	0.36	1.00	
(7) IT expenditure	12.75	2.11	8.32	18.98	0.09	0.18	0.05	-0.00	-0.16	-0.02	1.00
(8) Ind-Manufact	0.20	0.40	0.00	1.00	0.04	-0.08	0.03	-0.05	0.11	0.08	-0.05
(9) Ind-Retail&Wh	0.05	0.21	0.00	1.00	0.00	-0.02	0.03	-0.00	0.09	0.07	-0.07
(10) Ind-Services	0.61	0.49	0.00	1.00	0.03	0.07	0.10	0.15	-0.15	-0.18	0.03
(11) Ind-Public sect	0.14	0.35	0.00	1.00	-0.08	-0.00	-0.19	-0.15	0.03	0.12	0.06

	(8)	(9)	(10)	(11)
(8) Ind-Manufact	1.00			
(9) Ind-Retail&Wh	-0.11	1.00		
(10) Ind-Services	-0.62	-0.28	1.00	
(11) Ind-Public sect	-0.20	-0.09	-0.51	1.00

N = 189 firms. Dependent variable is server-level cloud adoption.

Table 2.3. Correlations and summary statistics for large enterprises only

	Mean	S.D.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Server-level cloud	3.50	7.60	0.00	60.00	1.00						
(2) Strategic SOA	0.26	0.44	0.00	1.00	0.07	1.00					
(3) Non-strategic SOA	1.86	0.86	0.00	4.00	-0.05	0.25	1.00				
(4) Web ser cust app	0.15	0.35	0.00	1.00	-0.02	-0.01	0.07	1.00			
(5) Goal outsourcing	-0.12	1.07	-2.18	5.67	0.04	0.00	0.02	-0.14	1.00		
(6) Pref deploy SaaS	0.01	0.09	0.00	1.00	0.02	0.05	0.12	-0.04	0.05	1.00	
(7) IT expenditure	16.81	2.05	10.31	24.12	0.02	0.09	0.02	0.08	-0.07	-0.01	1.00
(8) Ind-Manufact	0.26	0.44	0.00	1.00	-0.03	0.03	0.05	-0.10	0.10	-0.05	0.13
(9) Ind-Retail&Wh	0.08	0.28	0.00	1.00	-0.04	-0.09	-0.03	-0.05	-0.09	-0.03	-0.09
(10) Ind-Services	0.54	0.50	0.00	1.00	0.04	0.10	0.02	0.09	-0.05	0.08	0.01
(11) Ind-Public sect	0.12	0.32	0.00	1.00	0.00	-0.12	-0.06	0.04	0.02	-0.03	-0.10

	(8)	(9)	(10)	(11)
(8) Ind-Manufact	1.00			
(9) Ind-Retail&Wh	-0.18	1.00		
(10) Ind-Services	-0.63	-0.32	1.00	
(11) Ind-Public sect	-0.22	-0.11	-0.40	1.00

N = 268 firms. Dependent variable is server-level cloud adoption.

Table 2.4. The effect of IT modularity on cloud computing adoption regression results

	Model 2 (Pooled data, application-level cloud)		Model 3 (SMEs only, server-level cloud)		Model 3 (Large firms only, server-level cloud)
H1A: Strategic SOA	2.836	**H2A**	1.637	**H3A**	1.520
	(1.428)**		(2.214)		(1.109)
H1B: Non-strategic SOA for projects	-1.173	**H2B**	2.050	**H3B**	-0.672
	(0.645)*		(0.998)**		(0.567)
Custom application by Web service	-0.800		-6.371		-0.316
	(1.167)		(2.951)**		(1.359)
Goal of outsourcing	1.074		1.739		0.277
	(0.386)***		(0.909)*		(0.447)
SaaS as preferred deployment option	8.959				
	(2.722)***				
SaaS quality concerns	-0.472				
	(0.214)**				
SaaS flexibility	0.791				
	(0.241)***				
Firm size-SME/large firm	-2.085				
	(2.070)				
IT expenditure	-0.431		0.632		0.067
	(0.192)**		(0.454)		(0.235)
Industry-Manufacturing	-5.667		3.211		-7.596
	(8.374)		(3.291)		(7.735)
Industry-Retail&Wholesale	-7.918		2.342		-7.951
	(8.458)		(4.982)		(7.839)
Industry-Services	-7.077		3.297		-6.904
	(8.351)		(2.813)		(7.705)
Industry-Public Sector	-9.074				-6.970
	(8.403)				(7.796)
Biz Trans SOA x Firm size	-2.959				
	(1.858)				
Project SOA x Firm size	1.439				
	(0.892)				
Constant	19.692		-9.682		10.455
	(8.789)**		(6.550)		(8.669)
R^2	0.16		0.08		0.02
F-stat	5.76***		2.01**		0.53
Observations	457		189		268
Chow test F-stat	1.40				

Notes. The dependent variable is adoption of application-level cloud for Model 2 and adoption of server-level cloud for Model 3. Standard errors are in parentheses. * p<0.1; ** p<0.05; *** p<0.01.

CHAPTER 3: THE IMPACT OF CLOUD COMPUTING ON FIRM PERFORMANCE

Abstract

The IS literature has generated an equivocal debate on whether and how information technology (IT) in the general term improves firm productivity or performance. Cloud computing, as a novel IT paradigm that just has gained its momentum in commercialized usages in recent years, becomes the new context for the debate. As a paradigm that synthesizes multiple prior disruptive IT advances such as virtualization, Internet and utility computing, cloud computing inherently presents diverse yet sometimes perplexing facets when applied in practice, and incurs the important discussion on whether it just makes IT resources flexibly and cost-effectively accessible like a utility or it can do much more than that to enable and foster capabilities that really matter to a firm's competitiveness. With the lens of resource-based view, this study theoretically argues that cloud computing is beyond a utility and can be taken as a strategic resource alone and when complemented with other firm resources. Using cross-sectional and panel data from more than 200 large enterprises that span multiple industries, we show that, cloud computing as a whole, as well as several specific cloud services such as platform as a service (PaaS), can improve firm performance based on Tobin's q. These findings confirm and reinforce the perspective in the IS literature that cloud computing is not simply an IT commodity. Instead, it is a strategic value enabler and may be used directly or to leverage a firm's other resources to gain an edge in business competition if considered and implemented properly.

Keywords: cloud computing; information technology; IT capability; IT resources; resource-based view; firm performance; Tobin's q; business value of IT

3.1 Introduction

In practice, information technology (IT) has become increasingly important and an indispensable investment for the contemporary firms. However, studies have shown mixed findings on whether and how IT has an effect on firm performance (Ray et al. 2005; Weill 1992). On the one hand, some argue that, in spite of technological improvements and increased IT spending, firm productivity is not positively affected by these factors directly, which may be called the "productivity paradox" (Brynjolfsson 1993; Brynjolfsson and Hitt 1996; Brynjolfsson and Hitt 1998). Much from a resource based viewpoint, in his seminal article of "IT doesn't matter" and the subsequent book, Carr (2003) claimed that IT can be quickly commoditized because it is 1) a transport mechanism that is better used in interconnected, standardized functionality rather than isolated customization; 2) highly imitable because of the cost-effective off-the-shelf software and the embedded generic business processes; and 3) subject to rapid price deflation according to the Moore's law[18]. Other IS researchers in this line similarly argue that IT is a commodity which is easily obtainable and imitated by competitors, so that it cannot provide sustainable competitive advantage on its own (Clemons and Row 1991; Hitt and Brynjolfsson 1996). Rather, it is how firms leverage their IT investments to complement and enhance other organizational resources and capabilities (e.g., organizational infrastructure, business process, product and service, market insights, strategic and managerial practice) that determine firms' return on IT investments (Albadvi et al. 2007; Brynjolfsson and Hitt 2000; Devaraj and Kohli 2003; Li and Ye 1999; Melville et al. 2004; Ray et al. 2005; Santhanam and Hartono 2003; Tanriverdi 2005; Wu et al. 2006). On the other hand, many have argued that a direct positive effect of IT on firm performance is extant both in theory and empirical evidence. In the direct correspondences to

[18] Moore's law states that chip performance per dollar doubles every eighteen months. It is a general term for the phenomenon of faster, cheaper computing, named after Intel cofounder, Gordon Moore.

Carr's article, many have showed their disagreements and insisted that IT is not a commodity in many senses and it can directly generate competitive advantage for a firm. Strassmann refuted Carr's assertions one by one and emphasized the fact that advances in IT had given firms much more flexibility and freedom to concentrate on what is indeed meaningful and value-adding to them – their core business competencies and distinct characteristics (Carr 2003). Similarly, Pisello argued that affordable, standardized IT systems and applications had freed firms to focus on innovation instead of burdensome chores of IT management (Carr 2003). Gurbaxani pointed out that, even firms adopted common infrastructure and application systems, how they would utilize, integrate and manage the systems could be very different due to their idiosyncratic business needs and objectives (Carr 2003). Using the resource-based view, Bharadwaj et al. (1999) argue that IT investments can directly promote firms' intangible value such as superior product quality, improved customer service, creation of knowledge assets, as well as synergy and coordination, so as to contribute to firm performance in the long run. He further empirically confirms that IT investments have a direct, positive effect on Tobin's q – a firm performance measure that is forward-looking and captures a firm's intangible value and future growth potential. In the subsequent work, Bharadwaj (2000) claims that three types of firm-specific IT resources, namely IT infrastructure, human IT resources, and IT-enabled intangibles can all improve firm performance. An infrastructure, though composed of possibly commodity-like components, is tailored to the strategic needs of a specific firm so that it is a strategic resource. The human IT resources in a firm such as technical and managerial IT skills accrued from training, experience, relationships and insights of a firm's employees are certainly valuable and largely inimitable. IT-enabled intangibles, such as customer orientation, knowledge assets and synergy, are also highly immune to imitation and substitution. The theoretical arguments are empirically reinforced with the supportive evidence using a matched-sample comparison group methodology.

Corresponding to the two different views based on RBV, on the methodological level, there are also two distinct empirical models: the direct-effect model and the indirect-effect model. The direct-effect model of RBV is to link IT and firm performance directly without any moderating or mediating intermediate factors (Weill 1992). Improper samples, measurement errors, and missing control variables are recognized as the main reasons for the unexpected results in the direct-effect model (Brynjolfsson and Hitt 1996; Dos Santos et al. 1993; Hitt and Brynjolfsson 1996; Weill 1992). The indirect-effect model is to link IT and firm performance indirectly either through some mediating or moderating effects in an attempt to capture the missing links that might be ignored in the direct-effect model. For example, many researchers consider the moderating or interaction effects between IT and other resources such as process, practice and capability, and suggest that the effect of IT on firm performance is mostly realized by complementing those resources (Aral et al. 2012; Bharadwaj et al. 2007; Brynjolfsson and Milgrom 2012; Zhu 2004). Both models have been widely used in IT-performance research and have their own supportive arguments and values.

Cloud computing, constituted by a few precedent and disruptive technologies such as virtualization, Internet, utility computing, and service-oriented computing (Youseff et al. 2008), is a novel IT paradigm that offers highly flexible and cost-effective IT resource provisioning and usage, and emphasizes the freedom of business realization without the burden of IT management. Therefore, the equivocal debate about the effect of IT on firm performance may be escalated in the cloud computing context. As cloud computing has gained much momentum and application in commercial use in recent years, it is imperative to conduct the research investigation on whether cloud computing has an effect on firm performance and in what ways.

Numerous anecdotes and cases have indicated the beneficial effect of cloud computing on firm performance. For example, Reddit (Amazon Reddit 2012), a social news site, can scale its platform to support 4 billion page views per month, and was able to quickly double server capacity in minutes for President Obama's live Q&A session in 2012, thanks to the scalability and flexibility characteristics of cloud computing. As a British multinational hotels company, InterContinental Hotels Group (IHG) (InformationWeek 2011) uses a private cloud to host its CRM systems and public clouds provided by Amazon to develop and test its applications as well as to arrange its Web content to be closer to its customers around the world in order to give a more responsive website visit experience to them. More notably, RehabCare Group (InformationWeek 2011), one of America's largest acute care rehabilitation services supplier, uses a cloud-based app called Point of Care on the iPod Touch to automate their treatment data recording and sharing as well as business processes. The cloud-based approach significantly improves the effectiveness and efficiency of the organization's business operations.

Alongside such anecdotal evidence, Information Systems (IS) researchers have started to investigate the effect of cloud computing on business value, firm productivity and firm performance. From a qualitative, cost-benefit analysis perspective, Aljabre (2012) investigates the value that cloud computing can bring to a business, using the Amazon cloud services as a case study. It is found that Amazon's two major services – Elastic Computer Cloud (EC2) and

Simple Storage Service (S3) – can enable firms not only to reduce costs in hardware and personnel so as to free up capital and operational budgets for the investments that can bring direct business benefits, but also to bring together the key players in business by helping teams, customers and suppliers meet, share ideas and do business more effectively and efficiently. Aljabre (2012) argues that the benefits of cloud services give the firms the edge over their competitors, which ultimately increases their business value. Dean and Saleh (2009) from the Boston Consulting Group also elaborate the potential of cloud computing and observe three distinct levels of value that cloud computing can create: utility level, process transformation level, and business-model-innovation level. The three levels have an escalating sense which means that moving from a previous level to a next level generally causes more profound changes in business process and strategy, and creates a more significant value for a firm. They find that many companies have begun to benefit from the utility level. However, far fewer have been on the second and third levels. Nevertheless, they are confident about that, the benefits of each level are considerable for different types of companies and their diversified needs. For instance, a global energy company may eventually benefit from the utility level by saving a huge amount of annual IT costs. A small-to-midsize business may benefit from the process transformation level by implementation of shared services in document management. A global healthcare company may benefit from the business-model-innovation level by standardizing and automating the elements of the research process in an open cloud platform that connects pharmaceutical companies and their research partners. Based on the field interviews with seven early cloud adopter companies and supplemented by some published reports, Iyer and Henderson (2012) describe six cloud computing benefit patterns (i.e., increased business focus, reusable infrastructure, collective problem solving, business model experimentation, orchestrating dependencies, and Facebook effect) and how these patterns can help manage five business-related strategic risks (i.e., demand risk, inefficiency risk, innovation risk, scaling risk, and control risk). They also identify seven cloud computing capabilities that can be leveraged to mitigate the five types of business risks (i.e., controlled interface, location independence, sourcing independence, virtual business environment, ubiquitous access, addressability and traceability, and rapid elasticity). They therefore propose that deployment of cloud computing in companies can create business value. In order to evaluate the value of cloud computing, Klems et al. (2009) propose a framework to assist decision makers in estimating cloud computing costs and comparing them with the costs of a conventional IT solution. On the conceptual level, Leimeister et al. (2010) and Mohammed et al. (2010) investigate business and value creation by various actors in the context of a new value network enabled by cloud computing. Mladenow et al. (2012) present a systematic analysis of value drivers and leverages of clouds with emphasis on startups and small and medium sized enterprises (SMEs), both in B2B and B2C markets and use the framework to analyze how cloud computing can create value and thus increase competitiveness in a case study in the textile and apparel industry. Weinman (2012) argues that cloud computing does matter for companies to thrive in the increasingly digital world and uses the term “cloudonomics” to emphasize the economics generated around cloud computing. Using the event study methodology, Son et al. (2011) analyze 183 firm-level cloud computing adoption announcements and find that the announcements are associated with positive increases in the market value of the firms.

From the prior literature about cloud computing and firm performance, we can see that most of them are based on a descriptive, conceptual, case study or qualitative analysis. Even though this sort of work is helpful, studies driven by theory and quantitative, empirical analysis are much needed to explain the possible inner mechanism and verify their findings so as to gain more insights and understandings on this important issue of the impact of cloud computing on firm performance. This paper attempts to bridge this gap in the IS literature, utilizing the resource-based view and an empirical approach to examine this interesting and important research question about the impact of cloud computing on firm performance.

In this paper, we reference the experience and approaches on the topic of IT and firm performance from prior IS literature, both from the theoretical and the methodological perspectives. We mainly adopt the resourced-based view as a theoretical lens to investigate the issue of cloud computing and firm performance. Based on the theory-supported arguments and hypotheses, we conduct empirical tests using cross-sectional and panel data collected from a software adoption trend survey and other data sources. Considering the influences of both the direct-effect and indirect-effect methodological models, we combine the two to allow standalone and interaction terms of interest in our models in order to investigate possible individual and complementary cloud effects on firm performance. We argue that cloud computing as a whole as well as certain specific cloud services alone may be regarded as strategic resources that can provide 1) agile, flexible and scalable cloud infrastructures (Armbrust et al. 2010; Marston et al. 2011; Mell and Grance 2010; Qian et al. 2009; Vaquero et al. 2008; Zhang et al. 2010), and 2) valuable cloud-enabled intangibles such as innovation, collaboration and new business model (Böhm et al. 2011; Brook et al. 2014; Brynjolfsson et al. 2010; Etro 2009; Son et al. 2011; Xu 2012; Zhang et al. 2010), as well as renewed focus on core business activities (Garrison et al. 2012). Therefore, cloud computing and its various services as individual factors may directly contribute to firm performance. We also argue that cloud computing may contribute to firm performance indirectly by complementing other internal resources such as various enterprise systems (e.g., supply chain management and customer relationship management) to form renewed and enhanced capabilities (Bhatt and Grover 2005; Brynjolfsson et al. 2010; Melville et al. 2004). In this study, we focus on examining the cloud-performance relationship for large enterprises since the relationship for them is usually more unclear and complicated than the one for SMEs due to many factors they have to consider when using cloud computing such as the issues of security, privacy, compliance and regulation, availability, data lock-in, as well as compatibility and interoperability with the internal heterogeneous and legacy IT systems (Armbrust et al. 2010; Dillon et al. 2010; Marston et al. 2011; Rimal et al. 2009a; Zhang et al. 2010). To measure firm performance, we utilize Tobin's q instead of an accounting measure. Accounting measures have the problem of that, 1) they typically only reflect past information and are not forward looking, 2) they are not adjusted for risk, and 3) they are distorted by temporary disequilibrium effects, tax laws, and counting conventions (Bharadwaj et al. 1999). Accounting measures of firm performance are insensitive to the time lags necessary for realizing the potential of capital investments. This can be particularly problematic in the case of IT investments, where it may take several years for information systems to translate into bottom line performance effects, due in part to the time that it takes to learn and effectively use such systems (Brynjolfsson 1993; Kauffman and Weill 1989). Cloud computing investments, though may significantly reduce the time lags, still need some time to realize its full potential, especially in its intangible values. Tobin's q, defined as the capital market value of the firm divided by the replacement value of its assets, incorporates a market measure of firm value which is forward-looking, risk-adjusted, and less susceptible to changes in account practices (Montgomery and

Wernerfelt 1988). Tobin's q has been used extensively as a measure of a firm's intangible value, which is suitable in this paper since IT has often been cited as a contributor to the intangible value of a firm (Bharadwaj 2000; Bharadwaj et al. 1999; Bhatt and Grover 2005; Brynjolfsson and Hitt 2000; Lindenberg and Ross 1981; Rivard et al. 2006; Wernerfelt and Montgomery 1988).

Having the survey data from more than 200 large firms and combined with the data sources from Compustat and Center for Research in Security Prices (CRSP), we use several different models (OLS, random-effects OLS and propensity score) to show that cloud computing as a whole[19] and three basic cloud services as a whole[20] have a direct beneficial effect on firm performance measured by Tobin's q. On the individual cloud service level, IaaS, PaaS, KaaS and BPaaS are found to be directly linked to firm performance improvement, while SaaS is found to have a complementary effect with internal ERP systems on firm performance. As an attempt of theoretically and empirically investigating the cloud-performance relationship, this paper contributes to the lacking literature and systematic analysis on this issue. It suggests a possible underlying mechanism of how cloud computing is associated with firm performance. This should shed some lights on how to conduct research on this important and emerging question. It also has significant managerial implications for the executives and managers in large enterprises on how to leverage and optimize the effect of cloud computing alone and with their internal IT resources and capabilities, which are much needed as Marston et al. (2011) point out that, organizations are looking for such guidance in developing technology roadmaps in order to decide 1) which

[19] By combining IaaS, PaaS, SaaS, KaaS and BPaaS together. The definitions of these cloud services are given in the following section – Literature, Theory and Derived Hypotheses.
[20] By combining IaaS, PaaS and SaaS together.

applications are best positioned for moving to the cloud or having synergy with the cloud, and 2) how to implement the changes in the least disruptive manner.

The rest of the paper is organized as follows. First, we introduce the literature and theory that support our arguments and hypotheses that link cloud computing to firm performance either directly or complementarily with other resources. Second, we present the empirical methods such as data collection, operationalization of the constructs, and the model specifications. Third, we show the results of our empirical analysis based on the proposed models. Finally, we conclude our findings and research implications, give suggestions to practitioners on how to leverage the capabilities of cloud computing to improve firm performance, as well as discuss the limitations in the paper and the research directions that can be pursued in the future.

3.2 Literature, Theory and Derived Hypotheses

3.2.1 Resource-based view of the firm and what can be regarded as resources

We mainly utilize the theory of resource-based view (RBV) to argue that cloud computing can be a strategic resource alone or by complementing other resources to improve firm performance, therefore we would like to first introduce the resource-based view and what can be regarded as resources in RBV. The resource-based view (RBV) of the firm is a well-known theoretical framework in the studies of determinants of organizational performance in the strategic management literature (Crook et al. 2008). RBV emphasizes heterogeneous firm resource endowments as a basis for competitive advantage. Wernerfelt (1984) first proposes the notion of resource position barriers (i.e., barriers to imitation) and links resource attributes to profitability. Barney (1991) further defines strategic firm resources and skills as those that are valuable, firm-specific, rare, inimitable and non-substitutable to the firm, and proposes the RBV framework supporting the association of strategic firm resources and organization performance. The theory is widely adopted by IS researchers as a suitable and useful lens to study IT as a source to drive firm performance.

One of the critical issues in RBV is to define what is meant by a resource. Researchers and practitioners interested in RBV have used a variety of terms to talk about the definition and classification of firm resources, which may cause confusion and ambiguity. In order to simplify the interpretation of the theory, it is necessary to clarify the definition of a resource in RBV. Barney (1991, p. 101) defines firm resources as "all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc." Wade and Hulland (2004) define resources as assets and capabilities that are used to detect and respond to market opportunities or threats, based on the descriptions by Sanchez et al. (1996). Assets are defined as anything tangible or intangible that can be used in processes to produce products. Capabilities are repeatable patterns of actions that use assets to produce products (Sanchez et al. 1996). This view regards capabilities as one of the equal components in firm resources. Another contrasting view takes capabilities as a function of other resources, thus does not count them as a standalone, equal component. For example, Grant (1991) regards capabilities as the output of the function with the input of resources that can provide competitive advantage for a firm. The function can be about assembling, integrating, and deploying valued resources (Amit and Schoemaker 1993; Sanchez et al. 1996). Organizational capabilities may present a hierarchical structure in which unit capabilities integrate into higher-level functional capabilities (e.g., marketing and manufacturing) and functional ones further integrate into cross-functional capabilities (e.g., customer support capability) (Grant 2010). We integrate both views and recognize that assets and capabilities can be equal concepts in firm resources in some cases as well as have a causal or hierarchical relationship in other cases.

Bharadwaj (2000) classifies important IT resources into three categories: 1) physical IT infrastructure, 2) human IT resources, and 3) the intangible IT-enabled resources and capabilities. Ravichandran and Lertwongsatien (2005) adopt a similar categorization on IS resources: IS human capital, IT infrastructure flexibility, and IS partnership quality. Wade and Hulland (2004) suggest that the capabilities held by a firm can be sorted into three types: inside-out, outside-in, and spanning. Inside-out capabilities are deployed from inside the firm in response to market requirements and opportunities and tend to be internally focused (e.g., technology development, cost controls). Outside-in capabilities are externally oriented, placing an emphasis on anticipating market requirements, creating durable customer relationships, and understanding competitors (e.g., organizational agility, market responsiveness, managing external relationships). Spanning capabilities, which involve both internal and external analysis, are needed to integrate the firm's inside-out and outside-in capabilities (e.g., managing IS/business partnerships, IS management and planning). Subsequently, the three types of capabilities are simplified into two categories: internal (i.e., mainly inside-out) and external (i.e., mainly outside-in and spanning) (Hulland et al. 2007; Liang et al. 2010).

3.2.2 The direct effect of cloud computing on firm performance

As aforementioned, cloud computing may present a direct impact on firm performance. The investigation on this aspect is important for researchers as well as practitioners to understand whether cloud computing is merely an IT commodity that is easily accessed and imitated by competitors or it can become a strategic resource that provides heterogeneous, oftentimes intangible capabilities and values to firms so as to improve their competitive advantage and firm performance.

As we know, cloud computing is an overall concept that comprises many specific service models such as the three basic models of IaaS, PaaS and SaaS (Mell and Grance 2010) and other extended models like KaaS and BPaaS. Therefore, we can investigate the direct effect of cloud computing on firm performance on three distinct levels: cloud computing as a whole, basic/extended cloud computing as a whole, and individual, specific cloud service models.

3.2.2.1 Cloud computing as a whole and firm performance

As Dean and Saleh (2009) summarize, the value of cloud computing can be captured through three different levels: utility, process transformation, and business-model-innovation. Mapping them with the RBV framework of IT capability by Bharadwaj (2000), we argue that cloud computing can provide different values in IT infrastructure as well as IT-enabled intangibles through the three levels thanks to its multifaceted, synthesized traits that are inherited and enhanced from its component technology predecessors such as the Internet, distributed computing, virtualization, multi-tenancy, and service-oriented computing (Youseff et al. 2008). The overall theoretical framework for the direct effect can be found in Figure 3.1.

On the utility level, cloud computing is regarded as a mode of consuming IT resources as a utility (Buyya et al. 2009b; Rappa 2004). From the RBV perspective, the utility mode enables cloud users with the capability of using IT resources in an agile, flexible and scalable way and paying only what they have consumed on processing, storage, bandwidth and alike so that up-front capital costs of IT become operating expenses – the costs of IT have been lowered and more predictable. Indeed, the predominant reason for most of the firms today to adopt cloud computing is about cost savings (Marston et al. 2011). Firms find that their capital investments in internal IT resources are largely underutilized (utilization rate is only 5%-20%) at the usual time because the resources are planned to meet the expected demand of peak workload that only happen occasionally (Armbrust et al. 2010). Cloud users generally don't have to worry about predicting and planning the IT resource consumption in the future – they can reserve what they need just in time by easily and quickly scaling up or down the resources according to the changes of their needs. Firms significantly reduce their risks of over-provisioning and under-provisioning of IT resources by using cloud computing (Armbrust et al. 2010). The utility billing model of cloud computing also significantly reduces firms' IT maintenance and service costs (Marston et al. 2011) including IT labor costs, software and hardware operating costs, and power costs (Dean and Saleh 2009). Instead of draining the precious investments in IT maintenance and plumbing, IT staff in a firm that uses cloud computing can now focus on improving the functionality and features of their IT systems and rolling out new applications in an agile, less time-consuming way. The strategic planning of using cloud computing to save various capital investments and costs in IT systems, to deploy those scarce corporate resources into the areas that more matter to the firm's business strategies and to cost-effectively implement new IT functionality and services can make a firm's IT infrastructure more nimble, flexible and strategy-oriented so as to generate a competitive advantage for the firm. For example, Dole Food Company (Amazon Dole) chose the Amazon cloud services to host its Microsoft SharePoint solutions, which enabled it to launch a new SharePoint site in just minutes in the Amazon cloud and to save at $350,000 in operating expenses thanks to the cost-saving as well as the agility and flexibility capabilities from cloud computing. What is more important to the companies, however may be that, the utility-like use of cloud computing enables them with the capability and freedom of focusing on their core business operations and strategies rather than having to worry about and deal with the cumbersome IT hardware, software and personnel management (Garrison et al. 2012). The ability to focus on the core competitiveness allows firms to put their usually limited, valuable resources into what really matters to their business – be it customer orientation, know-how, product and service quality, or business agility and flexibility. Those often intangible values are certainly idiosyncratic to specific firms and hard-to-copy thus can generate competitive advantage. Companies have utilized this utility model to gain the benefits of cost savings as well as renewed focus on core business. For example, Dow Jones & Company (Amazon Dow Jones 2013) moved the software that hosts the Wall Street Journal in Asia to Amazon Web Services (AWS), saving more than $40,000 each year in hardware and maintenance and enabling its employees to focus on creating revenue-producing applications.

On the process transformation level, cloud computing (especially cloud platforms and infrastructures) provides complicated and powerful capabilities enabled by transforming business processes and how they are connected together. The enabled capabilities on this level are improved integration of and collaboration in business processes by leveraging the common assets of cloud computing (Dean and Saleh 2009). By sharing the common data and process standards, innovative and efficient ways of working are enabled to accelerate business processes and productivity. Cloud platforms and infrastructures allow firms to experiment, develop and deploy their tailored processes, functions, applications and business structures according to their own situations, needs and strategies in a cost-effective, fast and flexible manner, therefore they can generate strategic resources that are distinct to a firm and promote firm value. For instance, Mohawk Fine Papers (Computerworld 2012), the premium papers manufacturer, used Amazon's cloud platform through a cloud service broker Liaison Technologies to integrate all kinds of data with its ERP system such as ordering, HR systems, planning and scheduling. This made the company very nimble, flexible, and cost-effective at the B2B integrations and collaborations as well as data management with its customers, suppliers and other business partners. These capabilities were enabled by sharing common data and standard processes in the cloud services. The anecdote about RehabCare Group (InformationWeek 2011) shows the capability of a cloud platform to profoundly change and innovate business processes to improve firm performance. We can see that firms use cloud computing in a sophisticated way by transforming its business processes, therefore the values gained from such usage can be significant on this level.

On the third level of business model innovation, cloud computing provides the capabilities of creating new business models, innovations and ecosystems through linking, sharing, and combining resources within and between enterprises (Dean and Saleh 2009). These capabilities are certainly the best efforts that firms make to differentiate themselves from their competitors as profoundly as possible, therefore cloud computing on this level surely can generate strategic resources and improve firm performance. As an example, 3M (IBM 2012) embraces a new cloud-enabled business model for its visual attention service. The 3M Visual Attention Service (VAS) is an online scanning tool that scientifically analyzes design effectiveness based on how the average human eye responds. It helps designers, marketers and other communicators test the visual impact of their content and increase the probability that viewers will notice the most important elements of a design. The challenge was that, since the global design community is made up of copious small design organizations, 3M needed to make the new capability accessible from anywhere, affordable to many and available as needed during a design project. By using the cloud-enabled VAS, 3M is able to offer the service on a continuous basis without requiring customers to install special software to use it. The cloud solution also ensures that the latest version is always available for customers. The cloud-enabled business model allows 3M to offer a new solution, known as VAS, to a new audience – the creative design community, and to transform its role in the product development value chain by closely integrating with a global network of designers. Cloud computing allows 3M to deliver VAS in a fast, user-friendly manner that fits into a designer's existing design process. The role of cloud computing in creating new value chains and networks as well as various players have emerged as an important research topic in IS research (Böhm et al. 2010; Leimeister et al. 2010; Mohammed et al. 2010; Ojala and Tyrväinen 2011).

Overall, each level of cloud value can generate different yet strategic resources that are not so common, imitable or substitutable for firms to gain competitive advantage as shown in Figure 3.1. As a result, we posit that cloud computing as a whole may directly improve a firm's performance and the relevant hypothesis is as follows:

Hypothesis 1 (H1). Cloud computing as a whole is positively associated with firm performance.

3.2.2.2 Basic and extended cloud computing as a whole and firm performance

On top of the three basic cloud service models of IaaS, PaaS and SaaS described by Mell and Grance (2010), there are other derived service models that emphasize and enhance specific service notions such as Information/Knowledge as a Service[21] (I-aaS/KaaS) and Business Process as a Service (BPaaS) and so on. I-aaS/KaaS takes information and knowledge as services and lets users acquire and use it optimally as needed. In the taxonomic model of anything as a service (XaaS) that covers every extant cloud service model as layers, KaaS is a cross-layer paradigm that may span across several basic layers of IaaS, PaaS and SaaS. BPaaS is an extension of the SaaS service model that regards business processes as services with well-defined and often standardized interfaces (Whibley 2012). BPaaS enables agile, flexible and scalable business process creation, integration and configuration to facilitate companies to fulfill their business operations and goals. Comparing to the three basic tiers, the extended cloud services such as KaaS and BPaaS are usually more specialized with clear purposes or focus areas. Therefore, basic cloud services as a whole and extended cloud services as a whole may present different direct effects or magnitudes of effect on firm performance, and we would like to investigate the effects of the two groups separately and argue that both groups of cloud services can improve firm performance directly as in the following hypotheses:

Hypothesis 2A (H2A). Basic cloud services as a whole are positively associated with firm performance.

Hypothesis 2B (H2B). Extended cloud services as a whole are positively associated with firm performance.

3.2.2.3 Specific cloud service models and firm performance

[21] Usually the two terms are interchangeable and often taken as a unified term.

Cloud computing has three basic service models, namely Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) (Mell and Grance 2010). Based on them, there are many other extended service models that serve and emphasize a particular notion as a service including KaaS and BPaaS as mentioned previously. As each of the specific service models has its own characteristics and purposes, we would like to investigate the direct effects of each individual service model on firm performance as well.

3.2.2.3.1 IaaS and firm performance

Infrastructure as a Service (IaaS), as the lowest layer in the basic three-tier cloud service model by Mell and Grance (2010), is the capability provided to cloud users to provision virtualized processing, storage, networks, and other fundamental hardware resources on a pay-per-use basis. Some popular IaaS services are OpenStack, Eucalyptus, Rackspace Cloud Servers, and Amazon Elastic Compute Cloud (Amazon EC2) and Simple Storage Service (Amazon S3) (Marston et al. 2011; Zhang et al. 2013). As aforementioned, the pooled and virtualized computing resources in an IaaS cloud have a much better utilization rate because of its virtualization and multi-tenancy approaches. Cloud data centers are typically of very large-scale, located in least-cost geographic locations, and accommodate numerous networked commodity computers (Armbrust et al. 2010). From the microeconomic point of view, this approach enables very large economies of scale, which means that cloud computing can offer services below the costs of a medium-sized traditional data center and yet still make a good profit (Armbrust et al. 2010). From the cloud users' perspective, this means significant IT cost benefits. The theoretically unlimited computing resources are now more accessible and less costly to firms. From the resource-based view, Garrison et al. (2012) argue that organizations that implement this type of cloud service model can increase IT economies of scale by driving IT costs down in the shared, virtualized, utility-billing cloud computing environment and obtain an advantage over a direct competitor at least until the competitor also implements the cloud service. Perry and Hendrick (2012) find that the IaaS-level Amazon EC2 services have enabled many capabilities for the investigated companies. For example, five-year total cost of ownership (TCO) has been reduced by 70% on average for the companies including significant cost savings on infrastructure and infrastructure support. In addition, they find that the benefits of using Amazon EC2 increase as measured by the ratio of benefits realized in dollars per dollar invested in Amazon EC2. Furthermore, in addition to the simple use of IaaS to reduce the explicit and implicit IT costs, firms can implement their own computing platforms and develop their own processes and applications based on IaaS in a faster and more flexible way, which means the IaaS-enabled flexible IT infrastructures can generate strategic values to firms and hence directly benefits firm performance. A renewed focus on core business activities is also made possible because IaaS can free firms from managing complex IT hardware and infrastructures. Anecdotes show that companies have successfully utilized the capabilities enabled by IaaS. Deputy (Amazon Deputy 2011), a Sydney-based company that markets a customizable web-based employee management system to businesses and government agencies, saved $750,000 in capital expenditures by migrating the system to AWS. Zhang et al. (2013) demonstrate how to design and deploy an education IaaS system by using OpenStack, an open source IaaS project contributed and developed by NASA and Rackspace. They also show the capability to quickly implement a high-performance computing service, a net disk service and an education management service based on the IaaS system.

As a result, we posit that IaaS may enable firms with productivity and performance improvement. We thus propose the following hypothesis:

Hypothesis 3A (H3A). Infrastructure as a Service (IaaS) is positively associated with firm performance.

3.2.2.3.2 PaaS and firm performance

Platform as a Service (PaaS), as the second layer in the basic cloud service model by Mell and Grance (2010), is the capability provided to cloud users to develop and deploy their own or acquired applications utilizing the tools and platforms offered by PaaS providers. Some well-known PaaS services are Microsoft Azure, Google App Engine, Rackspace Cloud Sites, and Force.com from Salesforce (Marston et al. 2011). Lawton (2008) argues that PaaS has the capability to increase programmer productivity, enable companies to build and release products more quickly and reduce development costs. Mallasch et al. (2013) study PaaS as an alternative and new platform for commercial aviation applications in order to address the long-standing problem of point-solutions in the aviation industry – deploying ad hoc, specialized hardware and custom software with very specific functionality to address a very specific problem. The point-solutions are difficult to improve along the changes of the problems or technologies, hampering the operator’s flexibility, slowing innovation, and making it difficult to control costs. PaaS provides the capabilities to eliminate or alleviate those problems, generate major cost savings, significantly boost productivity, as well as provide value across traditional organization unit silos. Padhy et al. (2012) overview the key capabilities of a specific proprietary PaaS – Microsoft Azure. One of them is to provide highly scalable solutions to support large volumes of simultaneous users accessing many different applications hosted on the platform. Wajima (2010) describes Fujitsu's efforts on building a PaaS platform to address the evolving market demands for a service-based application development and execution environment to respond to the trend of small-scale rapid development. Zhang et al. (2012) also recognize the agility capability of PaaS on application development and delivery. As an anecdotal case, Life Technologies (Amazon Life Technologies 2013) provides a PaaS on the AWS Cloud to make it easier to analyze biological data and share them digitally, helping scientists accelerate research that may make personalized medicine a reality in the future. Life Technologies saved $375,000 in capital expenses by not building a private data center, and can now deliver software three times faster.

It is clear that the flexible PaaS cloud infrastructure and platform can enable firms to cost-effectively and flexibly develop different kinds of processes, functions and applications, integrate and connect functions across different units and firms, as well as facilitate collaboration with business partners to accelerate research and innovation. These all generate strategic IT structures and intangible values that contribute to the firms' performance directly.

Thereby we suggest that PaaS may improve firms' productivity and performance. The relevant hypothesis is as follows:

Hypothesis 3B (H3B). Platform as a Service (PaaS) is positively associated with firm performance.

3.2.2.3.3 SaaS and firm performance

Software as a Service (SaaS), as the top layer in the cloud service model by Mell and Grance (2010), is the capability provided to cloud end users to directly use cloud-based applications via networks. Examples of SaaS include enterprise-level applications such as Netsuite, Google Apps and Salesforce CRM (Marston et al. 2011). SaaS can be adopted as an excellent outsourcing model that exhibits the technological and economic benefits of IT services (Chou and Chou 2007a; Chou and Chou 2007b). Taking SaaS as the fourth wave of outsourcing, Joha and Janssen (2012) investigate two case studies to understand the design choices underlying the SaaS business model from the user organization perspective using the unified business model conceptual framework. They find that SaaS can provide a variety of tangible and intangible values[22]. From the dynamic capability perspective, it is found that SaaS has the capability to capture value and improve firm performance more in a turbulent business environment in conjunction with the effects of cloud supplier-client collaboration and cloud client's sensing and responding agility based on an empirical study on 215 firms (Chiang and Chou 2013; Chou et al. 2014). From the microeconomic point of view, Choudhary (2007) analyze and compare the differences of the SaaS and perpetual licensing models and the impact of these licensing schemes on the publisher's incentive to invest in software quality, and find that the SaaS licensing model leads to greater investment in product development under most conditions. This increased investment leads to higher software quality, greater profits for the software publisher, and greater social welfare in equilibrium under SaaS as compared to perpetual licensing. Harmon and Demirkan (2011) argue that SaaS can help IT managers in the second wave of green and sustainable IT strategies – market-focused sustainable IT services by enabling development of new business models for disruptive innovation and differentiation. Using the method of field study, Herrick (2009) observes that the Google Apps for Education suite, a set of SaaS

[22] 1) standardization and consolidation of processes and applications, 2) better utilization of firm resources, 3) flexibility in costs, system maintenance and upgrade, and reporting of business critical data, 4) better security, functionality and data integrity, 5) efficiency in computer resource utilization, lowered labor costs, increased productivity, and cost flexibility, 6) agility in upgrading or changing services or capacity very quickly, meeting urgent demands of the users, and 7) innovation in service functionality and linkage to emerging technologies.

applications developed by Google and comprises Google Mail, Calendar, Talk, Docs, Sites and Video, have boosted the collaboration, communication and productivity among the students, faculty and staff at Colorado State University (CSU). Hill (2012) observes that the book publishing industry has profoundly changed from traditional paper-based publishing to a highly dynamic market for ebooks and other digital products. This dynamic market forces book publishers to cut costs and shrinks ROI (return on investment) horizon for technology investments. As a result, book publishers have begun to migrate from relatively closed systems that are internally maintained, to SaaS-based platforms on the Web which is better suited to such a dynamic, digital market thanks to their swift capabilities to catch and respond to quickly-changing business opportunities in digital book publishing. Leadley et al. (2010) study the case of SaaS usage at Allianz, one of the leading integrated financial services providers worldwide, to support global Human Resource (HR) processes. They summarize the capabilities of SaaS as faster implementation time, easier overall resource planning, and increased provider responsiveness and service. Churakova et al. (2010) suggest that SaaS provide firms with the opportunity to focus on core capabilities, better capital allocation, and freedom to choose and change different SaaS vendors. Using a large cross-sectional dataset of U.S. firms, Malladi and Krishnan (2012) empirically examine and find an association between SaaS adoption and IT-enabled innovation of the firms. Rivero et al. (2010) propose a SaaS-based framework that supports web applications' reuse, configuration, multi-user efficiency, scalability and fast delivery in the context of research organizations. Satake (2009) uses Fujitsu's SaaS platform to address the emerging business needs in flexibility, efficiency and responsiveness. Anecdotes also show the values of SaaS on improving firm productivity and performance. For example, Johnston Press (ComputerWeekly.com 2012), a newspaper company in the United Kingdom wants to transform its business into a digital media company with an advertising-led revenue model. Deploying Salesforce.com on mobile devices is integral to the plan to provide cloud-based customer relationship management (CRM). The SaaS-based CRM software will enable field sales teams to work more directly with potential advertising customers, by providing a mobile office on the iPad for managing the sales process and running sales presentations at customer's premises. The field sales representatives use the CRM software on the iPad to capture the detail of a customer's advertising campaign. The company is also using another SaaS application, Salesforce.com's Chatter collaboration tool, to enable the sales team to collaborate with managers. The Citibank Wealth Management unit (Citibank CRM) replaces a fragmented CRM system with a unified, tailored Saleforce.com CRM application. The new SaaS-based CRM helps Citi greatly increase its wealth management advisors' productivity and the customer experience including saved time per week per advisor, increased advisor focus on client investment and growth, robust security for sensitive client financial data, and greater client satisfaction.

As the literature and anecdotes suggest, SaaS may create various values for firms. Therefore we propose the following hypothesis:

Hypothesis 3C (H3C). Software as a Service (SaaS) is positively associated with firm performance.

3.2.2.3.4 KaaS and firm performance

As Prahalad and Krishnan (2008) point out, value creation will be led by personalized consumer-cocreated experiences and global access to resources and talents in the new age of innovation.

Data, information and knowledge become firms' pivotal assets (i.e., intellectual capital) in order to know their customers better, serve customers in a tailored fashion, obtain know-how and insights to differentiate themselves from their competitors, and to grasp fugitive business opportunities and trends. Gurjar and Rathore (2013) argue that nowadays organizational competitiveness is defined by how quickly companies can synthesize the many sources of information. More complex data analysis in the form of ad-hoc analysis (to figure out what to do now) and predictive analysis (to understand what to do next) is the requirement of today's changing business needs. Knowledge assets may exist in the employees' skills and experiences, in the processes, policies and databases in a firm. A firm's knowledge capital is widely recognized as a strategic resource that can promote competitive advantage (Bharadwaj 2000). KaaS is designed to deliver information and knowledge as services over a cloud infrastructure to the users in a flexible and optimal way. Using a cross-sectional survey dataset collected from 443 firms, Darroch (2005) finds the empirical evidence to support that, a firm with a knowledge management capability will use resources more efficiently and hence be more innovative and perform better. Deeds and Decarolis (1999) reference the knowledge-based view of the firm, an extension to RBV, to understand the relationship between firm capabilities and performance. The knowledge-based view suggests that knowledge generation, accumulation and application may be the source of superior performance. They empirically test the relationship between stocks and flows of organizational knowledge and firm performance in the biotechnology industry and find that a firm's geographic location as the representation of knowledge flows and products in the pipeline and firm citations as the representations of knowledge stocks are significant predictors of firm performance. KaaS allows firms to easily and cost-effectively integrate, transfer and apply best practices, know-how and insights with their specific business experience and needs, so as to create specialized knowledge assets that are hard to be imitated by competitors. KaaS can also help firms know and serve their customers better in a more customized way to increase the intangible value of customer orientation, and share information and knowledge across different units within firms to increase the intangible value of synergy.

Overall, KaaS provides firms with multiple intangible values so it can improve firm performance. The relevant hypothesis is proposed as follows:

Hypothesis 3D (H3D). Knowledge as a Service (KaaS) is positively associated with firm performance.

3.2.2.3.5 BPaaS and firm performance

Davenport (2013, p. 5) defines a business process as "the specific ordering of work activities across time and space, with a beginning, an end, and clearly identified inputs and outputs". A single firm executes numerous business processes to achieve its strategic objectives, thereby providing a range of opportunities for the application of information technology to improve processes and organizational performance (Porter and Millar 1985). In the net-enabled organization, IT not only may improve individual processes but also may enable process synthesis and integration across disparate physical and organizational boundaries (Melville et al. 2004). Application of IT and complementary organizational resources may improve business processes or enable new ones, which ultimately may impact organizational performance (Brynjolfsson and Hitt 2000). Bharadwaj (2000) points out that firm capabilities originate from processes and business routines. Business Process-as-a-Service (BPaaS) is an important, extended cloud service model that regards business processes as services with well-defined and often standardized interfaces. BPaaS enables cost-effective, agile, flexible and scalable business process creation, integration and configuration to facilitate companies to fulfill their business operations and goals. Zhang and Zhou (2009) summarize that BPaaS provides tasks or functions that can be integrated with firm users' business processes. BPaaS is a new model for sharing best practices and business processes among cloud firm users and their partners in the value chain. Software testing, a very important business process in the lifecycle of software development, can be offered as a BPaaS in the cloud. Ghalimi (2008) suggests that service-based business process management (BPM) such as BPaaS provides firms with an on-demand capability to describe their business requirements and rapidly turn them into active processes or systems in a scalable, flexible and cost-effective way so that IT and business are brought together to improve firm performance. Whibley (2012) points out that BPaaS has the values of business case transformation, business process outsourcing (BPO), rapid prototyping and try before you buy, and extending business process to mobile devices. Some popular BPaaS applications are Cognizant, IBM Business Process Manager on Cloud, and Oracle Business Process Services. As an anecdotal example, Genpact (Genpact BPaaS), a BPaaS solution provider, helps a leading manufacturer continue its market expansion even in a tight economy by completing three acquisitions in an emerging market within six months. Genpact's BPaaS solution for the client firm provides an integrated platform for core HR functions and payroll in different countries. The BPaaS solution enables the client firm with the capabilities of significant cost savings by paying only a monthly charge based on usage, automated payroll processing, enhanced productivity, and end-to-end transparency with zero capital expenditure. Overall, BPaaS facilitates renovating and innovating firms' internal business processes and aligns them with the business goals better, thus generating tangible and intangible values. We therefore postulate that BPaaS is positively associated with firm performance and the relevant hypothesis is as follows:

Hypothesis 3E (H3E). Business Process as a Service (BPaaS) is positively associated with firm performance.

3.2.3 Complementary effect of cloud computing and enterprise resources on firm performance

In addition to the direct effect of IT, literature also finds that a complementary effect of IT and other resources on firm performance may exist. Resource complementarities have been conceptualized in two broad ways in the resource-based view literature: the interaction view and the channeling view (Ravichandran and Lertwongsatien 2005). The interaction view regards firm resources as complementary when the presence of one resource enhances the value or effect of another resource. This view is typically operationalized using multiplicative terms in statistical analysis. The channeling view conceptualizes resource complementarity based on how resources are channeled and utilized. Firms have choices about how resources are deployed. Complementarities arise when resources are used in a mutually reinforcing manner. Wade and Hulland (2004) argue that IS resources rarely contribute a direct influence on sustained competitive advantage. Instead, they complement other complex assets and capabilities to lead to sustained performance. Clemons and Row (1991) argue that IT investments themselves are similar to commodities, therefore are not immune from easy imitation and substitution and cannot provide sustainable competitive advantages to firms. They suggest that IT investments exert their influence on the firm through complementary relationships with other firm assets and capabilities. Using a retail industry survey, Powell and Dent-Micallef (1997) empirically find that IT alone cannot produce sustained competitive advantage, but that IT can leverage other intangible, complementary human and business resources to gain sustained competitive advantage. Bharadwaj et al. (2007) find that IT is increasingly viewed as complementary resources that enhance the value of other organizational resources and capabilities in the IS research. Melville et al. (2004) assert that IT and the complementary resources of the firm affect the effectiveness of business processes which consequently affects organizational performance. Zhu (2004) empirically finds that the complementarity of front-end e-commerce capability and backend IT infrastructure positively contributes to firm performance.

In this paper, we would like to utilize the interaction view of complementarity to analyze the complementary effects of cloud computing and other resources on firm performance. We think the interaction view is a more cogent one for this particular study according to the sense of complementarity of cloud computing and other resources mentioned in the prior literature. As Brynjolfsson et al. (2010) point out, the real strength of cloud computing comes from complementarities and co-invention. Firms that simply replace corporate resources with cloud computing, while changing nothing else, will miss the full benefits of the new technology. Only when firms adapt and reinvent suitable processes, will the potential of cloud computing be realized. The opportunities risen from cloud-enabled business model innovation and organizational redesigns can reshape entire industries.

3.2.3.1 Cloud computing, enterprise systems and firm performance

A firm's IT infrastructure consists of IT hardware, operating systems, platforms, system software, and enterprise-wide application software alike (Ross et al. 1996). IT infrastructure determines the business degrees of freedom a firm enjoys in its business plans. IT infrastructure spans and influences virtually every aspect of a firm so that its inherence, effectiveness and efficiency determine a firm's business choices – whether they are very restricted or enabled. Due to its complexity and comprehensiveness, IT infrastructure is hard to be imitated by competitors even though individual components may be commodity-like. Building such integrated infrastructures takes time and effort and involves experiential learning (Broadbent 1998). IT infrastructure, if properly designed, implemented and fit into a firm's specific needs and characteristics, can become a causally ambiguous resource that essentially drives the firm to gain competitive advantage over its rivals. For example, such an infrastructure may present the characteristics of promoting rapid application development, information sharing, standardization and interoperability, and synergy across business units (Reed and DeFillippi 1990). Overall, because of its reach and range, IT infrastructure, as one of the strategic IT-related resources, can promote firm performance (Bharadwaj 2000; Ravichandran and Lertwongsatien 2005).

Enterprise systems usually are companywide applications that touch many aspects and business functions in a firm, therefore they can be taken as a major part of IT infrastructure and pivotal to a firm's business success. Enterprise resource planning (ERP) application systems encompass a wide range of software products supporting day-to-day business operations and decision-making using common databases maintained by a database management system (Hitt et al. 2002). ERP systems have become increasingly prevalent since the early 1990s. The appeal of the ERP system is clear – the standardized and integrated ERP software environment provides a degree of interoperability that was difficult and expensive to achieve with standalone, custom-built systems. However, implementation of traditional on-premise ERP systems requires a substantial investment of time, money, and internal resources and is fraught with technical and business risks. ERP implementations are also known to be unusually difficult partially due to the pervasiveness of the changes associated with ERP including process redesign of multiple functional areas and the need to adapt processes to the capabilities of the software. There is also a high degree of managerial complexity of these projects. Though ERP systems are packaged software applications, the majority of the project cost is devoted to setup, installation, and customization of the software – services typically provided by external consultants such as Accenture. Given the scale of ERP implementation projects as well as the possibility for both large success and failures, it is reasonable to expect that ERP deployment has a significant and measurable effect on firm performance. Because implementation is a difficult and uncertain process, firms that are successful in implementing ERP may gain competitive advantage over other firms that are unwilling or unable to make similar changes, thus increasing the value of the firm. With the advent of cloud computing, companies have considered complementing ERP with cloud computing to make ERP more affordable, flexible and agile so as to address the difficulties in implementation of the traditional on-premise ERP systems as well as to augmenting their strategic values. Some popular cloud-based ERP systems are Acumatica, Epicor Express, Infor SyteLine, NetSuite, Plex Online, Sage Accpac Online and SAP Business by Design (Lenart 2011). When using a Web-based ERP system that is run as a SaaS in the cloud, the organization gains the combined benefits of scalability, lower total cost of ownership (TCO), real-time data access anytime and anywhere, streamlined business process rapid deployment and implementation, easy and cost-effective upgrades, lower capacity requirements, and interoperability. The most important values of the Cloud ERP model are reduction of hardware and license costs, scalability and manageability (Lenart 2011). Raihana (2012) thinks that cloud

ERP is a maturing deployment model that may provide a greater opportunity to capitalize on an ERP investment which encourages standardization through visible economic drivers (e.g., less staff, costs reduction, expandability and mobility) and provides the opportunity for greater focus on strategic activities. Many researchers have studied the factors that influence the adoption of the cloud ERP model including SaaS ERP. By interviewing twenty Microsoft employees, Johansson and Ruivo (2013) summarize the benefits of the Microsoft SaaS ERP adoption: reducing costs, system availability, simplified implementation, access ubiquity, flexibility in implementation and upgrade, compatibility, integrated analytics tools, and best practices in cost decreases and business process standardization. Saeed et al. (2012) use interviews and qualitative methods to analyze the motives of cloud ERP adoption. The cloud ERP adoption motives are divided into three categories, namely strategic, operational and technical. Strategic motives encompass flexibility for business innovation, faster time to market for products and services, concentration on core business, and pressure to keep up with competitors. Operational motives comprise on-demand scalability, low capital expenditure, low maintenance cost, better support provided by cloud ERP vendors, and reduced IT cost for the enterprise. Technical motives consist of high technical reliability provided by cloud ERP vendors, automatic upgrades provided by cloud ERP vendors, and higher technical security provided by cloud ERP vendors. Many cloud application vendors have offered cloud-based ERP systems. For example, NetSuite (NetSuite Two-tier ERP) offers a two-tier ERP model to address the challenge of integrating of a company's new subsidiaries and expansions with its corporate ERP in a rapid and affordable way and achieving the real-time global visibility and efficiency that its business demands. The two-tier model lets the company preserve its on-premise ERP investments in SAP or other systems while equipping global subsidiaries with a more nimble, flexible cloud-based ERP system and giving the headquarter the real-time visibility it needs.

There are other specialized ERP systems that serve particular enterprise functions or processes such as customer relationship management (CRM) systems and supply chain management (SCM) systems. Each of them may promote certain values for firms. For example, a CRM system may promote the values in customer orientation by helping better manage the customer services and relationships. By understanding the capacities and values of some popular, important specialized ERP systems and their relationships with cloud computing, we will know how an overall ERP system and cloud computing together can improve firm performance in various ways.

3.2.3.1.1 Human capital management (HCM) systems

Human resources are the employee-related resources in an organization such as training, experience, relationships, and insights (Barney 1991). Human IT resources may include technical IT skills (e.g., programming skills) as well as managerial IT skills (e.g., IT project management and leadership skills) (Bharadwaj 2000). Strong human IT resources facilitate various tasks in a firm such as IT-business alignment, communication and collaboration, product innovation and business vision. Human IT resources are usually attained and accumulated over a long time. From a resource-based perspective, it is clear that human IT resources are valuable, rare and hard to imitate and substitute, thereby serving as sources of competitive advantage (Bharadwaj 2000). Hitt et al. (2001) examine the direct and moderating effects of human capital on professional service firm performance. The results show that human capital has a positive effect on performance, and human capital positively moderates the relationship between strategy and firm performance. Two relevant concepts are human capital management (HCM) and the software that supports human capital management. Human capital management (HCM) is a set of practices related to people resource management. These practices are focused on the organizational need to provide specific competencies and implemented in three categories: workforce acquisition, management and optimization (Gartner HCM). The applications that help to enable human capital management consist of core administrative support, strategic HCM support, and other HCM. Human capital management includes the management of human IT resources (i.e., technical IT skills and managerial IT skills) as described in the tasks of the strategic HCM support: workforce planning, competency management, performance management, learning (education and training), and recruitment as well as of the other HCM: workforce reporting and analytics. Human capital management (HCM) software is the IT application that supports human capital management and its various tasks. Aral et al. (2012) empirically test for three-way complementarities among human capital management (HCM) software adoption, performance pay, and human resource (HR) analytics practices and find that the adoption of HCM software is the greatest in the firms that have also adopted performance pay and HR analytics practices. From a software vendor's perspective, Colomo-Palacios et al. (2012) talk about the benefits and the lessons learned in a project aimed to convert a human capital management application, the traditional Meta 4 PeopleNet solution, into a cloud-based one. They summarize the necessity for the change as cloud computing provides several important complementary and enhancing values: automatic, transparent functional and technical evolutions, corrective maintenance as well as data and application backup. Some well-known cloud-based HCM applications are SAP, Ultimate Software, Workday, Oracle, IBM Kenexa, ADP, and Salesforce's FinancialForce.com.

3.2.3.1.2 Customer relationship management (CRM) systems

The term of customer relationship management (CRM) emerged in the mid-1990s. Payne and Frow (2005, p. 168) give a holistic definition of CRM as "a strategic approach that is concerned with creating improved shareholder value through the development of appropriate relationships with key customers and customer segments. CRM unites the potential of relationship marketing strategies and IT to create profitable, long-term relationships with customers and other key stakeholders." Chen and Popovich (2003) suggest that customer retention and relationship development enabled by CRM can be regarded as measures of firm performance.

CRM originates from IT and organizational changes that are related to customer-centric processes. Companies that successfully implement CRM will reap the rewards of customer loyalty and long run profitability. Using a cross-sectional dataset of U.S. firms, Mithas et al. (2005) show that the use of CRM applications is positively associated with improved customer knowledge and improved customer satisfaction. Reinartz et al. (2004) empirically investigate what constitutes CRM processes and test the organizational performance consequences of implementing CRM processes. They find that the implementation of CRM processes has a moderately positive association with both perceptual and objective company performance. Cloud computing has been recognized as an important technology to enhance the values of CRM systems. Hai and Sakoda (2009) use a case study to exemplify the values of a SaaS CRM application for a large retail banking firm. They find that the new cloud-based CRM application fulfills the goals of the firm such as to improve relationship management, to streamline the creation and distribution of opportunities, to enable the prospecting of new business, to increase the sharing of information among business units, to permit a holistic view of a customer by any sales representative, to simplify upgrades, and to reduce maintenance costs. Singh and Singh (2011) study the case of Oracle CRM on Demand and find that deploying the cloud-based CRM solution can bring drastic improvement on the firm's business performance in a short span of time. Petkovic (2010) points out that one of the innovative, intangible values of cloud CRM applications is that they can connect with social networks and other new channels for a company to better understand its customers' needs so as to deliver targeted services as well as to attract new customers. Some renowned cloud-based CRM applications are Salesforce.com CRM, Sage CRM, and SugarCRM. Anecdotal cases also show the values of CRM systems enhanced by cloud computing. For instance, Chipotle Mexican Grill uses Salesforce CRM to make sure the company has great customer interactions consistently while it expands fast into more locations in order to keep the company's core value – to create relationships with customers and respect every customer. The Salesforce CRM application provides Chipotle with a scalable solution to offer business insights, keep pace with its growth, and expand to address social media over time. Seeing the trend that consumers are increasingly taking to social networks to share their opinions about their dining experiences, the company uses Salesforce CRM to evolve its communication model to connect with its customers in the ways that are most relevant to them. The customer support staff at Komatsu America (Bloomberg Businessweek 2009) can serve their customers as well as the owners and sellers of the company's heavy equipment in a much more proactive and responsive way by checking the real-time status of Komatsu equipment in North America on their smartphones. The information comes through a cloud-based CRM service called Komtrax, which is provided by Komatsu Japan to the company's global subsidiaries, distributors, and equipment owners. The cloud-based CRM system can dramatically improve customer service for the company.

3.2.3.1.3 Knowledge management systems (KMS)

Knowledge assets (i.e., intellectual capital) are a vital intangible resource for a firm. Knowledge assets may exist in the employees' skills and experiences, in the processes, policies and databases in a firm. A firm's knowledge capital is widely recognized as a strategic resource that can promote sustained competitive advantage. IT may play a critical role in knowledge management because it helps clarify assumptions, facilitate communications, elicit tacit knowledge, and construct and record histories of knowledge gains (Bharadwaj 2000). Technologies such as knowledge management software may complement firm-specific knowledge and insights to form specialized, strategic assets that promote firm performance (Bharadwaj 2000). Knowledge management (KM) refers to identifying and leveraging the collective knowledge in an organization to help the organization compete (Von Krogh 1998). Herschel and Jones (2005) explain that KM encompasses both tacit and explicit knowledge. KM is purported to increase innovativeness and responsiveness (Hackbarth 1998). Knowledge management systems (KMS) refer to a class of information systems applied to managing organizational knowledge. That is, they are IT-based systems developed to support and enhance the organizational processes of knowledge creation, storage/retrieval, transfer, and application (Alavi and Leidner 2001). Such systems can lead to a greater breadth and depth of knowledge creation, storage, transfer, and application in organizations which may contribute to better firm performance. Cloud computing has been used for knowledge management. Abadi (2009) speculate that large-scale data analysis tasks, decision support systems, and application specific data marts are more likely to take advantage of cloud computing platforms than operational, transactional database systems. Sultan (2013) suggests that cloud-based KMSs offer many novel capabilities and opportunities for all kinds of companies. KM is entering an era of "crowdsourcing" where ordinary people and employees are expected to make a significant contribution to knowledge creation and management, thanks to a new KM thinking and a breed of new tools and KMS based on cloud computing and Web 2.0. Some popular cloud-based knowledge management applications are Microsoft SharePoint and Salesforce.com Service Cloud.

An overall, combined representation of various specialized and multipurpose ERP systems covers a fundamental part of the IT infrastructure in a firm so that it can provide strategic values to the firm. Cloud computing, as we can see, enhances the values of many individual ERP systems, therefore it may also enhance and complement the infrastructure and intangible values of various ERP systems as a whole. The complementary relationship can be illustrated as in Figure 3.2.

Accordingly, we posit that cloud computing and ERP systems as a whole have a bilateral, reinforcing effect on firm performance improvement and propose the following hypothesis:

Hypothesis 4 (H4). Cloud computing as a whole has a positive moderating influence in the effect of enterprise resource planning (ERP) systems as a whole on firm performance.

3.2.3.2 Basic/extended cloud computing, enterprise systems and firm performance

As aforementioned, cloud service models can be classified into two major groups – basic cloud computing which includes IaaS, PaaS and SaaS, and extended cloud computing which includes KaaS, BPaaS and alike. We would also like to study the effects of the two groups of cloud computing on firm performance separately and argue that either of them can promote firm performance with cloud computing. The relevant hypotheses are as follows:

Hypothesis 5A (H5A). Basic cloud services as a whole have a positive moderating influence in the effect of enterprise resource planning (ERP) systems as a whole on firm performance.

Hypothesis 5B (H5B). Extended cloud services as a whole have a positive moderating influence in the effect of enterprise resource planning (ERP) systems as a whole on firm performance.

3.2.3.3 Specific cloud services, enterprise systems and firm performance

Individual, specific cloud service models may exert their specialized values on firm performance. For example, SaaS-based ERP systems, as mentioned many times before, may exhibit enhanced, complementary values on making firms more productive, innovative and profitable. Thus, we would like to postulate the complementary effect of each of them and the overall representation of ERP systems on firm performance, and the relevant hypotheses are as follows:

Hypothesis 6A (H6A). Infrastructure as a Service (IaaS) has a positive moderating influence in the effect of enterprise resource planning (ERP) systems as a whole on firm performance.

Hypothesis 6B (H6B). Platform as a Service (PaaS) has a positive moderating influence in the effect of enterprise resource planning (ERP) systems as a whole on firm performance.

Hypothesis 6C (H6C). Software as a Service (SaaS) has a positive moderating influence in the effect of enterprise resource planning (ERP) systems as a whole on firm performance.

Hypothesis 6D (H6D). Knowledge as a Service (KaaS) has a positive moderating influence in the effect of enterprise resource planning (ERP) systems as a whole on firm performance.

Hypothesis 6E (H6E). Business process as a Service (BPaaS) has a positive moderating influence in the effect of enterprise resource planning (ERP) systems as a whole on firm performance.

3.3 Empirical Methods

3.3.1 Data

The data we utilized in this study come from several sources. First, the usages of various cloud services, enterprise systems and other technologies are from the Forrester Quarter 4 2009 Software Survey dataset. Forrester Research Inc. is a company that conducts independent technology and market research to provide consulting services about technology. The dataset from Forrester is a comprehensive online survey about software adoption facts and trends in 2,165 companies ranging from very small businesses to global enterprises in North America (US and Canada) and Europe (The UK, Germany and France). All respondents were identified as persons who had the appropriate knowledge, experience and authority to answer the survey questions. The survey was conducted during Quarter 4 (September-November) in the year of 2009. Second, we used the 2009-2011 data from the Compustat North America Annual Fundamentals database, which was the basis for construction of the panel dataset and of the measures of firm performance and most of the industry- and firm-level controls. The database is managed by the Wharton Research Data Services (WRDS) and provides comprehensive accounting and market information of publicly held companies from the past 20 years. Third, we used the 2009-2011 data from the Center for Research in Security Prices (CRSP) Stock Header database for the measure of one control – firm age. Because cloud services and other IT-related measures were only available in the year of 2009 from the Forrester Q4 2009 Software Survey dataset, those measures were treated as relatively invariant over the time of the panel, whereas other measures such as firm performance, and industry and firm controls varied yearly. It is reasonable to assume that firms' cloud computing usage level did not change too much over the three years because the time period was short and most of the firms at that time were just trying cloud computing and not using it extensively so the cloud usages in the firms were unlikely to change much even though cloud computing was easier to adopt comparing to the conventional IT, and furthermore the strategic values of cloud computing and other technologies took a couple of years to be realized fully, even though the utilization of such technologies might have varied over the years. A panel from 2009 to 2011 is short enough to account for the annual cloud usage variation and the slow realization of technology values, and long enough to correct for potential identification issues such as unobserved heterogeneity and endogeneity through panel data models. The details of each measure can be found in Table B.1 and Table B.2 in Appendix B for the (panel) OLS models and the propensity score models respectively.

The final cross-sectional data sample contains 233 large firms in the year of 2009 which were used for the OLS and the propensity score models. The final panel data sample contains more than 200 large firms per year during the period of 2009-2011 with the minimum number of 216 in 2011 and the maximum number of 233 in 2009. The final data samples are reasonably representative in the distribution of firms across all different industries and have a relatively similar pattern comparing to the entire original Forrester Q4 2009 Software Survey dataset (See Figure 3.3).

3.3.2 Variables

3.3.2.1 Dependent variable – Tobin's q

Firm performance represented by Tobin's q serves as the dependent variable in our study. James Tobin introduced the q ratio first as a measure of a firm's future investments in 1969 (Tobin 1969). Unlike an accounting measure of firm performance, Tobin's q is a forward-looking performance measure that is based on a firm's market value estimate in the long run by capturing the financial market valuation that involves the level and risk of future profitability. When investigating the effect of IT investments on firm performance, Bharadwaj et al. (1999) argue that Tobin's q is a better measure of firm performance than the accounting measures because it can better reflect the true contribution that IT can bring to firm value – IT not only benefits firm performance in the long run, especially in strategic flexibility, risk detection and mitigation, and long-term growth but also contributes to a firm's intangible value such as product quality, market orientation, as well as customer relationships.

There are multiple ways to calculate Tobin's q which tend to produce very similar values (Chung and Pruitt 1994). In this paper, we adopt the method by Chung and Pruitt (1994) to calculate Tobin's q, similar to the way adopted by Bharadwaj et al. (1999). Chung and Pruitt (1994) propose a simple formula to calculate Tobin's q, yet the result is still highly reliable comparing to the more traditional method proposed by Lindenberg and Ross (1981). The formula is as follows: Tobin's q = (MVE + PS + DEBT) / TA, where MVE = (Closing price of share at the end of the financial year) × (Number of common shares outstanding), PS = Liquidating value of the firm's outstanding preferred stock, DEBT = (Current liabilities – Current assets) + (Book value of inventories) + (Long-term debt), and TA = Book value of total assets.

3.3.2.2 Independent variables – cloud computing

The independent variables about cloud computing as a whole and various specific cloud services can be derived from the Forrester Q4 2009 Software Survey dataset. Keywords of cloud computing such as cloud, cloud computing, IaaS, PaaS, SaaS, KaaS and BPaaS are used to identify the relevant survey questions in the Forrester dataset. In each question, every answer option is given a different point according to its relevance and importance for the variable[23]. To avoid possibly distorted influence by a particular independent variable, all the values of the independent variables are normalized. The composite independent variable, cloud computing as a whole, is measured by the summation of the normalized values of the various specific cloud services. The added-up value is also normalized. Basic cloud computing as a whole and extended cloud computing as a whole are measured as the first two major components of the principal

[23] See Table B.1 for details of how different points are given to each answer option in the survey question and how the variable is constructed according to the question.

component analysis (PCA) result for all the specific cloud services in the survey – IaaS, PaaS, SaaS, KaaS and BPaaS. Their values are also normalized.

3.3.2.3 Control variables

Multiple firm-level and industry-level control variables that can potentially affect Tobin's q are included in the (panel) OLS models as well as the propensity score models[24]. In selecting controls, we considered the specific needs in our study and largely followed the criteria used by Bharadwaj et al. (1999) and Tafti et al. (2013) when they investigated other IT-related constructs and firm performance measured by Tobin's q.

3.3.2.3.1 Industry-level controls

The industry structure may have an influence on the performance of firms in the industry (Bharadwaj et al. 1999). There are four industry-level controls in our (panel) OLS models - Herfindahl–Hirschman Index (HHI), weighted industry average Tobin's q, weighted industry capital intensity, and industry regulation.

The Herfindahl-Hirschman Index (HHI) is used to measure industry concentration which is a proxy for industry competitiveness. Though industry concentration is broadly believed to be associated with the q values of firms in the industry, two groups of contending theories have been extant on how industry concentration will affect the q values of firms: the structure-conduct-performance paradigm emphasizes market power brought by concentration, while the efficient-structure hypothesis claims that efficiency leads to superior performance (Bharadwaj et

[24] The control variables used in the (panel) OLS models and the propensity score models can be found in Table B.1 and B.2 respectively.

al. 1999). Weighted industry capital intensity indicates the entry barriers caused by the tangible investments in the industry and their effects on firm performance. High capital intensity industries usually have fewer competitors, which favors extant firms. It can also mean low intangible investments, which lowers the q values of firms in the industry. It is an empirical issue to examine the relationship between weighted industry capital intensity and Tobin's q (Bharadwaj et al. 1999). Industry regulation can impact a firm's performance. The regulated industries usually have higher barriers to enter thus may have fewer competitors and higher prices and profits while the regulations may also limit profit-making potential (Bharadwaj et al. 1999). Weighted industry average Tobin's q may capture the additional idiosyncratic industry characteristics that can influence q but have not been adequately explained by the other industry controls (Bharadwaj et al. 1999).

3.3.2.3.2 Firm-level controls

There are eight firm-level controls used in our (panel) OLS models – ERP systems as a whole, number of employees in the firm, advertising intensity, research & development (R&D) intensity, market share of the firm, capital intensity, firm age, as well as a set of four dummy industry controls.

The overall representation of various ERP systems used in a firm is an important firm-level control variable measured by the first component of the principal component analysis (PCA) result for all the component ERP systems[25]. Each component specialized ERP system such as

[25] The unrotated PCA result shows that all component ERP systems load positively onto the first principal component, with weightings between 0.25 and 0.33.

CRM and SCM is measured by points given to indicate the different levels of usage[26]. They are also from the Forrester Q4 2009 Software Survey dataset. The natural logarithm of the number of employees in the firm is used as the proxy for firm size. Advertising intensity is theoretically supported to be associated positively with firm performance measured by Tobin's q (Bharadwaj et al. 1999). R&D intensity is also a common variable positively associated with q in empirical studies (Bharadwaj et al. 1999). Market share of the firm is theoretically believed to positively influence firm performance and may serve as a proxy for certain intangible assets (e.g., firm reputation and managerial skills) that have not been captured in the models (Bharadwaj et al. 1999). Capital intensity of the firm is used to measure the intensity of the tangible investments in the firm which may influence the intangible investments and values associated with the firm's q. Firm age is the measure of the firm's time in business since establishment. It is a proxy for capturing the firm's accumulated experience and other intangible values that may influence its q value. A set of four dummy industry controls is used to indicate which industry the firm is in. The Forrester Q4 2009 Software Survey dataset provides a seven-industry measure that classifies the firm into one of the seven industries[27]. A NAICS code is also available for each firm. Similarities were found in the classification methods between the NAICS code and the seven-industry measure, therefore we referenced NAICS to simplify the original seven industry categories into four industry dummies – manufacturing, retail and wholesale, various services, and public sector[28]. For the random-effects OLS models, two dummy variables of years are used.

[26] The details of how the individual specialized ERP system measures are constructed can be found in Table B.3 in Appendix B.

[27] 1) Manufacturing, 2) Retail & Wholesale, 3) Services, 4) Media, Entertainment, & Leisure, 5) Utilities & Telecom, 6) Finance & Insurance, and 7) Public Sector

[28] Using the original seven industry dummies and the simplified four dummies generated very similar results in the regressions and did not change the direction and significance of the important coefficient estimates. We also compared the regression results using the simplified four industry dummies and a set of dummies based on the two-digit NAICS codes, and found no significant differences.

3.3.2.4 Other variables used in the propensity score matching (PSM) models

The propensity score matching (PSM) models are used as a robustness check as well as a supplement for the (panel) OLS models for a stronger causality investigation. Propensity score matching (PSM) is a matching technique used for observational data that estimates the treatment effect on an outcome variable (i.e., dependent variable) by controlling the covariates that cause the treatment (Dehejia and Wahba 2002). PSM was first introduced by Rosenbaum and Rubin (1983). The technique is suitable for the non-experimental situation where 1) few units are directly comparable between the control and treatment groups, and 2) finding a similar subset between the control units and the treatment units is difficult because there are various factors influencing whether a unit receives the treatment or not (Dehejia and Wahba 2002). Using the covariates (i.e., the observable control variables) for the treatment, PSM generates propensity scores based on which units are matched into comparable groups (i.e., strata or blocks) to reduce selection bias and hence the grouped units can be used to predict the outcome variable (Dehejia and Wahba 2002).

For the propensity score models in our study, Tobin's q is still the dependent variable (i.e., the outcome variable) as in the (panel) OLS models. There are other identical industry-level controls (i.e., Herfindahl–Hirschman Index, weighted industry average Tobin's q and industry regulation) and firm-level controls (i.e., ERP systems as a whole, market share of the firm, capital intensity and industry dummies). Specifically for the propensity score models, a set of treatment dummy variables about cloud computing and an observable control variable about SOA usage are added (see Table B.2 for details). The treatment variables are dummies to indicate whether a firm has used any cloud computing or specific cloud services, and the SOA control variable is used because SOA has a significant effect on cloud computing adoption. The observable control variables (i.e., covariates) mentioned previously are selected according to the prior literature and findings to make sure they are likely to be correlated with the treatment variables and the outcome variable (Mithas and Krishnan 2009). This is to satisfy the strong ignorability assumption of the propensity score approach which states that, with observed covariates being considered, assignment to a treatment group is independent of potential outcomes (Mithas and Krishnan 2009). In other words, we assume that unobservable variables are irrelevant to the models and thus ignorable (Mithas and Krishnan 2009).

Table 3.1 displays the construct correlations and descriptive statistics for the final sample of Year 2009 (233 large enterprises) used in our study. Factor analysis and multicollinearity check (after regression) are used to confirm the sufficient discriminant validity.

3.3.3 Estimation models

For the cross-sectional data of 2009, we used the OLS models (with robust standard errors) to test the direct and interaction effects of cloud computing as a whole, of basic/extended cloud computing as a whole, and of each specific cloud service on firm performance. For the panel data of 2009-2011, we used the random-effects OLS models (with robust standard errors) to do the similar tests as a robustness check for the regular OLS models[29]. Robust standard errors are used to correct for possible nonspherical errors. We also used the propensity score models to reexamine the results of the (panel) OLS models as well as to supplement any missing findings.

[29] Hausman tests are done with statistically insignificant results to ensure that the random-effects models are efficient comparing to the corresponding fixed-effects models.

3.3.3.1 OLS models for cloud computing as a whole and Tobin's q

The cross-sectional and panel OLS models for cloud computing as a whole and firm performance are as follows.

(Panel) OLS model 1:

$$TQ = \beta_0 + \beta_1 cloud + \beta_2 ERPsys + \beta_3 cloud \times ERPsys + \boldsymbol{\beta_c X_c} + \Sigma\beta_i Ind_i + \varepsilon \tag{1.1}$$

$$TQ_{i,t} = \beta_0 + \beta_1 cloud_i + \beta_2 ERPsys_i + \beta_3 cloud_i \times ERPsys_i + \boldsymbol{\beta_{c,t} X_{c,t}} + \Sigma_t\beta_t year_t + \Sigma_i\beta_i Ind_i + u_i + \varepsilon_{i,t} \tag{1.2}$$

3.3.3.2 OLS models for basic/extended cloud computing and Tobin's q

The cross-sectional and panel OLS models for basic/extended cloud computing as a whole and firm performance are as follows.

(Panel) OLS model 2:

$$TQ = \beta_0 + \beta_1 cloud\_bas + \beta_2 cloud\_ext + \beta_3 ERPsys + \beta_4 cloud\_bas \times ERPsys + \beta_5 cloud\_ext \times ERPsys + \boldsymbol{\beta_c X_c} + \Sigma\beta_i Ind_i + \varepsilon \tag{2.1}$$

$$TQ_{i,t} = \beta_0 + \beta_1 cloud\_bas_i + \beta_2 cloud\_ext_i + \beta_3 ERPsys_i + \beta_4 cloud\_bas_i \times ERPsys_i + \beta_5 cloud\_ext_i \times ERPsys_i + \boldsymbol{\beta_{c,t} X_{c,t}} + \Sigma_t\beta_t year_t + \Sigma\beta_i Ind_i + u_i + \varepsilon_{i,t} \tag{2.2}$$

3.3.3.3 OLS models for specific cloud services and Tobin's q

The cross-sectional and panel OLS models for specific cloud services and firm performance are as follows.

(Panel) OLS model 3:

$$TQ = \beta_0 + \beta_1 IaaS + \beta_2 PaaS + \beta_3 SaaS + \beta_4 KaaS + \beta_5 BPaaS + \beta_6 ERPsys + \beta_7 IaaS\times ERPsys + \beta_8 PaaS\times ERPsys + \beta_9 SaaS\times ERPsys + \beta_{10} KaaS\times ERPsys + \beta_{11} BPaaS\times ERPsys + \boldsymbol{\beta_c X_c} + \Sigma\beta_i Ind_i + \varepsilon \tag{3.1}$$

$$TQ_{i,t} = \beta_0 + \beta_1 IaaS_i + \beta_2 PaaS_i + \beta_3 SaaS_i + \beta_4 KaaS_i + \beta_5 BPaaS_i + \beta_6 ERPsys_i + \beta_7 IaaS_i\times ERPsys_i + \beta_8 PaaS_i\times ERPsys_i + \beta_9 SaaS_i\times ERPsys_i + \beta_{10} KaaS_i\times ERPsys_i + \beta_{11} BPaaS_i\times ERPsys_i + \boldsymbol{\beta_{c,t} X_{c,t}} + \Sigma_t\beta_t year_t + \Sigma\beta_i Ind_i + u_i + \varepsilon_{i,t} \tag{3.2}$$

The terms of $\boldsymbol{X_c}$ and $\boldsymbol{X_{c,t}}$ in the above six models (Model 1.1-3.2) consist of all the control variables in Table B.1 except ERP systems and industry dummies which are explicitly listed in the above models. In the panel OLS model, Model 1.2, we also use year dummy variables. The panel random-effects models (Model 1.2, 2,2 and 3.2) are employed to account for persistent individual unobserved effects.

3.3.3.4 Propensity score matching (PSM) models for cloud computing and Tobin's q

The cross-sectional probit models for generating propensity scores (i.e. probability models) for all kinds of cloud computing and firm performance are as follows.

$$Pr(AnyCloud = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \tag{4.1}$$

$$Pr(AnyCloud\_bas = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \tag{4.2}$$

$$Pr(AnyCloud\_ext = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \tag{4.3}$$

$$Pr(AnyIaaS = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \tag{4.4}$$

$$Pr(AnyPaaS = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \tag{4.5}$$

$$Pr(AnySaaS = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \tag{4.6}$$

$$Pr(AnyKaaS = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \tag{4.7}$$

$$Pr(AnyBPaaS = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \tag{4.8}$$

The terms of Φ are the cumulative distribution function (CDF) of the standard normal distribution. The terms of $\boldsymbol{X_d}$ in the above eight models (Model 4.1-4.8) consist of all the control variables in Table B.2 except those industry dummies which are explicitly listed in the above models. Using the dummy treatment variables of cloud computing such as *AnyCloud* which indicates whether a firm uses any cloud computing, the propensity score matching (PSM) models are capable of qualitatively determining the causal treatment effect of whether a firm uses any cloud computing can directly improve its firm performance rather than commonly the associative effect articulated by a regression-based approach (Mithas and Krishnan 2009). A probability model (e.g., a logit or probit model) to generate propensity scores (i.e., the probability of making the treatment variable equal one) for a dummy treatment variable is one pivotal step to estimate the treatment effect in a PSM model (Dehejia and Wahba 2002). We use probit models as the probability model since any specific probability model can be used and they all generate same estimated probability of selection (Dehejia and Wahba 2002; Mithas and Krishnan 2009).

Inspired by Mithas and Krishnan (2009) and tailored to our study, we conducted our PSM analysis in the following steps. First, we identified the treatment variables of cloud computing, the outcome variable of Tobin's q, and other covariates such as the SOA control variables and the other industry and firm controls as mentioned previously. Second, we defined the causal effect we are interested in, that is, we estimated the average treatment effect on the treated since we are interested in studying the causal effect of cloud computing adoption on firm performance for those firms that actually adopted cloud computing. Third, we made the strong ignorability assumption as mentioned earlier to solve the essential problem of causal inference. Fourth, we selected an estimation method (i.e., algorithm) used in the analysis. There are several different PSM algorithms available to choose from, namely nearest neighbor (NN), radius, stratification and kernel (Caliendo and Kopeinig 2008). Each algorithm has its own pros and cons. Practically, the algorithms will generate very similar results if there is a large overlap in the distribution of the propensity score between the control and treatment groups (Dehejia and Wahba 2002). We tried all the algorithms and they all generated similar results, thus we chose to only show the radius matching result in the study. The radius matching algorithm lets a researcher to predefine a propensity score radius for a treated unit within which all the control units are included and used (Dehejia and Wahba 2002). Fifth, we estimated the propensity scores and common supports (i.e., the overlapped propensity score ranges between the treatment and control groups) for the treatment variables using the probit models described previously. Sixth, we balanced the propensity scores between the treatment and control groups by forming strata or blocks based on similar propensity scores to make sure that a fair comparison of treatment and control units within each stratum. Finally, we estimated the causal treatment effects of cloud computing adoption on firm performance using the radius matching algorithm.

3.4 Results

Table 3.2 presents the cross-sectional (with robust standard errors) and panel random-effects (with robust standard errors) OLS results for the effect of cloud computing as a whole on firm performance side by side. All regressions are highly significant as evidenced by the F-statistics or Wald χ^2 statistics. Hypothesis 1, which predicts that cloud computing as a whole is positively associated with firm performance, is highly supported in both OLS models ($p < 0.01$). We did not find support for Hypothesis 4, which predicts the complementary effect of cloud computing as a whole and ERP systems as a whole on firm performance. As the overall representation of cloud computing is a more general term comparing to other cloud constructs used in this study, it may be better used to testify the debate of whether IT investments, in general, can be regarded as strategic resources hence whether they have a direct effect on firm performance in the context of cloud computing. Our results more support the theory of direct effect in the prior IS literature as it argues that IT has many intangible values that can exert a direct influence on a firm's value (Bharadwaj 2000; Bharadwaj et al. 1999). In the panel random-effects results, we can see that the year of 2010 (rather than the year of 2009) is positively and significantly associated with firm performance, which might indicate that the fuller, intangible values of using cloud computing had been realized in the future, which reflects the view by Bharadwaj et al. (1999) that IT investments have a strategic value in the long term.

Table 3.3 presents the cross-sectional (with robust standard errors) and panel random-effects (with robust standard errors) OLS results for the effects of basic and extended cloud computing as a whole on firm performance side by side. Hypothesis 2A, which proposes that basic cloud services as a whole (i.e., the combination of IaaS, PaaS and SaaS) are beneficial to firm performance, is highly supported by all the relevant OLS results ($p < 0.01$). Nevertheless, we did not find the support in any of the models for Hypothesis 2B, which predicts extended cloud services as a whole (i.e., the sum of KaaS and BPaaS) are positively associated with firm performance. For the two interaction-effect hypotheses, Hypothesis 5A and 5B, we neither find any support for them. In other words, neither basic cloud services as a whole nor extended cloud services as a whole present a statistically significant moderating effect on ERP systems when concerning firm performance. Referencing the supplementary results from the propensity score models in Table 3.5, we can confirm that there are positive direct effects of cloud computing as a whole and basic cloud services as a whole on firm performance since Hypothesis 1 and Hypothesis 2A are also supported in the propensity score matching (PSM) results at the significance level of 1%. This might reinforce the direct-effect theory of IT on firm performance rather than the indirect-effect theory.

Table 3.4 presents the cross-sectional (with robust standard errors) and panel random-effects (with robust standard errors) OLS results for the effects of various specific cloud services on firm performance side by side. We did not find any support from the relevant OLS results for Hypothesis 3A, which postulates that IaaS should have a direct, positive effect on firm value. However, in the supplementary results generated by the propensity score matching (PSM) models, we found a significant support for this hypothesis ($p < 0.05$), in a more qualitative sense as it states that any use of IaaS in a firm will improve its firm performance. Therefore collectively we think that Hypothesis 3A is weakly supported. This may reflect the fact that IaaS, as the lowest fundamental layer in the three basic-layer cloud service model, have the dual characteristics of being a utility and an enabler for a renewed focus on core business for a firm. On one hand, IaaS can be conveniently used as a utility to effectively reduce the IT costs if a firm would like to use it this way. On the other hand, IaaS can be utilized in a smarter way as a more strategic resource to free a firm to focus on its core competencies thus improving its firm value (Garrison et al. 2012). Depending on how or how much a firm uses IaaS either way, the composite value effect of IaaS may appear more utility-like or strategic-oriented. The collective weak support for Hypothesis 3A may reflect this underlying reason and the fact that many firms still remained using IaaS only in a utility manner in the year of 2009, which was far from the full value of IaaS. Hypothesis 3B, which predicts PaaS is directly beneficial to firms, is broadly supported by the OLS model results ($p < 0.1$ in the least-supportive random-effects results). The hypothesis is also supported by the PSM result ($p < 0.05$). Collectively this may indicate that PaaS is a highly valuable IT infrastructure resource based on which firms can flexibly develop their strategic values that are difficult to be imitated by their rivals (Mallasch et al. 2013). Somehow counter-intuitively, Hypothesis 3C, which argues SaaS can directly enhance firm value, is not supported either by the OLS results or by the PSM results, despite many observations in the anecdotes and literature that have shown the benefits of SaaS (Joha and Janssen 2012). We argue that this may reflect the fact that, until then, a SaaS application offered by a cloud vendor was largely homogeneous and non-customizable to the users so that it could not generate sustainable competitive advantage if it was used merely to reduce costs and improve efficiency and not integrated with other, more firm-specific functions or resources (Lu and Sun 2009; Truyen et al. 2012). Hypothesis 3D, which predicts KaaS is positively associated with firm performance is neither supported by the PSM result nor supported by the OLS results. Collectively we can conclude that the hypothesis is not supported. This may show the mixed effect of KaaS on firm performance – on one side information and knowledge is highly valuable in the new era of information economics (Gurjar and Rathore 2013), on the other when knowledge provided as services in cloud, they tend to be explicit, general-purpose and easy to access, so may not provide sustainable competitive advantage on its own. It might be dependent on how KaaS is combined with other firm-specific assets and processes to embody its value. Collectively we found a weak support for Hypothesis 3E, which claims that BPaaS can directly provide a strategic value to firms because it is broadly supported by the OLS results ($p < 0.1$ in the least-supportive random-effects result in Model 3.2 with robust standard errors), but not supported by the PSM result. Business processes are highly important to a firm because they constitute the basic capabilities that make its business work (Bharadwaj 2000). BPaaS itself provides easily accessible business processes in the cloud, therefore on one side, presents remarkable values to a firm when used properly for business case transformation (Whibley 2012), but on the other, may not generate strategic values if used only for efficiency and cost savings.

Table 3.4 also shows the interaction effects of specific cloud services and ERP systems on firm performance. For Hypothesis 6A, which predicts the positive interaction effect of IaaS and ERP systems as a whole, is not supported by a statistically significant ($p < 0.05$) but opposite (i.e., a negative sign) direction on the coefficient estimate. This might reflect the fact that IaaS provide firms with raw cloud-based IT resources based on which they can build up their own enterprise systems so that IaaS in this use is a substitute for ERP systems and it can undermine the value of ERP systems. We did not find support for Hypothesis 6B which predicts the positive interaction effect of PaaS and ERP systems as a whole. A similar reason can be obtained for the lack of support as for Hypothesis 6A since PaaS is also used to build up enterprise application which might substitute other incumbent ERP systems. We found an overall moderate support for Hypothesis 6C that proposes the complementary effect of SaaS and the overall representation of ERP systems on firm performance ($p < 0.1$ in the least-supportive result). This echoes our previous argument of that, SaaS alone may not generate strategic values since it is largely generic and difficult to be customized for each firm user, but can generate such values when strategically integrated with other internal resources such as the ERP systems. Hypothesis 6D, which predicts KaaS can complement ERP systems to improve firm performance, is not supported though the coefficient estimate has the correct, positive direction in all the results. This might indicate that KaaS was not widely recognized as an enhancing resource for ERP applications. We did not find support either for Hypothesis 6E, which predicts BPaaS is complementary to ERP systems as a whole on firm performance improvement though we noticed that the coefficient estimate has the opposite, negative direction in all the results. This might interestingly indicate that, as BPaaS can provide more flexible and cost-effective business processes in the cloud, it could substitute and replace some processes in the ERP systems so that they together present a substitutable, not complementary effect.

As to the other notable effects in the control variables, Herfindahl index is shown to have a negative effect ($p < 0.1$) on firm performance in the two random-effects results in Table 3.4, which supports the efficient-structure hypothesis of that the firms in a more competitive, efficient industry have a higher firm performance (Bharadwaj et al. 1999). Industry capital intensity is not significant and has an almost negligible coefficient estimate in all the results in Table 3.4. This may reflect that there are extant competing arguments toward its effect on Tobin’s q and therefore the effect is merely an empirical issue (Bharadwaj et al. 1999). The significant positive effect of regulation ($p < 0.1$) in the first OLS result in Table 3.4 shows support for the argument that regulation in an industry imposes entry barriers thus raising prices and profits (Bharadwaj et al. 1999). Market share is supported to have a significant positive effect on firm performance in all the results ($p < 0.1$ at least), which confirms the arguments by the prior literature that market share may present a firm's efficiency, market power, product quality, as well as other firm-specific intangible values such as reputation and managerial skills that are not specifically captured in the models in this study (Bharadwaj et al. 1999).

3.5 Conclusion and Discussion

3.5.1 Main findings and research implications

Cloud computing has gained its momentum in commercial usage over the past decade albeit mixed views and interpretations toward its values on firm performance. While it is more widely and unequivocally recognized in the anecdotes and literature that cloud computing has strategically benefited small and medium-sized enterprises (SMEs) fundamentally by enabling them with unprecedentedly affordable and accessible IT resources (Mladenow et al. 2012; Seethamraju 2014; Truong 2009), whether and what cloud computing services can generate strategic values for those large firms usually with substantial internal IT resources remained as entangled questions. To our knowledge, this is the first study to use the resource-based view to propose the relationship between cloud computing and firm performance and empirically examine the effects of cloud computing and its various service models on firm performance, with a particular focus on large enterprises.

First, we find strong evidences that cloud computing as a whole (i.e., the combination of IaaS, PaaS, SaaS, KaaS and BPaaS) can directly generate tangible (i.e., flexible IT infrastructure) and intangible strategic values (e.g., renewed focus on core business, innovation and business model change) to provide competitive advantage to firms. This overall finding supports the direct effect view in the debate that whether IT investments have a direct or indirect effect on firm performance in the prior IS literature (Bharadwaj et al. 1999). As cloud computing makes consumption of IT resources very cost-effective, scalable, flexible and accessible, many have doubted whether cloud computing will render IT resources more commodity-like thus cannot provide any strategic values in competitive advantage and firm performance. However, our main finding denies such argument and confirms that a remarkably flexible IT paradigm such as cloud computing may directly contribute to firm performance if it is used properly to generate tangible and intangible strategic values, not for the sake of merely cost savings. The finding also confirms that a Tobin's q measure may correctly capture the intangible and long-term values of cloud investments on firm performance (Bharadwaj et al. 1999). We also find that cloud computing as a whole does not have a complementary effect on the overall view of ERP systems that represents a firm's internal IT resources. This may be due to that cloud computing can be used to substitute (not to complement) such internal resources thanks to its support for fast application development and deployment. Second, we show that, one of the two subset representations of cloud computing –basic cloud services as a whole (i.e., IaaS, PaaS and SaaS), can provide direct strategic values to firm performance, while extended cloud services as a whole (i.e., KaaS and BPaaS) have no such an effect. This is an interesting finding to recognize that, since the extended cloud services are all based on the basic services and focus on more specialized areas, overall the basic ones are more strategically valuable than the extended ones. It also reflects the fact that those extended services provided in the cloud were somehow homogeneous and not widely used at that time so that it was hard for firms to appropriately utilize those services to generate strategic values. Again, the interaction effects of basic and extended cloud services as a whole and Tobin's q are not significant. As to the direct effects of the individual specific cloud services, IaaS and especially PaaS are found to have a significant direct effect on firm performance. This confirms that they are IT resources that can be used to compose flexible, firm-specific companywide IT infrastructures, processes and applications which can produce strategic values to firms (Bharadwaj 2000). SaaS, however, may not provide such strategic values probably because a SaaS application provided by a certain cloud vendor was quite homogeneous in functionality and could not be customized according to the specific needs of a particular SaaS user so that SaaS could not provide strategic values alone at that time. For example, the well-known SaaS-based email application Gmail by Google can be easily adopted by many different firm users as an enterprise email system, but the email system will appear identical to all of them, so it cannot provide any sustainable competitive advantage even though it improves their email system efficiency comparing to those firms that have not adopted such a system. One of the two extended cloud services, BPaaS, is found to have a weak, positive and direct effect on firm performance, based on the collective results of the OLS and PSM models. This finding, on one side, reinforces the importance of business process (Bharadwaj 2000) in a firm, on the other reflects the fact that such cloud-based resource could be relatively generic-purpose and easily acquired, therefore its direct effect might be weak or mixed. As to the interaction effects of the specific cloud services and the overall representation of ERP systems, we find that IaaS surprisingly has a negative interaction effect on ERP systems as a whole. This might remind us that, even though IaaS alone can directly provide strategic values to a firm by developing highly flexible and firm-specific IT resources, it may also undermine the value of the extant internal ERP systems. SaaS, on the contrary, while does not provide any sustainable values for a firm alone, may indeed provide such values together with ERP systems. In other words, a firm seems to be more likely to adopt complementary applications in SaaS when considering integrating them with its internal ERP systems but to develop IaaS-based substitutes for certain internal ERP functions when considering replacement of such functions.

We also find evidence to verify and support certain views towards the important industry and firm level controls for firm performance in the prior literature (Bharadwaj et al. 1999). We find industry competitiveness (the Herfindahl index) has a negative effect on firm performance, which supports the view of the efficient-structure hypothesis – firms in a more competitive industry generally have more firm values. Industry capital intensity has almost an insignificant, zero influence on firm performance in our results, which reflects the argument that its effect can be mixed and it is an empirical issue. A regulated industry might provide higher prices and profits to the firms in such industry, which confirms the entry barriers view of regulation. Market share is highly and positively related to firm performance, which confirms the various viewpoints that support such a relationship in the prior literature. The year dummy of 2010 (not the year dummy of 2009) is highly associated with firm performance, which may confirm the argument of that IT investments contribute to the firms' long-term and intangible values better captured by Tobin's q.

3.5.2 Managerial implications, limitations and future work

Decision makers and managers in large enterprises usually have doubts on the values of overall cloud computing and its various specific cloud services with special concerns on cloud risks and uncertainties such as data security and privacy (Marston et al. 2011), and there have been no systematic methods to determine whether, what and how cloud services can be used to help large enterprises improve firm values. As Brynjolfsson et al. (2010) proclaim, cloud computing is way beyond the utility model – its true values rely on cloud-enabled innovations and business model changes which can consistently provide firms with superior performance. Despite those cloud risks and uncertainties that cloud providers have put great efforts to tackle and improve, cloud computing overall have still presented remarkable strategic values to large firms in our study, therefore it is advisable for the decision makers and managers to bear in mind that cloud computing overall is an available strategic IT resource to them.

Since there are various cloud services to start with, here comes the question of which ones could provide more strategic values to a firm. This study provides such guidance that the basic cloud services of IaaS and PaaS, especially PaaS, may provide more direct strategic values when used to improve and innovate a firm's functions, applications and processes. For example, Life Technologies (Amazon Life Technologies 2013) utilized PaaS to create the platform based on which biological data can be quickly analyzed and shared among the scientists to innovate the processes of making personalized medicine. Using PaaS, large firms can not only create flexible strategic IT infrastructures that are tailored to the firms' specific needs but also generate intangible strategic resources such as customer-orientation and business responsiveness which are pivotal to firms' success in the era of highly customized and globalized economies (Prahalad and Krishnan 2008). Although PaaS and IaaS present remarkable direct benefits in values, caution should be paid to avoid the possible substitute effect between such resources (especially IaaS) and internal ERP systems. A general rule of thumb may be that a firm should use such resources to develop and add innovative functions rather than replacing incumbent ERP components if the firm has already implemented and customized a heavily embedded, companywide ERP system. Managers should exercise caution when considering using SaaS applications as enablers for their firm's strategies since SaaS applications directly may not exert any strategic values without being integrated with other internal strategic resources such as various ERP systems. Indeed, large firms have complained that SaaS is relatively generic and lack of function customization which reduces their interests in using such applications (Lu and Sun 2009; Truyen et al. 2012). Instead, when integrated and composed with other internal applications and processes, SaaS may significantly enhance those firm-specific resources to produce superior firm values. Managers should carefully consider which applications are appropriate to be outsourced to SaaS applications and how they can collaborate and integrate with internal processes and functions to leverage the benefit of SaaS. For example, highly industry standardized routines such as supply chain management (SCM) might be considered as SaaS to be integrated with other tailored processes and functions in the internal enterprise resource planning (ERP) system.

Even though extended cloud services as a whole (KaaS and BPaaS) do not have any significant direct and interaction effects on firm performance, individually they might present direct or complementary benefits for firms. Managers should also use caution when considering using KaaS or BPaaS directly or with internal ERP systems. KaaS and BPaaS are relatively general-purpose knowledge and business processes in the cloud, so it is pivotal for firms to carefully consider using them to create idiosyncratic, valuable resources. Managers should be aware of that, KaaS tends to generate more values through complementing with internal ERP systems since knowledge needs to be embedded in other processes to exert its value, and BPaaS tends to have more values when used directly to create novel business processes since it might replace and substitute certain incumbent processes in the ERP systems. Decision makers and managers should also be aware of that the full value of cloud computing, like of other IT investments, only can be realized in the relatively long run. Cloud computing is still a novel IT paradigm that many large firms have only adopted on a trial basis. Patience and proper performance measures such as Tobin's q should also be given when determining such a novel technology's full value even if a firm has followed the general guidance and cautions offered in this study.

Although this study is a beneficial attempt on the effect of cloud computing on firm performance, it surely has its own limitations that can be addressed in future work. First, we used a survey dataset in the year of 2009 to construct our main variables of interest, but we did not know whether how long the firms had started using cloud computing till 2009. If this information was available, our models could be more significant in explaining the effect. We can utilize a panel data set containing the variables of interest across multiple years to reexamine and reinforce our findings if such dataset is available in the future. Investigations on interaction effects between cloud computing and other intangible internal resources such as organizational structure can be done to generate a fuller picture of how cloud computing can affect firm performance when data are available. Even though the final cross-sectional and panel samples used in our study were reasonably representative of the population, caution should nevertheless be exercised when generalizing the results since cloud computing was still a novel paradigm that quite a majority of the firms investigated did not use it or its specific services which might have not represented the full values and patterns of cloud computing on firm performance.

To conclude, we studied the effect of cloud computing on firm performance. We found that overall cloud computing has a direct, beneficial effect on the firm value measured by Tobin's q. We also found that basic cloud services as a whole have a significant positive effect on firm performance. Specific cloud services such as IaaS, PaaS and BPaaS may directly generate tangible and intangible strategic values if used appropriately. IaaS may have a negative, substitute effect on firms' internal resources such as ERP systems while SaaS may have a positive, complementary effect on the internal resources in generating firm values. In other words, cloud computing presents direct and complementary strategic values on firm performance.

3.6 Figures and Tables

Figure 3.1. Theoretical framework for the direct effect of cloud computing on firm performance

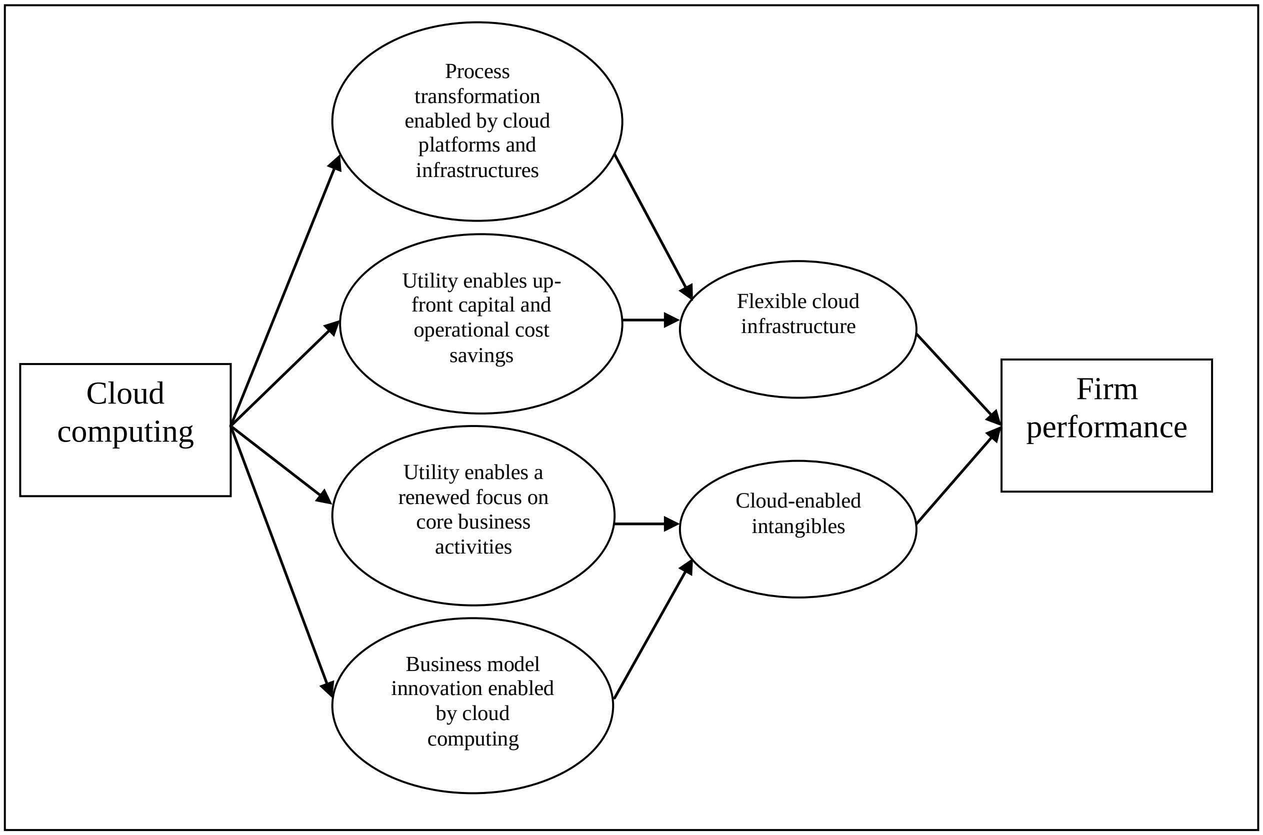


Figure 3.2. Theoretical framework for the complementary effect of cloud computing and ERP systems on firm performance

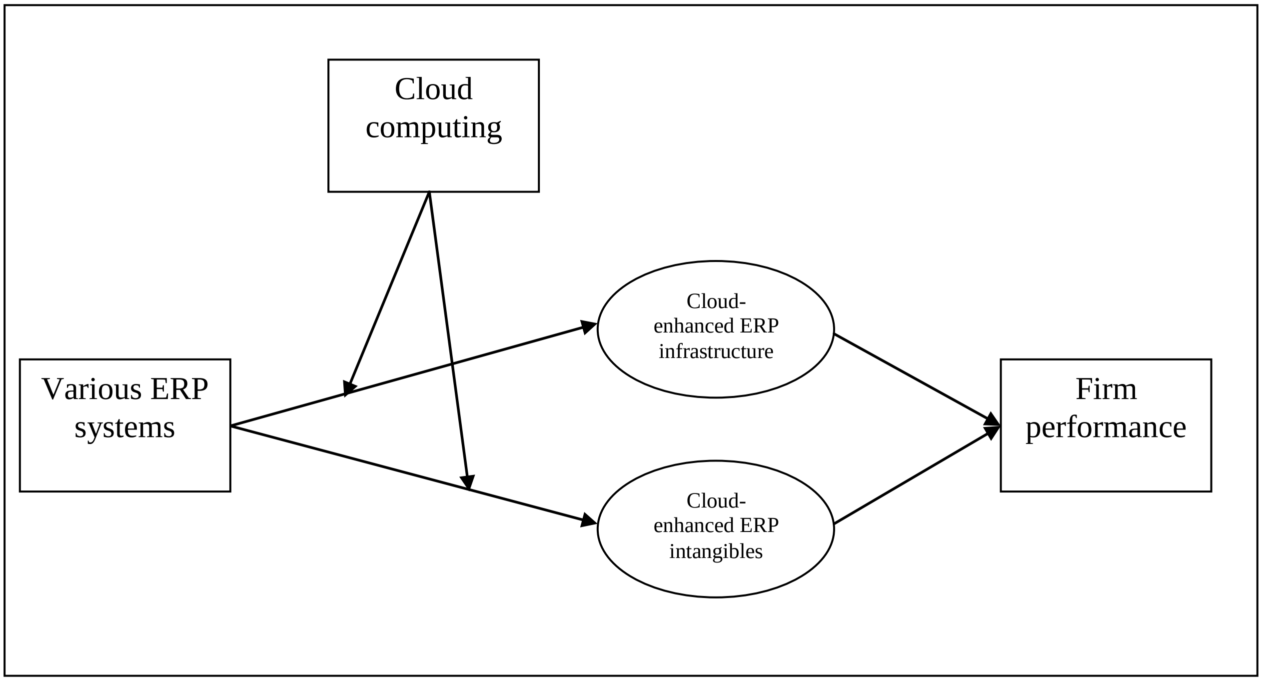


Figure 3.3. Data sample representativeness

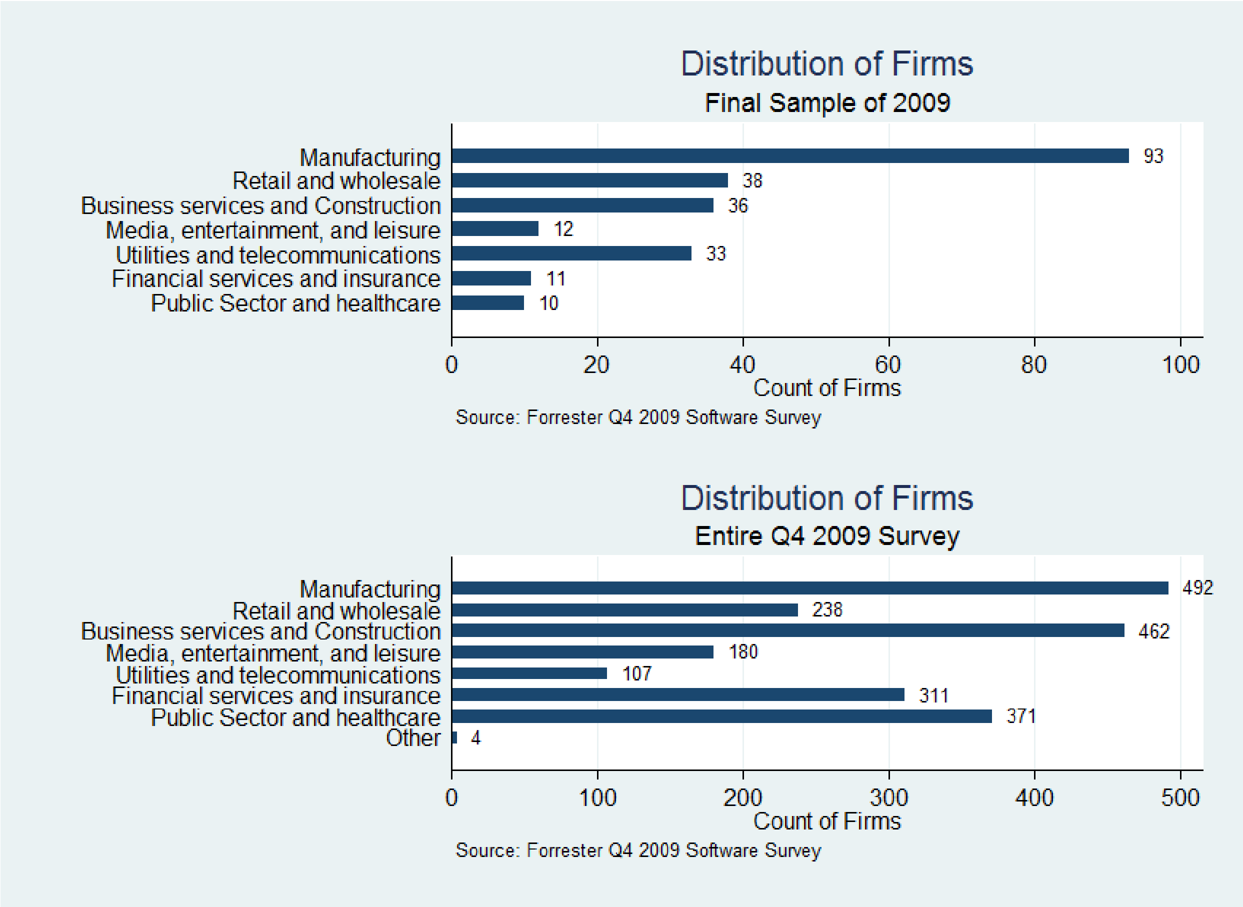


Table 3.1. Correlations and summary statistics of the cross-sectional data of 2009

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Tobin's q	1.00										
(2) Cloud as a whole	0.32	1.00									
(3) Cloud-Basic	0.31	1.00	1.00								
(4) Cloud-Extended	0.02	0.10	0.02	1.00							
(5) IaaS	0.21	0.68	0.65	0.40	1.00						
(6) PaaS	0.26	0.61	0.56	0.41	0.27	1.00					
(7) SaaS	0.14	0.67	0.66	0.40	0.38	0.27	1.00				
(8) KaaS	0.19	0.69	0.72	-0.44	0.32	0.20	0.26	1.00			
(9) BPaaS	0.22	0.61	0.65	-0.55	0.15	0.18	0.28	0.46	1.00		
(10) ERP systems	0.09	0.01	0.02	0.01	-0.05	-0.01	0.10	-0.02	0.03	1.00	
(11) Herfindahl index	0.02	-0.07	-0.06	-0.09	-0.08	-0.09	-0.03	-0.08	0.09	-0.04	1.00
(12) Indus Tobin's q	0.36	0.12	0.12	-0.04	0.12	0.08	-0.02	0.15	0.05	-0.01	0.15
(13) Indus cap intens	0.06	-0.09	-0.07	-0.15	-0.09	-0.17	-0.06	0.03	0.02	0.02	-0.00
(14) Regulation	0.08	0.05	0.05	-0.05	-0.01	0.05	-0.00	0.10	0.03	0.09	-0.26
(15) log(Employees)	-0.01	0.05	0.05	-0.04	0.02	0.01	0.01	0.09	0.02	0.21	0.12
(16) Advertising	-0.07	-0.05	-0.05	-0.06	-0.06	-0.02	-0.07	-0.01	-0.00	0.00	-0.06
(17) R&D intensity	-0.01	-0.01	-0.01	-0.03	-0.00	-0.01	-0.03	-0.00	0.02	0.01	-0.09
(18) Market share	0.06	-0.01	-0.01	-0.06	-0.05	-0.03	-0.01	0.04	0.01	0.01	0.63
(19) Capital intensity	-0.07	-0.05	-0.05	-0.02	-0.03	-0.05	-0.03	-0.02	-0.02	0.03	-0.03
(20) Firm age	0.07	0.11	0.11	-0.02	0.02	0.07	0.07	0.16	0.03	0.07	-0.02
(21) Ind-Manufact	0.14	0.08	0.08	0.01	0.10	0.01	0.04	0.13	-0.02	0.15	-0.17
(22) Ind-Retail&Wh	0.07	0.06	0.06	-0.02	0.04	0.03	0.02	0.03	0.08	-0.03	0.46
(23) Ind-Services	-0.21	-0.08	-0.08	0.03	-0.09	-0.01	-0.01	-0.12	-0.02	-0.13	-0.16
(24) SOA	0.11	0.19	0.18	0.22	0.21	0.22	0.17	-0.05	0.07	0.16	0.04

	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
(12) Indus Tobin's q	1.00										
(13) Indus cap intens	0.21	1.00									
(14) Regulation	-0.16	0.03	1.00								
(15) log(Employees)	-0.15	0.09	0.08	1.00							
(16) Advertising	0.01	0.00	-0.07	-0.26	1.00						
(17) R&D intensity	0.07	-0.00	-0.04	-0.30	0.58	1.00					
(18) Market share	-0.03	-0.04	-0.17	0.40	-0.12	-0.13	1.00				
(19) Capital intensity	-0.00	0.23	0.09	0.15	-0.03	-0.04	-0.08	1.00			
(20) Firm age	-0.04	0.07	0.28	0.30	-0.11	-0.11	0.05	0.01	1.00		
(21) Ind-Manufact	0.24	0.05	0.08	-0.09	-0.03	0.01	-0.13	-0.07	0.11	1.00	
(22) Ind-Retail&Wh	0.23	0.07	-0.14	0.04	0.11	0.04	0.18	0.16	-0.08	-0.36	1.00
(23) Ind-Services	-0.36	-0.10	-0.00	0.04	-0.03	-0.12	-0.02	-0.05	-0.05	-0.66	-0.36
(24) SOA	-0.02	0.01	0.03	0.26	-0.15	-0.12	0.09	0.19	-0.03	-0.10	0.01

	(23)	(24)
(23) Ind-Services	1.00	
(24) SOA	0.12	1.00

Table 3.1 (cont.)

	Mean	S.D.	Min	Max
(1) Tobin's q	1.02	0.61	-0.27	4.32
(2) Cloud as a whole	0.02	1.01	-0.53	5.75
(3) Cloud-Basic	0.02	1.01	-0.52	5.83
(4) Cloud-Extended	-0.00	1.01	-4.53	3.78
(5) IaaS	0.21	1.31	-0.29	3.92
(6) PaaS	0.12	1.26	-0.22	5.24
(7) SaaS	0.19	1.15	-0.49	2.44
(8) KaaS	0.11	1.25	-0.22	5.80
(9) BPaaS	0.05	1.05	-0.22	5.45
(10) ERP systems	0.03	1.03	-0.72	3.28
(11) Herfindahl index	0.09	0.11	0.00	0.82
(12) Industry Tobin's q	0.97	0.38	0.02	2.60
(13) Industry capital intensity	-1.75	65.92	-668.51	117.92
(14) Regulation	0.18	0.38	0.00	1.00
(15) log(Employees)	3.31	1.66	-1.01	6.19
(16) Advertising	0.08	0.26	0.00	3.54
(17) R&D intensity	0.08	0.25	0.00	2.81
(18) Market share	0.07	0.12	0.00	0.83
(19) Capital intensity	8.94	62.63	-325.77	632.91
(20) Firm age	26.68	21.70	1.00	85.00
(21) Ind-Manufacturing	0.40	0.49	0.00	1.00
(22) Ind-Retail&Wholesale	0.16	0.37	0.00	1.00
(23) Ind-Services	0.39	0.49	0.00	1.00
(24) SOA	0.34	1.09	-0.76	1.90

N = 233 firms. Dependent variable is Tobin's q.

Table 3.2. Cross-sectional and panel random-effects OLS results for cloud computing as a whole and Tobin's q

Dependent Variable: Tobin's q	Model 1.1	Model 1.1 with Robust S.E.	Model 1.2 Random Effects	Model 1.2 Random Effects with Robust S.E.
H1: Cloud as a whole	0.161	0.161	0.147	0.147
	(0.037)***	(0.062)***	(0.041)***	(0.056)***
ERP systems	0.053	0.053	0.028	0.028
	(0.036)	(0.036)	(0.041)	(0.041)
H4: Cloud x ERP systems	-0.028	-0.028	-0.031	-0.031
	(0.034)	(0.044)	(0.038)	(0.041)
Herfindahl index	-0.330	-0.330	-0.629	-0.629
	(0.495)	(0.654)	(0.502)	(0.616)
Industry Tobin's q	0.534	0.534	0.001	0.001
	(0.108)***	(0.107)***	(0.003)	(0.001)
Industry capital intensity	0.000	0.000	-0.000	-0.000
	(0.001)	(0.000)	(0.000)	(0.000)
Regulated industry	0.170	0.170	0.121	0.121
	(0.103)*	(0.116)	(0.115)	(0.140)
log(Employees)	-0.024	-0.024	-0.039	-0.039
	(0.028)	(0.023)	(0.030)	(0.026)
Advertising	-0.077	-0.077	-0.166	-0.166
	(0.177)	(0.153)	(0.174)	(0.140)
R&D intensity	-0.089	-0.089	-0.065	-0.065
	(0.187)	(0.194)	(0.189)	(0.170)
Market share	0.656	0.656	0.742	0.742
	(0.434)	(0.463)	(0.455)	(0.401)*
Capital intensity	-0.001	-0.001	0.000	0.000
	(0.001)	(0.000)*	(0.000)	(0.000)
Firm age	0.000	0.000	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Industry-Manufacturing	-0.291	-0.291	0.034	0.034
	(0.193)	(0.226)	(0.213)	(0.210)
Industry-Retail&Wholesale	-0.283	-0.283	0.165	0.165
	(0.217)	(0.238)	(0.235)	(0.224)
Industry-Services	-0.343	-0.343	-0.224	-0.224
	(0.191)*	(0.216)	(0.213)	(0.191)
y09			-0.039	-0.039
			(0.024)	(0.027)
y10			0.065	0.065
			(0.024)***	(0.020)***
Constant	0.830	0.830	1.243	1.243
	(0.228)***	(0.264)***	(0.236)***	(0.228)***
R^2	0.25	0.25	0.13	0.13
F-stat	4.61***	4.31***		
Wald χ^2			56.20***	94.19***
Observations	233	233	670	670
Number of firms	233	233	233	233

Notes. The Hausman tests are insignificant at 10%, which indicates that the random-effects models are efficient comparing to the fixed-effects models. Standard errors are in parentheses. * p<0.1; ** p<0.05; *** p<0.01

Table 3.3. Cross-sectional and panel random-effects OLS results for basic/extended cloud computing as a whole and Tobin's q

Dependent Variable: Tobin's q	Model 2.1	Model 2.1 with Robust S.E.	Model 2.2 Random Effects	Model 2.2 Random Effects with Robust S.E.
H2A: Cloud-Basic	0.159	0.159	0.149	0.149
	(0.037)***	(0.063)**	(0.041)***	(0.057)***
H2B: Cloud-Extended	0.022	0.022	-0.023	-0.023
	(0.037)	(0.044)	(0.041)	(0.047)
ERP systems	0.052	0.052	0.029	0.029
	(0.037)	(0.036)	(0.041)	(0.041)
H5A: Cloud-Basic x ERP systems	-0.025	-0.025	-0.027	-0.027
	(0.034)	(0.045)	(0.038)	(0.042)
H5B: Cloud-Extended x ERP systems	-0.021	-0.021	-0.022	-0.022
	(0.041)	(0.048)	(0.045)	(0.048)
Herfindahl index	-0.371	-0.371	-0.705	-0.705
	(0.509)	(0.624)	(0.511)	(0.572)
Industry Tobin's q	0.542	0.542	0.001	0.001
	(0.109)***	(0.106)***	(0.003)	(0.001)
Industry capital intensity	0.000	0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.000)	(0.000)
Regulated industry	0.174	0.174	0.114	0.114
	(0.104)*	(0.117)	(0.116)	(0.141)
log(Employees)	-0.023	-0.023	-0.040	-0.040
	(0.028)	(0.024)	(0.030)	(0.027)
Advertising	-0.072	-0.072	-0.173	-0.173
	(0.178)	(0.152)	(0.175)	(0.143)
R&D intensity	-0.089	-0.089	-0.065	-0.065
	(0.188)	(0.194)	(0.190)	(0.171)
Market share	0.689	0.689	0.769	0.769
	(0.440)	(0.451)	(0.459)*	(0.377)**
Capital intensity	-0.001	-0.001	0.000	0.000
	(0.001)	(0.000)*	(0.000)	(0.000)
Firm age	0.000	0.000	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Industry-Manufacturing	-0.293	-0.293	0.042	0.042
	(0.195)	(0.227)	(0.215)	(0.210)
Industry-Retail&Wholesale	-0.284	-0.284	0.176	0.176
	(0.219)	(0.240)	(0.236)	(0.226)
Industry-Services	-0.347	-0.347	-0.219	-0.219
	(0.192)*	(0.217)	(0.214)	(0.191)
y09			-0.039	-0.039
			(0.024)	(0.028)
y10			0.064	0.064
			(0.024)***	(0.020)***
Constant	0.827	0.827	1.250	1.250
	(0.229)***	(0.266)***	(0.237)***	(0.229)***
R^2	0.25	0.25	0.13	0.13
F-stat	4.05***	3.87***		
Wald χ^2			56.41***	95.92***
Observations	233	233	670	670
Number of firms	233	233	233	233

Notes. The Hausman tests are insignificant at 10%, which indicates that the random-effects models are efficient comparing to the fixed-effects models. Standard errors are in parentheses. * p<0.1; ** p<0.05; *** p<0.01

Table 3.4. Cross-sectional and panel random-effects OLS results for specific cloud services and Tobin's q

Dependent Variable: Tobin's q	Model 3.1	Model 3.1 with Robust S.E.	Model 3.2 Random Effects	Model 3.2 Random Effects with Robust S.E.
H3A: IaaS	0.039	0.039	0.028	0.028
	(0.033)	(0.038)	(0.037)	(0.042)
H3B: PaaS	0.091	0.091	0.065	0.065
	(0.032)***	(0.038)**	(0.036)*	(0.038)*
H3C: SaaS	-0.011	-0.011	-0.018	-0.018
	(0.037)	(0.035)	(0.042)	(0.037)
H3D: KaaS	-0.017	-0.017	0.013	0.013
	(0.039)	(0.034)	(0.044)	(0.042)
H3E: BPaaS	0.117	0.117	0.115	0.115
	(0.042)***	(0.056)**	(0.048)**	(0.061)*
ERP systems	0.033	0.033	0.018	0.018
	(0.038)	(0.039)	(0.044)	(0.044)
H6A: IaaS x ERP systems	-0.077	-0.077	-0.084	-0.084
	(0.035)**	(0.034)**	(0.040)**	(0.036)**
H6B: PaaS x ERP systems	-0.024	-0.024	0.006	0.006
	(0.034)	(0.038)	(0.038)	(0.038)
H6C: SaaS x ERP systems	0.066	0.066	0.050	0.050
	(0.031)**	(0.031)**	(0.035)	(0.030)*
H6D: KaaS x ERP systems	0.025	0.025	0.016	0.016
	(0.035)	(0.025)	(0.040)	(0.028)
H6E: BPaaS x ERP systems	-0.016	-0.016	-0.007	-0.007
	(0.041)	(0.049)	(0.046)	(0.055)
Herfindahl index	-0.714	-0.714	-0.919	-0.919
	(0.540)	(0.559)	(0.534)*	(0.533)*
Industry Tobin's q	0.558	0.558	0.001	0.001
	(0.112)***	(0.110)***	(0.003)	(0.001)
Industry capital intensity	0.000	0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.000)	(0.000)
Regulated industry	0.184	0.184	0.103	0.103
	(0.104)*	(0.119)	(0.116)	(0.143)
log(Employees)	-0.023	-0.023	-0.039	-0.039
	(0.027)	(0.024)	(0.030)	(0.027)
Advertising	-0.054	-0.054	-0.152	-0.152
	(0.175)	(0.146)	(0.174)	(0.138)
R&D intensity	-0.105	-0.105	-0.086	-0.086
	(0.184)	(0.185)	(0.189)	(0.161)
Market share	0.888	0.888	0.882	0.882
	(0.446)**	(0.429)**	(0.464)*	(0.366)**
Capital intensity	-0.001	-0.001	0.000	0.000
	(0.001)	(0.000)**	(0.000)	(0.000)
Firm age	0.001	0.001	0.000	0.000
	(0.002)	(0.002)	(0.002)	(0.002)
Industry-Manufacturing	-0.283	-0.283	0.038	0.038
	(0.191)	(0.228)	(0.213)	(0.205)
Industry-Retail&Wholesale	-0.241	-0.241	0.193	0.193
	(0.215)	(0.243)	(0.235)	(0.224)
Industry-Services	-0.343	-0.343	-0.220	-0.220
	(0.188)*	(0.221)	(0.213)	(0.188)
y09			-0.038	-0.038

Table 3.4 (cont.)

Dependent Variable: Tobin's q	Model 3.1	Model 3.1 with Robust S.E.	Model 3.2 Random Effects	Model 3.2 Random Effects with Robust S.E.
			(0.024)	(0.028)
y10			0.065	0.065
			(0.024)***	(0.021)***
Constant	0.761	0.761	1.214	1.214
	(0.225)***	(0.266)***	(0.235)***	(0.222)***
R^2	0.31	0.31	0.16	0.16
F-stat	3.82***	3.61***		
Wald χ^2			66.30***	124.20***
Observations	233	233	670	670
Number of firms	233	233	233	233

Notes. The Hausman tests are insignificant at 10%, which indicates that the random-effects models are efficient comparing to the fixed-effects models. Standard errors are in parentheses. * p<0.1; ** p<0.05; *** p<0.01

Table 3.5. Cross-sectional propensity score matching (PSM) results using the radius matching method

Hypothesis and Treatment Variable	Propensity Score Matching (PSM) Result				
	Number of Treated	Number of Control	Average Treatment Effect on the Treated (ATT)	Standard Error	T Value
H1: AnyCloud	85	135	0.231***	0.089	2.594
H2A: AnyCloud_bas	82	138	0.253***	0.091	2.783
H2B: AnyCloud_ext	25	195	0.457	0.169	2.711
H3A: AnyIaaS	31	179	0.299**	0.169	1.766
H3B: AnyPaaS	17	108	0.497**	0.225	2.209
H3C: AnySaaS	66	156	0.190	0.101	1.884
H3D: AnyKaaS	14	165	0.156	0.142	1.097
H3E: AnyBPaaS	16	191	0.510	0.237	2.150

Notes. Dependent variable is Tobin's q. * p<0.1; ** p<0.05; *** p<0.01

CHAPTER 4: THE ROLE OF CLOUD COMPUTING IN STRATEGIC ALLIANCE FORMATION

Abstract

With the wide acceptance and usage of cloud computing in industries, anecdotal evidence has shown that cloud computing can exert beneficial influences on formation of inter-organizational strategic alliances. In the current dynamic, competitive business environments, firms tend to form strategic alliances to tackle challenges and grasp opportunities which are not easily achievable alone. Prior information systems literature has studied the relationship between information technology as the general term and strategic alliances. As cloud computing is regarded as a disruptive technology and business model, it is important to investigate this new paradigm's influence on firms' strategic alliance formation. Using panel data from 2009 to 2012 that spans multiple industries, this study investigates the relationship supported by the theoretical arguments and empirical analysis. We find that cloud computing in general and its specific services may exert varied effects on different types of alliances. For cloud computing as a whole, we find that it primarily benefits non-equity alliance formation. Among the specific cloud services, we find that Infrastructure as a Service (IaaS) is a very versatile cloud service that may benefit all kinds of alliance formation. Other cloud services tend to only benefit certain types of alliance formation. We find that Platform as a Service (PaaS) is positively associated with non-equity alliances. Software as a Service (SaaS) is positively associated with arm's-length and non-equity alliances. Business Process as a Service (BPaaS) is primarily beneficial for non-equity and collaborative alliance formation. BPaaS can also complement firms' internal ERP systems to increase arm's-length alliances. We also find that Knowledge as a Service (KaaS), which makes firms more accessible to information and knowledge, may instead reduce firms' needs to rely on

alliances to obtain such resources hence lowering formation of joint-venture and collaborative alliances. Overall, these findings suggest that cloud computing can facilitate various types of alliance formation.

Keywords: cloud computing; information technology; service-oriented architecture; alliance; transaction cost economics; resource-based view of the firm; neo-institutionalism; relational theory; social networks

4.1 Introduction

With the advent of the Internet and the Web, how the world communicates and collaborates has been fundamentally changed. Through a connected world, people and organizations can work together, share ideas, co-develop products or services, and exchange needed resources quickly even when they reside distantly around the world. Since then, multiple novel technologies on top of the duo have been introduced to enhance collaboration and alliance. Web 2.0 and its derived applications such as social media are such technologies that have changed the way people and firms collaborate. For example, social media such as Facebook has become indispensable for many firms as it makes them connect directly and conveniently to their customers and business partners in virtual social networks. The new paradigm, cloud computing, has further enriched and enhanced the possibility of how firms connect and collaborate. Cloud computing makes IT resources and applications accessible, cost-effective and flexible so that collaboration can be more easily implemented. One such example is Microsoft SharePoint which supports various teamwork activities by integrating social networks, wikis, blogs, online messaging, video conferencing, and so on in the Microsoft cloud. Anecdotes have shown evidence that cloud computing is beneficial for inter-firm collaboration and alliance. Mohawk Fine Papers (Computerworld 2012), a US-based premium papers manufacturer, hired a cloud service broker called Liaison Technologies to help it integrate various B2B data and connections with its on-premises ERP system in Amazon’s clouds. The cloud approach enabled the firm to swiftly and cost-effectively connect and collaborate with its customers, suppliers and business partners. On a more strategic level, the cloud approach actually enabled the firm to realize a more nimble business strategy to seek potential business partners that was impossible to pursue in the past. A recent study conducted by SCM World (Forbes 2014), revealed that cloud-based customer relationship management (CRM) systems are becoming more pervasive in large enterprises as they can help the firms to achieve agility and speed in solving complicated problems through more effective collaboration with their business partners. Accenture Life Sciences Cloud for R&D (Accenture 2014) is one of the cloud computing platforms that can enable pharmaceutical companies to collaborate with each other to reduce costs, streamline processes, share research and clinical data, accelerate the new drug development timelines, and maintain quality and compliance.

The anecdotes raise the research question about the relationship between cloud computing and strategic alliances. It is important to investigate and verify in what mechanisms cloud computing and its various specific services facilitate which types of strategic alliances based on a theoretical framework and the derived empirical methods. This question is pivotal and pertinent to the IS researchers as well as the practitioners and managers in the industrial sectors because cloud computing has become very influential and has been recognized as a major game changer of doing business (Brynjolfsson et al. 2010).

Strategic alliances have been an important research topic in organizational behavior and strategic management since the late 1990s. Strategic alliances are defined by Gulati (1998, p. 293) as "voluntary arrangements between firms involving exchange, sharing, or co-development of products, technologies, or services". One of the antecedents of strategic alliances, information technology (IT), has received extensive attentions and analysis in the IS literature on the conceptual, theoretical and empirical levels and is believed to have substantially changed the way that firms collaborate. Brown and Pattinson (1995) conceptually articulate the convergence of the telecommunications, media and computer industries to provide a new infrastructure that was emerging in the late 1990s and predict that such a new infrastructure would promote strategic alliances across different industries. They then use a case study of the hotel chain of Radisson Hotels Australia in the Australasian travel and hospitality industry to illustrate that technological advances increase the speed of formation of strategic alliances and strengthen the alliances once formed by enhancing the communication between alliance partners. From the transaction cost economics perspective, Clemons and Row (1992) argue that information technology helps reduce the coordination costs as well as the transaction risks and other-party opportunism related to increased coordination hence fostering inter-firm collaboration. Similarly, Clemons et al. (1993b) argue that IT can reduce coordination cost without incurring excess transaction risks, leading to more inter-firm coordination. They predict a so-called the "move to the middle" phenomenon that is enabled by IT to favor a shift toward longer relationships with a smaller set of suppliers thanks to the important effects of IT on promoting transaction economies of scale and decreasing learning curves in terms of inter-organizational coordination and cooperation. Kumar and Van Dissel (1996) develop a framework to describe the formation of cooperative alliances. Information technology plays two important roles in facilitating inter-organizational collaboration formation in the framework. On one hand, IT plays an enabling role of offering needed tools on making collaboration feasible. On the other hand, IT plays a supportive role in reducing transaction costs and risks due to the automated collaboration on supporting sustained collaborative exchange. In their conceptual model for strategic management of information technology, the Strategic Alignment Model, Henderson and Venkatraman (1993) emphasize the very need for the managers to view the IT strategy of the firm not only from the internal perspective but also from the external perspective. The external perspective focuses on using IT to connect business partners and form alliances to obtain enhanced, complementary IT competencies for the firm. In a related article about the continuous alignment of business and IT strategies, Venkatraman et al. (1993) also emphasize the importance of considering IT strategy that outreaches a firm's own boundary. In other words, a firm's IT strategy must also embrace an externally-oriented view in addition to the internally-oriented view to consider the useful IT resources available in the IT marketplace including inter-firm collaboration and strategic alliances. In his conceptual work about the effect of IT on organizational structure changes based on a literature review, Wang (1997) uses an evolutionary constructionist view to explain the three stages for the IT-enabled changes: knowledge link, transaction link, and business alliance link. Along with the IT advances, an organization would typically go through the sequential transition processes of a knowledge link, a transaction link with reengineered business processes, and an inter-organizational business alliance link when necessary. The author also points out that IT in communication facilitates collaborations and alliances amongst organizations across different industries. Focusing on the alliance projects in the construction industry, Baldwin et al. (1999) recognize the importance of the information exchange (IE) technologies in solidifying the relationships among the business partners in an alliance project as IE can guarantee data delivery, improve data quality, reduce data handling, ameliorate alliance partner communication as well as alleviate the risk of project delay, using a case study and a questionnaire survey.

A set of articles studies the impact of IT on the strategic alliances in supply chain. Buhalis and Main (1998) point out that IT is a premise of strategic alliance formation in supply chain. Using field interviews and a mail survey, Carr and Smeltzer (2002) investigate different types of IT and their impacts on buyer-supplier relationships. The authors find that electronic data exchange

(EDI), information systems, and computer-to-computer links with key suppliers increase the frequency of communication and information sharing among buyers and suppliers, information systems and computer-to-computer links with key suppliers increase the richness of information shared among buyers and suppliers, and up-to-date information systems increase the trust between buyers and suppliers. In other words, various IT technologies may help improve the relationships between buyers and suppliers in a supply chain one way or another. Esper and Williams (2003) believe that inter-firm IT is an indispensable component to effectively implement and achieve the benefits of supply chain collaboration and use a descriptive case study to illustrate the enabling and supporting roles of IT in facilitating the extended supply chain collaboration involving buyers, suppliers, shippers, carriers and third-party logistics providers (3PLs) in collaborative transportation management (CTM). Utilizing the transaction cost economics and organization theory, Bensaou (1997) conceptually and empirically investigates the influence of exogenous and endogenous factors on inter-organizational cooperation. One of the endogenous factors is inter-organizational IT. The author empirically tests and compares the roles of the factors in the buyer-supplier relationships in the US and Japanese automobile industries. It is found that IT plays different predictive roles for the two nations as it is only significant in Japan indicating Japan's use of IT to promote the concept of electronic partnership in the buyer-supplier relationships. Mainly referencing the organizational information processing theory, Feger (2011) empirically tests the argument of that coordinated enterprise information systems as information solutions can facilitate collaboration because the systems can improve information-processing capacity and finds it is supported when the level of uncertainty is high using the survey-based data, even though the study is more focused on internal supply chain collaboration within a firm rather than inter-firm collaboration. However, the theory and finding may be easily extended in the inter-firm collaboration context. Grover et al. (2002) combine the theories of transaction cost economics (TCE) and relationalism to explain more comprehensively the positive effect of IT on buyer-supplier collaboration. They recognize not only the explicit contractual role of TCE in explaining the effect by reducing transaction costs and promoting market-based governance structures but also the implicit, open-ended contractual role of relationalism that extends TCE by considering intrinsic motivations of trust and respect established among the parties through their long-term past transactions and collaborative experiences. Using a survey data from the buyers in the original equipment manufacturer (OEM) electronics industry, the authors find that IT can help establish relational behavior in the dyad of buyers and suppliers by positively offsetting the negative relation between transaction costs and relationalism. Subramani (2004) adopts transaction cost economics, resource-based view as well as organizational learning and action theories as lenses to investigate the role of supply chain management systems (SCMS) in relationship-specific intangible investments and subsequent benefits in buyer-supplier networks from the perspective of supplier firms. The authors use the field studies and interviews to empirically test the arguments and find that the suppliers' SCMS uses for exploitation and exploration increase the exchanges of business-process specificity and domain-knowledge specificity which lead to increased operational and strategic benefits and eventually improved competitive performance caused by strategic benefits for the suppliers. Though not explicitly stated, Williams et al. (2002) use observable industrial experiences and the transaction cost theory to explain the structural changes in strategic alliances brought by the Internet-based electronic supply chain. The authors argue that, comparing to the traditional EDI-based supply chain, the new e-supply chain system may make organizations favor more frequent, flexible alliances and partnerships because the new system reduces technological expenditures, increases alliance opportunities, decreases search, qualification and transaction costs, as well as provides the possibility for the organizations to achieve a balance between the cost benefits of arm's length alliances and the structural benefits of the traditional supply chain. Tafti et al. (2013) specifically investigate the impacts of IT architecture flexibility in the context of strategic alliances in terms of both alliance formation and valued that can be drawn from the formation. Using the panel data spanning seven years from 2000 to 2006, the authors empirically find that adoption of a more flexible IT architecture overall can lead to more strategic alliances amongst firms and the market-based performances of the focal firms will be improved as well.

A subset of articles discusses a specific technology's role in strategic alliances – electronic data interchange (EDI). EDI is an inter-organizational network technology used to exchange structured data between business partners' computer systems (Brousseau 1994). Since the mid-1970s, EDI has been used to automate the document and information exchange between the business partners through a telecommunications network (Brousseau 1994). EDI reduces the administrative, labor and economic costs as well as the error rate so as to significantly increase the accuracy and speed of information exchange between the parties in a business relationship. In the 1990s, EDI became widely popular and recognized as the de facto technology to establish partnerships among the organizations, especially in the banking, manufacturing and retailing industries (Baldwin et al. 1999). Maltz and Srivastava (1997) use the case study and the data from an American department store chain to illustrate that EDI can reduce environmental uncertainty and risk (e.g., product demand fluctuations), various costs (e.g., carrying costs, administrative costs, markdowns), product stocks, as well as increase assortments for the business partners (e.g., retailers, distributors, manufacturers, customers) in a supply chain in the retail apparel industry.

Cloud computing has not received sufficient research on the possible mechanisms through which it can benefit strategic alliances in the prior IS literature. A major reason for this lack of study was due to its novelty and complexity of the applications in various industries, so only till the late 2000s, has cloud computing gained the momentum in commercial applications, especially in those large enterprises. As a result, the IS literature about cloud computing has just started to flourish with the majority focusing on the early stages of analysis in cloud computing features and trends, pros and cons, benefits and costs, and risks and concerns mitigation, largely on a conceptual and observational level. There is little literature that has addressed the issue of the mechanism of cloud computing on improving inter-organizational collaborations and alliances, especially from the perspective of an integrated theoretical and empirical framework. This paper tries to bridge this gap in the IS literature and answer the important question about the relationship between cloud computing and strategic alliances.

A review of the prior IS literature on strategic alliances reveals that three main theoretical lenses have been utilized to study the paradigm: transaction cost economics (TCE), resource-based view (RBV) of the firm, and social network theory.

The concept of transaction cost economics (TCE) was popularized by Williamson (1981) as a theoretical framework for predicting the kind of decisions of make or buy for a company to perform certain economic tasks. The various transaction costs exist due to the factors of transactional frequency, asset specificity, behavioral uncertainty, bounded rationality, and opportunistic behavior when transactions are conducted (Williamson 1981; Williamson 1985). When the company perceives that the external transaction costs exceed the internal transaction costs in order to perform certain economic tasks, it will perform them internally within the boundaries of the company; on the contrary, if it perceives that the internal transaction costs are larger than the external ones, it will outsource them to be performed externally by someone else in the market. This type of make vs. buy governance mechanism has been extended to encompass a fuller spectrum that includes many intermediate mechanisms lying between the two poles of markets and hierarchies such as spot contracts, franchises, partnerships, strategic alliances, joint ventures, and mergers and acquisitions (Afuah 2003). Adopting a meta-analysis approach based on the prior TCE-based empirical research on firm boundary decisions (i.e., make, buy or ally), Geyskens et al. (2006) quantitatively analyze and find the support of TCE on explaining make vs. buy as well as ally vs. buy decisions. Brockhoff (1992) conceptually asserts and empirically verifies that various perceived transaction costs by the firms play an important role in making their inter-firm research and development (R&D) cooperation decisions.

The resource-based view of the firm originates from the strategic management literature (Crook et al. 2008) and was adopted by the IS researchers to analyze the antecedents of firm performance in the IS context. Barney (1991) introduces the idea of that a set of tangible and intangible resources firms possess can contribute to their sustained performance. These so-called strategic firm resources and skills should possess the attributes of being valuable, firm-specific, rare, inimitable, and non-substitutable. Many articles have utilized the RBV to study strategic alliances. Das and Teng (2000) use the RBV to analyze strategic alliances in four major aspects:

rationale, formation, structural preferences, and performance. The rationale is that firm resources will create new values when pooled together via alliances. The characteristics of strategic resources from different firms may facilitate alliance formation due to their values from the mutual perspectives of the participating firms. Partner firms' resource profiles may also determine their different alliance type preferences such as joint ventures or contract-base alliances. Eventually, the alliances may affect the participants' firm performances in various ways. Rungtusanatham et al. (2003) use the RBV to theoretically postulate that a firm's connections and relationships with its partners in a supply chain can be viewed as either strategic resources or capabilities of acquiring supply chain knowledge that can be used to boost its operational performance. Harrison et al. (2001) conceptually summarize the effect of resource complementarity in strategic alliances between organizations and suggest that it is the valuable, rare and inimitable synergy gained by combining complementary resources dispersed in different organizations that attracts the organizations to form alliances. The synergy can also offer the organizations new opportunities for knowledge learning and capability development. Mowery et al. (1998) utilize the resource-based view of the firm to argue that a firm can acquire needed capabilities from other participating firms in a strategic alliance and empirically confirm the importance and effects of overlapping portfolios of technological resources between the firms in alliance formation.

A set of literature compares or integrates the theories of TCE and RBV to study inter-corporate alliances and partnerships. Yasuda (2005) compares the capabilities of TCE and RBV on explaining various alliance formations in high-technology industries such as technology license, joint R&D, sourcing agreement and joint venture. The author empirically finds that the foremost motive for setting up a strategic alliance is to access the needed resources from other partners via the alliance and the secondary motive is to shorten the time required for development or marketing, and concludes that the resource-based view is a more capable theory than transaction cost economics in the explanation. Chen and Chen (2003) use the theories of TCE and RBV to explain the adoption of different governance structures in alliances. Using the data from a survey, the authors empirically discover that the TCE is useful in explaining whether a firm will choose the approach of a joint venture or a contractual alliance while the RBV is useful in explaining which specific type of contractual alliance a firm will choose between exchange and integration alliances if the firm is believed to use a contractual alliance. Tsang (2000) conceptually propose that TCE and RBV can complement each other as a theoretical pluralism in explaining joint venture, a specific type of strategic alliance because TCE focuses on the explanation of the cost aspect of a transaction while RBV focuses on the explanation of the benefit aspect of a transaction.

Some literature has considered using the social network theory to address the research questions in strategic networks and alliances. By combining resource-based view and institutional perspective in the context of alliances, Lin et al. (2009) use a panel data spanning four US industries to empirically affirm that complementary resources together with societal and network statuses can benefit alliance formation and the focal firm's performance in an alliance network, contingent on some firm and environmental factors. Gulati (1999) raises the importance of firm network resources that a firm accumulates in its previous and current alliance networks on its future alliance formation. The author empirically finds that such network resources can provide a firm with information and experience to seek new business opportunities. Similarly, Ahuja

(2000) uses the RBV and the social network theory to identify the important roles of technical, commercial, and social capitals in affecting firms' inducements and opportunities in alliance formation. The author also empirically tests and confirms the proposed roles of the capitals. Using a cross-sectional data in the global construction contracting industry, Sarkar et al. (2001) empirically find that resource complementarity as well as cultural and operational compatibilities have different direct impacts and indirect impacts via the mediators of relationship capital (i.e., mutual trust, reciprocal commitment, and bilateral information exchange) on the common benefits in project performance for all the partners as well as on the private benefits in strategic performance for the focal firm in a project-based alliance in the industry. Lavie (2006) theoretically investigates the role of network resources in strategic alliances using the theories of RBV and social network, and proposes that a firm's relational capability of creating and retaining valuable cooperative relationships with its alliance partners (e.g., relative bargaining power) is more important than the nature of resources it has access to (e.g., imperfect imitability and imperfect substitutability) in an alliance network. Eisenhardt and Schoonhoven (1996) use the RBV to argue that the strategic and social positions of a firm in terms of various resources determine its level of strategic alliances and find supportive results from the empirical analysis using a panel of entrepreneurial semiconductor firms in the US. Zaheer et al. (2000) highlight the important role of inter-firm strategic networks in affecting the firms' conduct and performance. The values of network relationships are analyzed through other lenses in addition to TCE and RBV including industry structure, positioning in an industry as well as dynamic network constraints and benefits. The synthesis of the different views and theories enhances the understanding of the role of networks and alliances in firms. Bellon and Niosi (2001) argue that three major schools of neo-institutionalism, namely transaction cost economics (TCE), competence theories of the firm (CT) and evolutionary theories (ET) in economics and business, have a common ground of assumptions yet attempt to address different aspects of the issues in inter-firm strategic alliances so that the three schools of theories can be combined to form a more comprehensive lens through which the issues in alliances can be better understood. The authors also point out that evolutionary theories are more suitable for examining the dynamics of cooperation and alliances, while transaction cost economics is more adept at explaining the instant, static situations in inter-organizational relationships in terms of transactions and associated costs, and competence theories are more capable of inspecting strategic alliances in terms of resources, dynamic capabilities and knowledge.

Considering the theories used in the prior alliance literature, we would like to primarily utilize the lenses of transaction cost economics (TCE), resource-based view (RBV) and social network theory to conduct and enrich our understanding of the effect of cloud computing on strategic alliances. The IS literature has recently started to study the inter-organizational activities enabled and improved by cloud computing such as knowledge sharing (Rosenthal et al. 2010), collaborative R&D and innovation (Soriano et al. 2007), and value chains and networks (Böhm et al. 2010; Gonçalves and Ballon 2011; Petrescu 2012). However, this type of literature is still in scarcity and most of the articles adopt a descriptive or conceptual approach which is based on facts, anecdotes or cases rather than a theoretical framework and the derived empirical analysis. This paper tries to answer such a need to bridge the gap in the IS literature. Using four-year panel data with firms across multiple industries, we empirically find that cloud computing as a whole may benefit non-equity alliance formation rather than joint venture in general. As to the specific cloud services, Infrastructure as a Service (IaaS) can promote all kinds of alliance formation including joint venture, non-equity, collaborative as well as arm's-length due to its versatile usability. Platform as a Service (PaaS) can promote formation of non-equity alliances, reflecting its important role in nurturing contractual cooperation. Software as a Service (SaaS) is positively associated with arm's-length and non-equity alliance formation which indicates its role in facilitating more market-like transactions. Business process as a Service (BPaaS) mostly improves non-equity and collaborative alliance formation, which highlights its capability of bolstering flexible business processes that are pivotal to such alliances. BPaaS may also have a complementary effect on firms' internal ERP systems in arm's-length alliance formation because BPaaS lessens the negative effect of ERP systems on such alliance formation by making ERP systems more flexible and transaction cost effective. Knowledge as a Service (KaaS), however, has a negative effect on joint-venture and collaborative alliance formation, which may indicate that as it enables some valuable information and knowledge more accessible, KaaS decreases the firms' needs of having to form alliances for such purpose. As a result, this article contributes not only to the IS literature by extending the understanding of the effect of IT on alliances into the new context of cloud computing but also to the public policy and the practitioners in industries that concern the impacts and trends of cloud computing on business by giving informative guidance and implications on how cloud computing may be used to facilitate strategic alliance formation.

The remaining sections of the paper are organized as follows. First, we briefly introduce the concept and definition of strategic alliances. Second, based on the prior literature and theories, we argue that cloud computing as a whole and its individual service models (i.e., IaaS, PaaS, SaaS, KaaS and BPaaS) can facilitate different types of strategic alliances (i.e., collaborative vs.

arm's-length, or joint-venture vs. non-equity). Third, we present the empirical methods such as data collection, measures and variables, and the model specifications. Fourth, we present the results of our empirical analysis based on the proposed models. Finally, we make conclusions about our findings, give research and managerial implications, and discuss the limitations and future research directions.

4.2 Theory and Literature

4.2.1 Alliance taxonomy

Traditionally, the distinction of alliance forms originated from the study of the nature of the firm initiated by Coase (1937) who considered the firm as a governance structure in terms of organizing transactions. The view was advanced into wide recognition with the introduction of the market-hierarchy pair in terms of transaction costs incurred by transactional frequency, asset specificity, uncertainty, bounded rationality and opportunism (Williamson 1975; Williamson 1985). Exchanges that incur small transaction costs will be conducted in a market. On the contrary, exchanges that incur large transaction costs will be conducted in a hierarchically organized firm. The dyad was then taken as two extremes and extended into a continuum that can encompass many intermediate or hybrid governance structures. Some scholars have criticized this idea of the market-hierarchy continuum for being too simplified, rigid and mechanical to capture the complex realities of exchange. For example, it neither considers the role of reciprocity and collaboration, the social and cultural contexts, the intermingling of different forms of exchange (Powell 2003), nor the role of inter-firm trust (i.e., knowledge-based trust and deterrence-based trust), joint value maximization, process issues, coordination costs, and the multiplicity of social and economic contexts (Gulati 1998). Scholars exemplify that networks are such an arrangement that cannot be fit into the market-hierarchy continuum (Powell 2003). Nevertheless, the market-hierarchy continuum does offer a good reference as a bottom line based on which many existing governance structures can be identified and derived. For example, Afuah (2003) enumerates spot contracts, franchises, strategic alliances, joint ventures, etc. as some of the hybrid forms of governance structure along the market-hierarchy continuum.

Similar to the continuum, Hagedoorn (1990) sorts the various modes of cooperative agreements in terms of inter-organizational dependence. At one end of large organizational interdependence lie joint ventures and joint R&D alike, and at the other end of small organizational interdependence lie one-directional technology flow, licensing, customer-supplier relations, R&D contract and the similar. Lying in between are mutual technology exchange agreements, direct investment and so on. Todeva and Knoke (2005) list a detailed classification of the forms of inter-firm relations arranged in the order of market to hierarchy that includes industry standards groups, subcontractor networks, licensing, franchising, cartels, R&D consortia, equity investments, and joint ventures, etc. In their work of introducing conceptual foundations for strategic alliances, Varadarajan and Cunningham (1995) briefly classify inter-organizational alliances into two broad categories based on their degree of rigidity of the cooperative arrangement: equity joint venture and non-equity alliances. In an equity joint venture, a separate, distinct corporate entity is formed by the alliance partners to put together and share skills and resources as equities whilst in a non-equity alliance, no such standalone corporate entity is established, rather, the alliance partners agree to share skills and resources through the inter-organizational connections. Joint technology/product development is one such non-equity alliance. Hagedoorn and Narula (1996) concur with this broad classification dichotomy and explain that contractual alliances are more quasi-market while (equity) joint ventures are more quasi-hierarchical. When studying the trends of R&D alliances in the industry of pharmaceutical biotechnology since the mid-1970s, Roijakkers and Hagedoorn (2006) classify the modes of cooperation into two major categories: equity-based partnerships and contractual partnerships. The former may include joint ventures and minority holdings and the latter may include joint R&D agreements. Hagedoorn and Hesen (2007) identify three main partnership models when they conduct the study of contract law in the context of inter-firm technology alliances: equity joint ventures, non-equity partnerships, and licensing contracts. Slightly unlike the previous equity-based dichotomy of partnerships, licensing contracts is taken as a separate category because the authors think that licensing contracts are unilateral and involve the one-way flow of information from one firm to another firm, which is different from the other two types of alliances that entail reciprocal investments. In their study of IT flexibility and alliances, Tafti et al. (2013) define a taxonomy of alliances that contains two dyads: arm's-length or collaborative alliances, and equity joint-venture or non-equity alliances.

Comparing the aforementioned taxonomies of strategic alliances, we find that they are largely similar in essence and we would like to adopt a synthesized, dyad-type taxonomy so we follow the alliance taxonomy used by Tafti et al. (2013). Tafti et al. (2013) define arm's-length alliances as those in which multiple firms agree to share information or license rights so as to produce, market, or exchange a service or product. Referencing the market-hierarchy continuum, arm's-length alliances are most similar to market transactions in that they incur small transaction costs, have loosely coupled governance structures and typically don't involve joint development, integration, or process/capability recombination (Tafti et al. 2013). Collaborative alliances are those that entail any characteristics of 1) firm-specific or tacit knowledge sharing, 2) inter-firm product/service/process recombination or 3) intense business process coupling between firms (Tafti et al. 2013). Dissimilar to arm's-length alliances, collaborative alliances usually entail a lot of tacit knowledge sharing or firm resource recombination. Table C.1 in Appendix C presents examples of collaborative and arm's-length alliances. Alliances can be distinguished by whether they are equity-based or not as well. Equity joint-venture alliances (or simply joint ventures) are those collaborative or arm's-length alliances that bring partner resources together to create a new, separate and distinct corporate entity (Tafti et al. 2013). Non-equity alliances, on the contrary, are those collaborative or arm's-length alliances that do not involve such corporate entity creation. Joint ventures more resemble a hierarchical governance structure in the market-hierarchy continuum than non-equity alliances. Typically they have more firm-specific assets and collaborative activities involved (Tafti et al. 2013).

In the subsequent sections, we first discuss how cloud computing as a whole can affect strategic alliance formation. We then discuss how specific cloud services may influence different types of alliances directly or by complementing firms' internal enterprise resource planning (ERP) systems.

4.2.2 Cloud computing as a whole and strategic alliance formation

When discussing how overall cloud computing can affect strategic alliance formation, we utilize the lenses of transaction cost economics, resource-based view, social network theory and other related theories to investigate the relationship.

Dean and Saleh (2009) from the Boston Consulting Group summarize three levels of cloud computing value: utility level, process transformation level, and business-model-innovation level. Each level provides firms with different benefits. On the utility level, cloud computing can generally reduce the transaction costs incurred in inter-firm alliance formation, pushing a firm's governance structure toward the market end in the market-hierarchy continuum, thanks to its traits that promote IT cost-effectiveness, flexibility and scalability (Marston et al. 2011; Zhang et al. 2010). This level can also enabled firms to be freed from IT management and refocus on core business competitiveness and strategy (Garrison et al. 2012; Gong et al. 2010; Vaquero et al. 2008), which means firms will possess and strengthen more firm-specific strategic resources that are attractive to other firms such as superior product quality, know-how and company reputation, thus increasing the possibility to be the target of strategic alliances. For example, Mohawk Fine Papers (Computerworld 2012) were freed from the cumbersome work of point-to-point EDI connections with its business partners by using the cloud services offered by a cloud broker. The company was then able to swiftly and economically make connections with new business partners according to its strategic considerations. Cloud computing enabled the company to flexibly implement and adapt its strategies as the business environment changes. If the firm was unsatisfied with its alliance decisions, it could easily and cost-effectively switch to other options. This shows that cloud computing largely alleviates many concerns firms may have in alliance formation so that they are more willing to attempt new alliances for necessary resources. On the process transformation level, cloud computing may provide the benefit of cost-effective, flexible and agile process integration and reconfiguration, which may both reduce the transactions costs associated with inter-firm business process integration and provide strategic resources in alliances by combing and forming unique, valuable processes that benefit the alliance participants. On the business-model-innovation level, cloud computing may enable innovative business strategies and models acclaimed by Brynjolfsson et al. (2010). These resources and capabilities in a firm certainly are very idiosyncratic and attractive to potential alliance partners. Focusing on the high-tech industries such as information technologies, biotechnology and new materials, Hagedoorn and Schakenraad (1990) summarize the motives of inter-firm cooperation as follows: 1) reduction of costs and risks of R&D, 2) quick pre-emption on a world scale, 3) technology transfer and complementarity, 4) market expansion and new market development, 5) innovation lead time reduction, 6) monitoring technology trends and opportunities, 7) national circumstances, and 8) seeking financial resources. For example, cloud computing may provide opportunities for less-developed regions and economies to have access to needed IT resources in a cost-effective manner so as to enable them to quickly improve their technology and innovation capabilities including those achieved through strategic alliances (Greengard 2010; Kshetri 2010; Marston et al. 2011). Marston et al. (2011) point out that cloud computing can significantly lower the cost of entry for small businesses and startups to conduct compute-intensive business analytics that was only available to large enterprises before. This business analytics can generate specific insights and knowledge that are rare, valuable, unique and inimitable, and non-substitutable to a firm, thus becoming the firm's strategic resources based upon which the firm can become an attractive target that other firms may consider making alliances with. SCM World (Forbes 2014) illustrates that cloud computing is highly welcomed in large-scale supply chain systems because such cloud-based systems can provide the firms with a more effective and economic collaboration platform based on which they can swiftly solve complex problems. Schilling and Hill (1998) point out that strategic alliances may help firms to acquire necessary technologies that only available from other firms to shorten the new product development process. Cloud computing can facilitate such alliances by providing a flexible, agile and cost-effective platform based on which firms can easily connect to each other and share knowledge and technologies. McKendrick (ZDNet 2009) foresees that cloud computing will enable the new component delivery model for software development. He predicts that many companies will emerge as service component vendors that focus on their core competencies and expertise to develop and provide superior service-based functions such as payroll, billing and human resource management which can be combined, reconfigured or reused with other services or systems for certain business needs. By concentrating to what they excel at, the service component vendors actually provide strategic IT resources that are valuable, rare, inimitable and non-substitutable to other firms. In a similar way, companies that have adopted cloud computing can offer such service components to be used by other firms even though they are not particularly service component vendors per se. Many firms will become strategic resources providers whose resources are complementary or attractive to each other so that they are more likely to form inter-organizational alliances in order to gain access to those needed strategic resources from alliance partners (Harrison et al. 2001; Henderson and Venkatraman 1993; Lin et al. 2009; Sarkar et al. 2001).

From a transaction cost perspective, Fink (2013) investigates the role of cloud computing in the governance structure change in electronic markets enabled by the Internet. They first identify five inhibiting factors that have made firms adopt a relational hybrid governance structure rather than a purely market-based one in the trend of shifting from hierarchy to market in electronic markets: transactional economies of scale, learning curve effects, supplier incentives, information transparency, and relational attributes. The authors claim that cloud computing can mitigate the inhibiting effects of the five factors so that it can shift the governance structure from relational hybrid to a more market-based one – recurrent hybrid. In more detail, they explain that cloud computing can reduce fixed costs to mitigate the negative effect of transactional economies of scale. Cloud computing is more standardized so that the learning costs and curve are lower when adopting it. Cloud computing has improved adaptability and works as an intermediary between suppliers and customers so that suppliers' incentive to make relationship-specific investments is lessened. Cloud computing also supports various information transparency needs. Finally, cloud computing reduces switching costs, which provides a new safeguard toward transaction risks without having to adopt relational hybrid to reduce such risks. Ried et al. (2010) predict the emergence of inter-firm or collaborative cloud in the future as they see that cloud computing can facilitate various kinds of data sharing among firms due to the reduced transaction costs in communication and coordination enabled by cloud computing.

Considering cloud computing and cloud-based strategic alliances as novel outsourcing methods, Lacity et al. (2010) indicate that cloud computing may have the potential to reduce transaction costs and uncertainty as well as to enable firms to focus on developing their core capabilities and strategic resources, to access to skills and expertise from external sources, and to optimize internal business processes, so that it can facilitate various outsourcings including alliance-based outsourcing, by reviewing the prior IT outsourcing empirical literature. Mladenow et al. (2012) find cloud computing can create values for small and medium-sized enterprises (SMEs) and startups in the textile and apparel industry through collaboration in the business-to-business (B2B) market. For example, from the TCE perspective, cloud computing can increase the speed of transaction processing and decrease the transaction costs for strategic alliances in the supply chain network because of its utility-like billing mode, agility in deployment, and instant scalability in IT capacity. From the RBV perspective, cloud computing can facilitate information transparency, transfer and sharing to decrease the information asymmetries between collaboration partners due to its standardized interfaces and common language usage such as XML for communication. From the social network perspective, cloud computing can foster the formation of social communities within which the participating actors can improve their understandings to each other and establish long-term relationships and trust through repeated transactions. From the competency theory perspective, cloud computing can create novel business models and opportunities so that firms can seek new ways to form strategic alliances to better utilize their capabilities of flexibility, agility and creativity in the textile and apparel industry. Based upon the theories of transaction cost economics and social networks, Petrescu (2012) analyzes the effect of cloud computing on B2B networks. The author concludes that cloud computing can reduce transaction costs, asset specificity and opportunism because of its characteristics of low cost, ubiquitous accessibility, interface standardization and flexibility, so that it allows firms to communicate and coordinate with each other more efficiently, which fosters inter-organizational collaboration in B2B networks. Rosenthal et al. (2010) point out that biomedical research is getting more and more data-centric so that collaboration between different disciplines and laboratories are inevitable for biomedical innovation. The authors suggest that cloud computing can help collaboration in biomedical research because it can reduce the transaction costs associated with the connection and integration work as well as increase the agility and flexibility of resource and data sharing. DNAnexus (BusinessWire 2016), is a cloud platform vendor that focuses on genome informatics and data management. The cloud-based DNAnexus platform provides the leading global network of genomics and scientific computing for various relevant parties such as pharmaceutical and biotech firms to conduct fast, effective research and collaborations to solve genomic challenges. Bharadwaj et al. (2013) argue that the pervasive use of cloud computing in industries can be one of the important drivers of a firm's scale of digital business strategy to be realized via alliances and partnerships by sharing strategic digital assets or resources with alliance partners. There is a trend of that firms tend to be more modularized in their business processes and focus more on their core competencies and capabilities in digital settings, and reply more on plug-and-play capabilities to access needed resources from their collaborative partners.

Based on the previous literature and evidence of that cloud computing as a whole can directly facilitate strategic alliances through multiple mechanisms such as transaction cost reduction to encourage more market-end transactions on the market-hierarchy continuum, strategic resource creation and exchange, relational trust establishment in social networks, and strategic capability and competency enhancement, we postulate that cloud computing may primarily facilitate non-equity alliance formation rather than joint-venture alliance formation. The relevant hypothesis is as follows:

Hypothesis 1 (H1). Cloud computing as a whole is positively associated with formation of non-equity alliances rather than joint ventures.

4.2.3 Specific cloud services and strategic alliances

Mell and Grance (2010) summarize three basic cloud service models: Infrastructure as a service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). On top of them, there are extended service models such as Knowledge as a Service (KaaS) and Business Process as a

Service (BPaaS). KaaS is about treating knowledge as services and it can cover all three basic layers of IaaS, PaaS and SaaS. BPaaS is about taking business processes as services and it is typically regarded as an extension of SaaS. We would like to examine the direct effects of each of them on strategic alliances as well as the complementary effect of BPaaS and firms' internal ERP systems since BPaaS is most likely to interact with ERP systems in terms of processes comparing to other specific cloud services.

4.2.3.1 Direct effects of IaaS on strategic alliances

Infrastructure-as-a-Service (IaaS), as the lowest layer in the three essential cloud service models by Mell and Grance (2010), is the capability to provide virtualized hardware resources as services such as processing, storage and network bandwidth on a pay-as-you-go basis. Amazon Elastic Compute Cloud (Amazon EC2) and Rackspace Cloud Servers are two well-known examples of IaaS.

The model of IaaS virtualizes raw computing hardware resources into scalable, flexible and shareable services that support multiple tenant usage. Based on the capabilities of IaaS, Abd-Elrahman and Afifi (2011) propose an IaaS-based collaborative model that facilitates the convergence and collaboration of heterogeneous content providers and improves the mobility and security issues for content consumers. Comparing to other layers of cloud services, IaaS is the most basic and homogeneous service. From the point of view of a cloud user, different cloud providers offer almost identical IaaS services to them – the services are all about basic virtualized hardware such as computing capacity, storage and network bandwidth, etc. Nevertheless, because of its raw IT resource nature, IaaS can be used by firms to develop various resources and capabilities that are valuable to different types of alliance formations. For example, IaaS can make IT resources cost-effective and flexible so that firms can reduce transaction costs in arm's-length alliances. Firms can also build IT platforms, infrastructures, processes and applications based on IaaS so that IaaS can facilitate collaborative alliances as well. IaaS can enable firms with the capability to refocus on their core competitiveness to create and possess more valuables strategic resources that are attractive to other firms so that they have more chances to form arm's-length or collaborative alliances. IaaS can even be taken as compatible, common assets between the alliance firms based on which joint ventures can be established. Overall, IaaS may facilitate the total number of alliances a firm makes in a year regardless of the alliance types. Therefore, we can postulate that IaaS can facilitate all different types of strategic alliances as well as the total number of alliances and the relevant hypotheses are as follows:

Hypothesis 2A (H2A). Infrastructure as a Service (IaaS) is positively associated with the total number of strategic alliances a firm makes in a year.

Hypothesis 2B (H2B). Infrastructure as a Service (IaaS) is positively associated with formation of joint ventures.

Hypothesis 2C (H2C). Infrastructure as a Service (IaaS) is positively associated with formation of non-equity alliances.

Hypothesis 2D (H2D). Infrastructure as a Service (IaaS) is positively associated with formation of collaborative alliances.

Hypothesis 2E (H2E). Infrastructure as a Service (IaaS) is positively associated with formation of arm's-length alliances.

4.2.3.2 Direct effects of PaaS on strategic alliances

Platform as a Service (PaaS), as the middle layer in the three basic models by Mell and Grance (2010), is the capability to provide appropriate platforms and tools based on which cloud users can develop and deploy their own or acquired applications in the cloud. Two popular examples of PaaS are Microsoft Azure and Force.com from Salesforce. PaaS can provide cloud users with a variety of IT platforms that suit the needs of their application development and deployment as well as with the benefit of transaction cost reduction in terms of platform interoperability, security, scalability, flexibility and agility. When studying the feasibility of a proposed e-marketplace prototype for the SMEs to conduct trustworthy collaboration in the local food industry, Petrakou et al. (2011) find that PaaS can be used to promote a flexible infrastructure within which governance rules and mutual trust can be more easily established because it can reduce transaction costs associated with the collaborative activities. Zhao and Shen (2010) propose a PaaS-based common platform called Supply Chain Platform as a Service (SCPaaS) for firms to conduct strategic alliances through customized supply chain formation in a dynamic and automatic way. SCPaaS provides a common platform where various supply chain services can be created, published, discovered, shared and maintained by different service providers conveniently. Similar to IaaS, as PaaS is relatively general-purpose IT resources and focuses on the platform-providing aspects for firms to develop further applications on top of them, it may increase the total number of alliances. As to joint ventures, they usually require each alliance partner to contribute bilateral investments in capital, technology, etc. (Gulati and Singh 1998), the alliance partners may want to avoid incompatible technology investments developed on different PaaS platforms. Considering this factor, it may be reasonable to hypothesize that PaaS may be not so helpful in formation of joint ventures, but of non-equity alliances. As a result, we propose that PaaS may positively contribute to the total number of alliances and formation of non-equity alliances. The corresponding hypotheses are as follows:

Hypothesis 3A (H3A). Platform as a Service (PaaS) is positively associated with the total number of strategic alliances a firm makes in a year.

Hypothesis 3B (H3B). Platform as a Service (PaaS) is positively associated with formation of non-equity alliances.

4.2.3.3 Direct effects of SaaS on strategic alliances

Software as a Service (SaaS), as the top layer in the three basic models by Mell and Grance (2010), is the capability to provide ready-to-use cloud-based applications to cloud end users. Two famous examples of SaaS are Netsuite and Salesforce CRM. SaaS is typically managed by a SaaS provider and shared with many SaaS tenants. The SaaS tenants do not need to do any maintenance and support for the SaaS application. The SaaS provider is responsible for all updates and upgrades. The SaaS provider also takes care of IT resource availability and scalability for the SaaS tenants to meet their needs for customer base growth. A SaaS vendor may also provide application programming interfaces (APIs) to its SaaS application so that the cloud tenants can use the APIs to integrate the SaaS application with their internal systems and their alliance partners' systems. Comparing to IaaS and PaaS, SaaS is inherently more heterogeneous and packaged as end products since different SaaS providers usually provide distinct, ready-to-use applications and functions to their customers in order to compete with their competitors. Facca et al. (2009) vision that the service-based dynamics and competition in the future market will make firms tend to form more alliances with others and propose a SaaS-based platform called the COIN generic service platform to facilitate such collaboration and interoperability via services. Denno (2011) points out that SaaS can provide a consistent, process-oriented approach for inter-firm collaboration in a trade collaboration system (TCS). The author highlights two advantages of SaaS that are particularly relevant to the context of TCS: no need to install and upgrade the application by the SaaS application users, and the ability to provide interoperability via standardized interfaces. Using empirical data from SaaS providers, Susarla et al. (2010) suggest that standardized interfaces in SaaS can facilitate SaaS vendors and users to adopt arm's-length alliances as well as verifiable, detailed and specific contracts or service level agreements (SLAs) to coordinate and collaborate on complex business analytic tasks characterized by knowledge interdependencies across SaaS vendors and users. Compared to arm's-length alliances, collaborative alliances require significantly a more substantial knowledge sharing (both explicit and tacit) or inter-firm resource integration and recombination (Tafti et al. 2013) amongst the alliance partners. SaaS, at the current status of providing somehow standardized services to the users, is hard to meet the requirements of collaborative alliances in general. Instead, SaaS can reduce the transaction costs of providing, selling or exchanging a service or product and push the governance structure choice toward the market end of the market-hierarchy continuum to facilitate arm's-length alliance formation. Similarly, as joint ventures usually require alliance partners to allocate firm-specific assets and conduct collaborative activities to create a new business entity, SaaS is unlikely to help joint venture formation. As a result, the relevant hypotheses are as follows:

Hypothesis 4A (H4A). Software as a Service (SaaS) is negatively associated with formation of joint ventures.

Hypothesis 4B (H4B). Software as a Service (SaaS) is positively associated with formation of arm's-length alliances.

4.2.3.4 Direct effects of KaaS on strategic alliances

Knowledge as a Service (KaaS) is the paradigm that treats information and knowledge as services that can be consumed and applied to other services to conduct information/knowledge-intensive tasks. KaaS can spread across all the three basic layers of IaaS, PaaS and SaaS. With the advent of the era of big data, information and knowledge have become pivotal for companies to thrive in the new business environment that emphasizes customer orientation and swift business opportunities. KaaS is created to serve such purposes. Contractor and Lorange (2002) notice that customization, flexibility, agility, and value chain disintegration have been highly appreciated with the advent of the knowledge-based economy in the twentieth century. This trend motivates formation of strategic alliances as different firms collaborate with each other to obtain necessary resources and knowledge to thrive in a dynamic, competitive business environment that emphasizes information and knowledge. Inter-organizational cooperation has become unprecedentedly important. The transactional risks and costs of knowledge transfer across different firms have been alleviated by both the enhancement of intellectual property protection on a global scale and the improvement of knowledge articulation and codification enabled by information technology. Makino and Delios (1996) empirically investigate the relationship between local knowledge and international alliances and find that to access local knowledge is one of the major motives for a foreign firm to partner with local firms in the host country. Simonin (1999) recognizes knowledge as the most important resource of the modern firm and strategic alliances are often used by firms to acquire knowledge from their partners to internalize and develop their own new competencies. Parise and Henderson (2001) emphasize the value and importance of inter-firm strategic alliances for the acquisition and absorption of various knowledge resources such as tacit knowledge, firm-specific knowledge and complex knowledge in dynamic markets. Reid et al. (2001) find that knowledge-intensive companies tend to increase their strategic alliances with other companies due to higher competition and customer needs as well as regulatory barrier relaxation. From the reviewed literature, the authors find that the foremost motivation for strategic alliance formation among knowledge-intensive companies is to gain access to and acquire new knowledge resources from their partners, and the secondary motivation is to generate knowledge. They also argue that those companies with very valuable knowledge assets will be the main targets as alliance partners. Parise and Sasson (2002) emphasize the pivotal role of information and knowledge during three major stages of alliance formation (i.e., the phases of find, design and manage) in ensuring a successful and fruitful alliance. Each phase requires different information and knowledge to successfully guide the correct decisions toward the final success of a strategic alliance. Based on knowledge-based view of the firm, Grant and Baden‐Fuller (2004) propose a knowledge-accessing theory to argue that the main purpose and advantage for a firm to form strategic alliances are to access and apply its partners' knowledge that can be shared and complemented with its own knowledge to create value for its businesses, rather than to acquire, learn and absorb knowledge from its partners to increase the firm's internal stock of knowledge. Using the proposed theory, the authors show that strategic alliances can improve the efficiency of integrating knowledge into complex goods and services production as well as of knowledge utilization. The efficiency effects are further augmented where knowledge requirements in the future are unknown and where innovative products with early-mover advantages are created. Knudsen (2007) concurs that firms make inter-firm alliances in new product development (NPD) to access new knowledge and opportunities as well as to share risk and cost of potential misappropriation of knowledge.

Konsynski and McFarlan (1990) point out that sharing data is one major motive for a firm to make strategic alliances with other firms which can be named as information partnerships. Based on social network analysis, Sammarra and Biggiero (2008) find the importance of three types of knowledge, namely technological, market and managerial knowledge, on formation of strategic alliances and networks for innovation. Steensma (1996) emphasizes a firm's organizational learning from other firms via strategic alliances to acquire and improve its technical competencies.

KaaS is a novel technology to help articulate and codify information and knowledge to address the need for its rapid, flexible and cost-effective transfer among different firms. As knowledge is codified and measured as cloud-based services with standardized interfaces that are consumed by firm users, the risks and costs of transactional hazards and undertakings in alliances are mitigated significantly. In other words, with much of the needed information and knowledge provided by KaaS, firms are less willing to form alliances (especially those that involve heavy knowledge sharing) in order to acquire the needed knowledge from the alliance partners. Therefore, we would like to propose that KaaS are likely to reduce joint ventures, collaborative alliances as well as the total number of alliances, and the relevant hypotheses are as follows:

Hypothesis 5A (H5A). Knowledge as a Service (KaaS) is negatively associated with the total number of strategic alliances a firm makes in a year.

Hypothesis 5B (H5B). Knowledge as a Service (KaaS) is negatively associated with formation of joint ventures.

Hypothesis 5C (H5C). Knowledge as a Service (KaaS) is negatively associated with formation of collaborative alliances.

4.2.3.5 Direct effects of BPaaS on strategic alliances

Business Process as a Service (BPaaS) is an extension of SaaS and provides novel, cloud-based business process services for firms to flexibly adapt, share and integrate their business processes to conduct better collaborations and alliances. It turns business processes into portable, combinable, and configurable services that can be shared and used by different firms. This approach simplifies the transactions between firms from the transaction cost perspective and also provides valuable business process resources to firms from the resource-based perspective. Becker et al. (2012) point out that business process management (BPM) is essential for firms to have successful alliances with their partners because they normally need to deal with quite complicated business process adaptation, coordination and combination during formation of strategic alliances nowadays. Montarnal et al. (2014) claim that BPaaS can support the coordination of inter-firm alliances as a scalable, flexible and agile solution that promotes process sharing, interoperability and collaboration between firms. Since collaborative alliances usually involve more business process undertakings and emphasize recombination or coupling of business and other processes across alliance partners (Tafti et al. 2013), BPaaS may facilitate formation of collaborative alliances. BPaaS may also benefit non-equity alliances because it can facilitate process connection and integration between firms without having to form new joint business entities. Since business process is the original source of firm capabilities (Bharadwaj 2000) and constitutes the functions of the firm, it may present an overall positive effect on alliance formation. Therefore, the hypotheses are as follows:

Hypothesis 6A (H6A). Business Process as a Service (BPaaS) is positively associated with the total number of strategic alliances a firm makes in a year.

Hypothesis 6B (H6B). Business process as a Service (BPaaS) is positively associated with formation of non-equity alliances.

Hypothesis 6C (H6C). Business process as a Service (BPaaS) is positively associated with formation of collaborative alliances.

4.2.3.6 Complementary effects of BPaaS and ERP systems on strategic alliances

Enterprise systems usually are companywide applications that touch many aspects and business functions in a firm, therefore they can be taken as a major part of IT infrastructure and pivotal to a firm's business success. Enterprise resource planning (ERP) application systems encompass a wide range of software products supporting day-to-day business operations and decision-making using common databases maintained by a database management system (Hitt et al. 2002). However, implementation of traditional on-premise ERP systems requires a substantial investment of time, money, and internal resources and is fraught with technical and business risks. ERP implementations are also known to be unusually difficult partially due to the pervasiveness of the changes associated with ERP including process redesign of multiple functional areas and the need to adapt processes to the capabilities of the software. There is also a high degree of managerial complexity of these projects. BPaaS can mitigate those difficulties when implementing and adapting ERP systems to be suitable for a specific firm's need. Since BPaaS and ERP systems are very similar in terms of processes, there may be a positive, complementary effect between them in strategic alliance formation. BPaaS reduces the transaction costs in the alliances involving ERP system connection and integration and makes these alliances more arm's-length. The complementary effect may be also present for all kinds of alliances since business processes are prevalent and pivotal to firms. Therefore, the relevant hypotheses are as follows:

Hypothesis 7A (H7A). Business Process as a Service (BPaaS) has a positive moderating influence in the effect of enterprise resource planning (ERP) systems as a whole on the total number of strategic alliances a firm makes in a year.

Hypothesis 7B (H7B). Business Process as a Service (BPaaS) has a positive moderating influence in the effect of enterprise resource planning (ERP) systems as a whole on formation of arm's-length alliances.

4.3 Empirical Methods

4.3.1 Data

The data for this study come from several sources. First, we adopt the data on usages of various cloud services, service-oriented architecture (SOA), and enterprise systems reported in the Quarter 4 (September-November) 2009 Software Survey from Forrester Research Inc.[30] which is a company that conducts independent technology and market research to provide consulting services about technology to the clients and the public. The online survey conducted by Forrester is very comprehensive and records the answers from the respondents identified as persons who had the appropriate knowledge, experience and authority to answer the survey questions about software adoption facts and trends in 2,165 companies ranging from very small businesses to global enterprises in North America (US and Canada) and Europe (UK, Germany and France). Second, we utilize the data for all types of strategic alliances (arm's-length, collaborative, non-equity, and joint-venture) from the SDC Platinum database from 2009 to 2012 as the basis for construction of a panel data set. As cloud computing measures in Forrester Q4 2009 Software

[30] Named as Forrester Q4 2009 Software Survey thereafter

Survey were provided in only one year, we treat them as not being changed much in the period of 2009 to 2012, a short time window of four years. As to the time of 2009 and around, cloud computing, as a novel technology and application, was still not very pervasive in enterprises, especially in those large companies. Many companies were still in the stage of trials in using cloud computing. A panel from 2009 to 2012 is short enough to assume that the adoption of cloud computing does not change much during this period, and it is long enough to correct for potential unobserved heterogeneity and endogeneity by panel analysis. The SDC Platinum database is considered to be a reliable source of data on alliances and has been utilized in many previous studies (Schilling 2009). The database provides very useful information for strategic alliances such as alliance dates, participants' ticker symbols, participants' names, business descriptions, Standard Industrial Classification codes, alliance deal name, alliance status, alliance deal text (detailed alliance description), alliance activity description, a joint venture flag that indicates whether the alliance is a joint venture or not, and so on. Schilling (2009) and Tafti et al. (2013) showed that the SDC Platinum database is a reliable representative of the population of various alliances. Third, we use the Compustat North America database, which is managed by the Wharton Research Data Services (WRDS) and provides comprehensive financial and market information on many publicly held companies from the past 20 years. The annual fundamentals dataset from 2009 to 2012 is used in this study for the industry and firm control variables and is merged with the other two data sources together to form the final panel data from 2009 to 2012. The details of each measure used in the panel logistic and count models can be found in Table C.2 in Appendix C. The details of each measure used in the propensity score matching (PSM) models can be found in Table C.3.

The final panel data sample contains 126 firms on average per year during the period of 2009-2012. The final sample is used for the panel logistic and count models as well as the PSM models[31]. The panel data contain small and medium-sized enterprises (SMEs) and large firms. Chow tests were conducted after the logistic and count regressions and showed no statistical significance, which means the records of the SMEs and large firms can be combined together in the analysis. The final data sample is reasonably representative in the distribution of firms across all different industries and has a relatively similar pattern comparing to the entire original Forrester Q4 2009 Software Survey dataset (See Figure 4.1).

4.3.2 Variables

4.3.2.1 Dependent variables – alliance types and alliance counts

The variables regarding arm's-length, collaborative, non-equity, joint-venture alliances, and the total number of different alliances a firm makes in a year serve as the dependent variables for all the models used in this study including the panel logistic and count models as well as the propensity score matching (PSM) models.

For the panel logistic models, the dependent variables are binary variables indicating certain alliance types: collaborative or arm's-length, and joint-venture or non-equity[32]. As Tafti et al. (2013) argue that a joint venture can be either arm's-length or collaborative even though it is more likely to be collaborative, the two sets of alliance types can be viewed as two different facets of the same alliance. To determine whether an alliance is collaborative or arm's-length, we followed the classification methods given by Tafti et al. (2013) and perused the alliance deal text

[31] The panel data from 2009 to 2012 are used as a pooled data set regardless of the years for the PSM models.
[32] See Table C.2 for details of the two binary alliance-type constructs.

that describes the alliance in details for every record to make sure each of them was correctly classified. It was much easier to determine an alliance is joint-venture or non-equity since there was a Joint Venture Flag column in the SDC database indicating whether the alliance is a joint venture with "Yes" or not with "No". However, through the manual classification process, we found that there was a very small portion of records that had a discrepancy between their Joint Venture Flag values and their alliance deal texts. That is, although the Joint Venture Flag had a value of "No", the corresponding alliance deal text clearly stated that it was a joint venture. In this case, we manually corrected the alliance type from non-equity to joint-venture.

For the panel count models (i.e., panel Poisson and negative binomial models), the dependent variables are positive integers[33] indicating the numbers of total alliances or certain types of alliances a firm has made during a specific year between 2009 and 2012. The construct of total number of various types of alliances was created to count the total number of different alliances a firm made in a particular year no matter whether they belonged to arm's-length/collaborative, or non-equity/joint-venture. Other count constructs were also created to count the numbers of joint ventures, non-equity alliances, collaborative alliances and arm's-length alliances for a specific firm in a specific year.

4.3.2.2 Independent variables – cloud computing

The independent variables about cloud computing and its specific service models can be derived from the Forrester Q4 2009 Software Survey dataset. The independent variables of specific cloud service models can be derived directly from the corresponding survey questions by giving different points to different answers according to their relevance and importance to the research

[33] See Table C.2 for details of the alliance-count constructs.

variables [34]. To avoid distorted influence by a particular variable, all the values of the independent variables are normalized. The composite variable, cloud computing as a whole, is calculated by summing the normalized values of all the specific cloud services and then normalizing the resulting value of summation.

4.3.2.3 Control variables

Multiple firm-level and industry-level control variables that can potentially affect alliance formation are included in the panel models as well as in the PSM models[35]. In selecting controls, we considered the specific needs in our study and largely followed the criteria used by Tafti et al. (2013) when they investigated IT flexibility and strategic alliance formation.

4.3.2.3.1 Industry-level controls

The industry structure may have an influence on the performance of firms in the industry (Bharadwaj et al. 1999). There are three industry-level controls in our panel models [36] - Herfindahl–Hirschman Index (HHI), weighted industry average Tobin's q, and industry regulation[37]. The Herfindahl-Hirschman Index (HHI) is used to measure industry concentration which is a proxy for industry competitiveness. The index may influence different alliances differently. Industry regulation[38] can impact a firm's alliance formation, making certain alliances easier, others harder. Weighted industry average Tobin's q may capture the additional

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[34] See Table C.2 for details of how different points are given to each answer option in the survey question and how the variable is constructed according to the question.
[35] The control variables used in the panel models and the PSM models can be found in Table C.2 and C.3 respectively
[36] Including panel logistic, Poisson and negative binomial models.
[37] Weighted industry capital intensity was also included in the panel regressions, but we eventually dropped it as it was not statistically significant in the regressions.
[38] An industry is regarded as regulated if it is in airlines, banking, pharmaceuticals, or utilities. The details of this construct can be found in Table C.2.

idiosyncratic industry characteristics that can influence alliance formation but have not been adequately explained by the other industry controls.

4.3.2.3.2 Firm-level controls

There are six firm-level controls used in the panel models – SOA, ERP systems as a whole, number of employees in the firm, advertising intensity, a set of three dummy industry controls, and a set of three year dummy variables[39].

The most important one is service-oriented architecture (SOA). SOA is a software architecture that provides software application functionality as distinct services which can be used and combined to serve different business functions or processes (Erl 2005). Sanchez and Mahoney (1996) suggest that a modular product design that allows product components to have standardized interfaces reduces asset specificity and provides embedded coordination that decreases search, monitoring, and enforcement costs for product development processes. Such modular product architectures, with the embedded information structures, can facilitate organization design modularization and increase the flexibility of firms to react to environmental change. With the modularized product and organization designs, loosely coupled learning processes can be employed to manage knowledge that is created and exchanged in product development processes. Adopting the modularized approach for product and organization designs also make firms more focus on developing specialized knowledge about the strategic modules or resources that are critical for their businesses, therefore firms may develop fewer

[39] Firm-level controls of R&D intensity and market share of the firm were dropped from the models because R&D intensity was highly correlated to advertising intensity and market share was highly correlated to the Herfindahl-Hirschman Index. Capital intensity was also dropped because it was statistically insignificant and redundant considering the final data sample had only 126 firms on average per year.

components internally and choose to obtain more components from external suppliers through loosely coupled strategic alliances. Modular architectures with standardized interfaces can promote flexibility of inter-firm connectivity and collaboration. Schilling (2000) proposes a theoretical framework of general modular systems which contains a variety of factors that can affect the magnitude of system modularity including synergistic specificity, heterogeneity of inputs and demands, and urgency. Subsequently, the framework is applied to guide the empirical study of the industrial differences in modular organizational form usage including strategic alliances (Schilling and Steensma 2001). It is found that the environmental factors such as rapid technological change can positively moderate the association of heterogeneous inputs and demands with firms' tendency to adopt the strategy of specialization and modularity thanks to learning curve advantages because by focusing on some specified product or service modules, firms are able to progress faster by deploying their efforts along a concentrated learning curve rather than over scattered learning curves (Schilling and Steensma 2001). As a result, the firms become more specialized and competent in some particular aspects of a value network, and more likely to use loose coupling such as strategic alliances to obtain other necessary resources (Schilling and Steensma 2001). Tafti et al. (2013) empirically investigate the effect of IT architecture flexibility on alliance formation and its derived market value. IT architecture flexibility is represented using three different dimensions: open communication standards, cross-functional transparency, and IT modularity. The authors find that IT modularity is positively associated with formation of equity-based joint ventures because joint ventures typically require significant reconfiguration of business processes and IT modularity can reduce the cost of such reconfiguration from the transaction cost perspective. IT architecture modularity can promote organizational modularity which in turn can facilitate joint venture creation (Tafti et al. 2013). In their empirical tests, IT modularity is operationalized as a service-based architecture, typically the usage of service-oriented architecture (SOA). SOA can facilitate resource exchange and sharing as well as collaboration by enabling direct communication. This mechanism enables decentralized decision making which reduces decision risks and increases flexible, effective collaboration (Jammes and Smit 2005). Jung (2011) conceptually proposes an SOA-based service network model that identify and describe the relationships of services in a network similar to the ones in a social network. The author suggests that the service network model can facilitate business alliance formation because social network analysis can be applied to the model for firms to identify the appropriate alliance partners according to their service characteristics and relationships in the network. Xiang (2007) proposes that SOA can help address the challenges and problems extant in the current inter-firm cooperation system that lacks flexibility and standardization by transforming the inter-form cooperation business models into SOA components. Utilizing the characteristics of SOA such as modularity and standardized interfaces, the author believes that the SOA-based system makes firms much easier and more flexible to collaborate.

A couple of articles specifically study the effect of the service-oriented approach on inter-firm collaboration in the manufacturing industries. The manufacturing industries are typical ones in which inter-firm collaboration prevails such as the automobile industry, the apparel industry and the original equipment manufacturing (OEM) industry. The emergence of service-oriented manufacturing (SOM) is a result of increased interaction between manufacturing and services in the past decades (Huang et al. 2011). The paradigm of SOM emphasizes the importance of the derived services related to production and their relationships and interactions in a service-oriented manufacturing network (SOMN). This type of service-oriented supply chain is typically suitable to be implemented in the service-oriented architecture (Jung 2011) because their common ground is to regard entities and activities as services. Shen et al. (2007) present a service-oriented system architecture that can support manufacturing enterprises to conduct dynamic and automatic services collaboration. They point out that this architecture can be easily extended to other e-commerce applications. As SOA presents the features of promoting collaboration and alliance, it is necessary to control it in the models.

The overall representation of various ERP systems used in a firm is an important firm-level control variable measured by the first component of the principal component analysis (PCA) result for all the component ERP systems[40]. Each component specialized ERP system such as CRM and SCM is measured by points given to indicate the different levels of usage[41]. The natural logarithm of the number of employees in the firm is used as the proxy for firm size. Advertising intensity is controlled to account for its effects on strategic alliance formation. A set of three dummy industry controls is used to indicate which industry the firm is in – manufacturing, retail and wholesale, or various services[42]. Three year dummies are also included in the models.

4.3.2.4 Other variables used in the PSM models

[40] The unrotated PCA result shows that all component ERP systems load positively onto the first principal component, with weightings between 0.24 and 0.33.

[41] The details of how the individual specialized ERP system measures are constructed can be found in Table C.4 in Appendix C.

[42] The three industry dummies are simplified from the seven industries given in Forrester Q4 2009 Software Survey which offers similar industry categorizations as in the Compustat NAICS codes.

The propensity score matching (PSM) models are used as a robustness check as well as a supplement for the panel logistic and count models for a stronger causal inference. Propensity score matching (PSM) is a matching technique used for observational data that estimates the treatment effect on a dependent variable (i.e., outcome variable) by controlling other variables (i.e., covariates) that are correlated to the treatment (Dehejia and Wahba 2002).

In the PSM models in this study, the dependent variables are as the same as in the panel models. Similar industry and firm level control variables are also used. Specifically for the PSM models, a set of treatment dummy variables about cloud computing and its specific services are used. The treatment variables are dummies to indicate whether a firm has used any cloud computing or specific cloud services.

Table 4.1 displays the construct correlations and descriptive statistics for the final sample of Year 2009 (132 firms) used in our study.

4.3.3 Estimation Models

For the panel data of 2009-2012, we used the random-effects logistic and count (Poisson and negative binomial) models to examine the same hypotheses from different angles[43]. We also used the propensity score matching models to reexamine the results of the panel models as well as to supplement any missing findings.

4.3.3.1 Panel logistic model for specific cloud services and strategic alliances

[43] Hausman tests are done with statistically insignificant results to ensure that the random-effects models are efficient comparing to the corresponding fixed-effects models.

We used the following panel logistic model to examine the effects of specific cloud services on formation of two types of strategic alliances (i.e., joint-venture type and collaborative type).

Panel logistic model:

$$Ln(Pr(Alliance\ type = 1) / 1 - Pr(Alliance\ type = 1))_{i,t} = \beta_0 + \beta_1 IaaS_i + \beta_2 PaaS_i + \beta_3 SaaS_i + \beta_4 KaaS_i + \beta_5 BPaaS_i + \beta_6 SOA_i + \beta_7 ERPsys_i + \beta_8 BPaaS_i \times ERPsys_i + \boldsymbol{\beta_{c,t} X_{c,t}} + \Sigma_t \beta_t year_t + \Sigma_i \beta_i Ind_i + u_i + \varepsilon_{i,t} \quad (1)$$

Note: Alliance type in the model can be joint-venture (binary) and collaborative (binary).

4.3.3.2 Panel count (Poisson and negative binomial) models for specific cloud services and strategic alliances

We used the following panel count models to examine the effects of specific cloud services on five different numbers of strategic alliances (i.e., total number of alliance regardless of type, number of joint venture, number of non-equity alliance, number of collaborative alliance, and number of arm's-length alliance).

Panel Poisson model:

$$Ln(Number\ of\ alliance)_{i,t} = \beta_0 + \beta_1 IaaS_i + \beta_2 PaaS_i + \beta_3 SaaS_i + \beta_4 KaaS_i + \beta_5 BPaaS_i + \beta_6 SOA_i + \beta_7 ERPsys_i + \beta_8 BPaaS_i \times ERPsys_i + \boldsymbol{\beta_{c,t} X_{c,t}} + \Sigma_t \beta_t year_t + \Sigma_i \beta_i Ind_i + u_i + \varepsilon_{i,t} \quad (2.1)$$

Panel negative binomial model:

$$Var(Number\ of\ alliance)_{i,t} = exp(\beta_0 + \beta_1 IaaS_i + \beta_2 PaaS_i + \beta_3 SaaS_i + \beta_4 KaaS_i + \beta_5 BPaaS_i + \beta_6 SOA_i + \beta_7 ERPsys_i + \beta_8 BPaaS_i \times ERPsys_i + \boldsymbol{\beta_{c,t} X_{c,t}} + \Sigma_t \beta_t year_t + \Sigma_i \beta_i Ind_i + u_i + \varepsilon_{i,t}) \quad (2.2)$$

Note: Number of alliance in the models can be total number of alliance regardless of type, number of joint venture, number of non-equity alliance, number of collaborative alliance, and number of arm's-length alliance.

The terms of $\boldsymbol{X_{c,t}}$ in the above three models (Model 1, Model 2.1 and Model 2.2) consist of all the control variables in Table C.2 except SOA, ERP systems, year dummies and industry dummies which are explicitly listed in the above models. The panel random-effects models are employed to account for persistent individual unobserved effects.

4.3.3.3 Propensity score matching (PSM) models for cloud computing and strategic alliances

We used the following PSM models to double check the effects of cloud computing as a whole and specific cloud services on strategic alliance formation and to infer stronger causal relationships from cloud computing to alliance formation. The PSM models take the final sample data of 2009-2012 as a pooled cross-sectional data.

Probit model to generate propensity scores for cloud computing as a whole:

$$Pr(AnyCloud = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \quad (3)$$

Note: Alliance type in Model 3 can be joint venture (binary) and collaborative (binary).

Probit models to generate propensity scores for specific cloud services:

$$Pr(AnyIaaS = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \quad (4)$$

$$Pr(AnyPaaS = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \quad (5)$$

$$Pr(AnySaaS = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \quad (6)$$

$$Pr(AnyKaaS = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \quad (7)$$

$$Pr(AnyBPaaS = 1) = \Phi(\beta_1 SOA + \boldsymbol{\beta_d X_d} + \Sigma\beta_i Ind_i + \varepsilon) \quad (8)$$

Note: Number of alliance in Model 4-8 can be total number of alliance regardless of type, number of joint venture, number of non-equity alliance, number of collaborative alliance, and number of arm's-length alliance.

The terms of Φ are the cumulative distribution function (CDF) of the standard normal distribution. The terms of $\boldsymbol{X_d}$ in Model 3-8 consist of appropriate control variables in Table C.3 except SOA and those industry dummies which are explicitly listed in the above models. Using the dummy treatment variables of cloud computing, the PSM models are capable of qualitatively determining the causal treatment effect of whether a firm uses any cloud computing can directly promote strategic alliance formation. A probit (or logit) model as shown in Model 3-8 to generate propensity scores (i.e., the probability of making the treatment variable equal one) is one pivotal step to estimate the treatment effect in a PSM model (Dehejia and Wahba 2002). Inspired by Mithas and Krishnan (2009) and tailored to our study, we conducted our PSM analysis in the following steps. First, we identified the treatment variables of cloud computing, the outcome variables of strategic alliance formation, and other covariates such as the SOA control variables and the other industry and firm controls as mentioned previously. Second, we defined the causal effect we are interested in, that is, we estimated the average treatment effect on the treated since we are interested in studying the causal effect of cloud computing adoption on strategic alliance formation for those firms that actually adopted cloud computing. Third, we made the strong ignorability assumption to solve the essential problem of causal inference. Fourth, we selected an estimation algorithm used in the analysis. There are multiple PSM algorithms available to choose from, namely nearest neighbor (NN), radius, stratification and kernel (Caliendo and Kopeinig 2008). Each algorithm has its characteristics. The algorithms will generate very similar results if there is a large overlap in the distribution of the propensity score between the control and treatment groups (Dehejia and Wahba 2002). We chose to only show the nearest neighbor (NN) result in the study even though we tried all the algorithms and they all generated similar results. The nearest neighbor (NN) algorithm selects a certain amount of control units whose propensity scores are closest to the compared treated unit (Dehejia and Wahba 2002). Fifth, we estimated the propensity scores and common supports for the treatment variables using the probit models described previously. Sixth, we balanced the propensity scores between the treatment and control groups by forming strata or blocks based on similar propensity scores. Finally, we estimated the causal treatment effects of cloud computing adoption on strategic alliance formation using the nearest neighbor (NN) algorithm.

4.4 Results

Table 4.2 presents the panel random-effects logistic regression results for the effects of specific cloud services on two different types of strategic alliance formation side by side. Table 4.3 presents the panel random-effects Poisson regression results primarily (with the panel random-effects negative binomial regression results omitted) since we found that the corresponding Poisson and negative binomial results are very similar without statistically significant differences in most cases. There is only one column that shows the additional panel random-effects negative binomial regression results for collaborative alliances because there is some significant difference between the BPaaS coefficient estimates. All panel regressions are highly significant as evidenced by the Wald χ^2 statistics. Table 4.4 presents the propensity score matching (PSM) results. Since there are numerous combinations of the treatment variables and the dependent variables, we only show those significant results in the table.

By consolidating all the available results from the three tables, we can get a comprehensive image about how cloud computing can affect strategic alliance formation.

We found that Hypothesis 1, which predicts cloud computing as a whole is positively associated with formation of non-equity alliances rather than joint ventures, is supported by the PSM result ($p < 0.01$) though we could not find any supportive evidence from the panel regressions. Collectively, we could conclude that Hypothesis 1 is weakly supported. This reflects the argument that cloud computing can generally push inter-organizational transactions toward the market end of the hierarchy-market continuum, but at the same time indicates that cloud computing has many different specific service models, so the overall cloud effect on alliance formation can be mixed.

Hypothesis 2A, which claims that IaaS is positively associated with the total number of strategic alliances a firm makes in a year, is highly supported by the collective panel count regression and PSM results. Hypothesis 2B, which predicts that IaaS can benefit formation of joint ventures, is highly supported by the panel count results ($p< 0.01$), but not by the panel logistic and the PSM results. We found a weak support for Hypothesis 2C which proposes that IaaS is positively associated with non-equity alliance formation because it is supported by the PSM result ($p < 0.05$) but not by the panel count results. We found Hypothesis 2D, which states that IaaS is positively associated with formation of collaborative alliances, is supported by the panel count results ($p < 0.05$). For Hypothesis 2E which argues that IaaS increases formation of arm's-length alliances, it is supported by both the panel count results ($p < 0.05$) and the PSM result ($p < 0.05$). Collectively from these results, we found that IaaS is really a versatile type of cloud service because more or less evidence shows that it can benefit all different kinds of alliances as well as the total number of alliances.

Hypothesis 3A, which predicts that PaaS is positively associated with the total number of strategic alliances a firm makes in a year, is only weakly supported by the PSM result ($p < 0.1$). Similarly, we only found support for Hypothesis 3B in the PSM result ($p < 0.05$) which supposes that PaaS can benefit formation of non-equity alliances. These findings about the effects of PaaS on strategic alliances may indicate that, even though PaaS is similar to IaaS in providing raw IT resources to firms to develop their own functions and applications, it is, after all, more heterogeneous than IaaS thus causing more transaction costs in the context of alliances so it may not help certain alliance formations as IaaS is able to.

Hypothesis 4A, which claims that SaaS is negatively associated with formation of joint ventures, is only weakly supported by the panel logistic result ($p < 0.01$). This may reflect that unlike IaaS and PaaS, SaaS is more like an end product that can be consumed by cloud firm users directly so it is more about product or service exchange and more helpful for contractual collaborations such as non-equity alliances. We found broad support for Hypothesis 4B which claims that SaaS can nurture arm's-length alliances in all three types of results (i.e., the panel logistic and count results as well as the PSM result) at the significance level of 1%. SaaS is more favorable in promoting arm's-length alliances in general as it is more compatible with market-based exchanges and collaborations.

Hypothesis 5A, which claims that KaaS is negatively associated with the total number of strategic alliances, is only supported by the panel count results ($p < 0.05$). Only the PSM result ($p < 0.1$) supports Hypothesis 5B which proposes that KaaS decreases formation of joint ventures. We only found support from the panel count results ($p < 0.05$) for Hypothesis 5C which is about the negative effect of KaaS on collaborative alliance formation. These findings suggest that KaaS may be employed to decrease the use of alliances to acquire knowledge because much of it already can be obtained from KaaS.

Hypothesis 6A, which suggests that BPaaS is positively associated with the total number of strategic alliances a firm makes in a year, is only supported by the PSM result ($p < 0.1$). Hypothesis 6B, which is about BPaaS can benefit formation of non-equity alliances, is also only supported by the PSM result ($p < 0.01$). We found support from the panel negative binomial result ($p < 0.1$) as well as the PSM result ($p < 0.05$) for Hypothesis 6C which predicts that BPaaS is positively associated with collaborative alliance formation. These results show that BPaaS is most beneficial for collaborative alliances which usually involve inter-firm business process connection and integration even though it can also benefit other alliances.

We also found support for the complementary effects of BPaaS and the overall representation of various ERP systems on strategic alliance formation. Hypothesis 7A, which predicts the complementary effect of BPaaS and ERP systems on the total number of strategic alliances a firm makes in a year, is supported by the panel count results ($p < 0.05$). Hypothesis 7B, which claims that BPaaS is complementary to ERP systems on formation of arm's-length alliances, is supported by the panel count results as well ($p < 0.05$).

4.5 Conclusion and Discussion

4.5.1 Main findings and research implications

This paper may be the first of its kind to investigate the relationships between cloud computing and strategic alliances in various forms. It utilizes multiple theoretical lenses to draw the causal effect of cloud computing on strategic alliances such as transaction cost economics (TCE), resource-based review (RBV), social network theory and other related theories. Based on the theoretically supported arguments, corresponding empirical models are suggested and tested using a panel of 2009-2012 merged from Forrester Q4 2009 Software Survey, Compustat database, as well as SDC Platinum database. The empirical results shed lights on multiple aspects of the focal research question – in what mechanisms cloud computing can facilitate strategic alliance formation. First of all, the overall effect of cloud computing is to reduce various transaction costs during the formation of a strategic alliance so that it mainly facilitates those non-equity alliances rather than the joint ventures. Joint ventures typically cause much more inter-firm transaction costs than non-equity alliances because they involve the creation of entirely new business entities with more firm-specific assets (Tafti et al. 2013). Joint ventures usually tend to be more collaborative than arm's-length even though they can be either collaborative more arm's-length. Our finding of that cloud computing as a whole can promote non-equity alliances suggests that cloud computing generally pushes the governance structure in a firm from a hierarchical style toward a market style. Through its three value levels of utility, process transformation, and business-model-innovation (Dean and Saleh 2009), cloud computing also provides strategic IT resources that can enhance a firm's core business and capabilities so that the firm become more valuable to other firms in alliances. With cloud computing, firms need not form costly joint ventures, but convenient non-equity alliances to fulfill their goals to acquire and exchange necessary resources.

In addition to this overall effect of cloud computing, its specific services may exert distinct effects on various alliance formations. IaaS, the lowest layer in the basic three-tier cloud service model (Mell and Grance 2010), is the most versatile and all-rounded one that can almost promote all kinds of alliance formations (thus the total number of alliances a firm engages in a year) – be it a joint venture, a non-equity, a collaborative, or an arm's-length. This finding is counterintuitive to most of the prior understandings on IaaS which took it as very commodity-like, homogeneous raw IT resources that firms can easily acquire and utilize in the cloud computing market. IaaS per se is indeed a set of virtualized raw IT resources that are charged on a utility-like basis, but that is the view from the IaaS providers, not from the IaaS firm users. For the IaaS providers, all such providers may offer very similar IaaS services such as computing capacity, storage, databases and network bandwidth, even on the aspects of charging prices in order to compete with their rivals. This means that IaaS prices from various providers reach the market equilibrium, IaaS firm users have the price power, and IaaS services become commodity-like. Although these trends may diminish the profits of the IaaS providers, they may indeed benefit the IaaS firm users a lot. From the standpoint of the IaaS firm users, they can acquire cost-effective, good-quality IaaS resources from trusted IaaS providers and utilize the resources to optimize the benefits of IaaS. As IaaS enables firm users to effectively and efficiently develop their own IT functions and applications that suit their business needs and objectives, it can help the firms become more differentiated from their competitors, produce better quality products or services, serve their customer better, eventually fulfill their business goals and strategies. Because of the raw-material characteristics of IaaS, it can enable firms to achieve whatever they want to pursue. Firms can utilize IaaS as a common ground to build up new IT systems and business processes or merge their existing ones for the needs of new joint ventures. IaaS can certainly help firms to conduct non-equity alliances as well because it facilitates firms to create flexible resources that can be used in connection with their business partners in such alliances. IaaS helps firms develop compatible functions and processes that are ready to be connected, composed and integrated with their alliance partners in the collaborative alliances. IaaS is also capable of promoting arm's-length alliances because it can accelerate the development speed of the products and services, improve their quality, and reduce the inter-firm transaction costs in the arm's-length alliances. As a result, IaaS is very adept at encouraging firms to utilize various types of alliances to address their business needs and achieve their business goals.

PaaS is the middle layer in the basic three-tier cloud service model of IaaS, PaaS and SaaS. On one side it resembles the raw IT resource nature of IaaS, on the other it features more heterogeneous functions and purposes for firm users to develop their own specific functions and applications. As a result, PaaS might facilitate the total number of alliances a firm engages as well as non-equity strategic alliances in particular. Currently different PaaS vendors provide various types of PaaS platforms from which firm users can choose to suit their own needs to develop different applications for different uses. For example, Microsoft Azure[44] offer a proprietary cloud platform on which firm users can build up Web apps, mobile apps and conduct data analytics, etc. Another famous PaaS provider, Force.com[45] from Salesforce dedicates to offer a suite of tools for building business process apps. Those proprietary, closed cloud platforms are not likely to provide a common ground that is needed in a joint venture formed between alliance partners. Rather the firm users who use different PaaS platforms will be able to create their own flexible functions and applications that facilitate them to make non-equity alliances.

As SaaS is the top layer in the basic three-tier cloud service models and resembles conventional end IT applications and software most, it is most diversified and heterogeneous in terms of service functions. Firm users can directly utilize SaaS applications to replace their in-house counterparts to achieve a better cost-benefit result, or to connect to their alliance partners with the provided interfaces in the SaaS applications. SaaS reduces the transaction costs associated with end product or service exchanges so that it primarily helps formation of arm's-length alliances. Currently, SaaS applications are largely not customizable to the individual needs of each firm, so it is generally not firm-specific assets that are useful in joint ventures. Rather, SaaS facilitates non-equity alliances more since those alliances do not require significant firm-specific asset integration.

[44] For more details about Microsoft Azure, visit the website https://azure.microsoft.com/en-us
[45] For more details about Force.com, visit the website http://www.salesforce.com/platform/products/force

As information and knowledge become pivotal to firms to succeed in the current dynamic markets that emphasize deep market and customer understanding, quick response to changes, and swift visions and capabilities to sense and grasp business opportunities, firms usually need to conduct various activities in order to acquire needed information and knowledge. Many alliances are formed by firms for the purpose to get access to and acquire knowledge from their alliance partners. However, with information and knowledge is provided as cloud services such as KaaS, firms can conveniently acquire such resources from the cloud services rather from alliances. Therefore, KaaS might have the effect to decrease firms' needs to form alliances to acquire information and knowledge. As knowledge is more prevalent in joint-venture alliances as well as collaborative alliances, KaaS may decrease the needs to form such alliances. Overall, KaaS may also decrease the total number of alliances a firm need to form in a given year.

Business process constitutes a firm's business routines and operations. As collaborative alliances naturally involve more inter-firm process integration, business processes provided in the cloud may well-suited to improve such alliances. BPaaS can also facilitate non-equity alliances since it reduces the transaction costs of certain business processes that are important in alliances so that firms only need to form non-equity alliances to achieve the objectives that would only be possible in joint ventures without BPaaS. As business processes are fundamental to a firm, BPaaS may also present a positive effect on a firm's total number of alliances. When BPaaS is complemented with a firm's internal ERP systems, they together can exert a positive effect on the total number of alliances a firm makes and the number of arm's-length alliances, these again reflect that BPaaS enables cost-effective, flexible processes that are important to a firm's business and helps reduce the rigidity of the conventional process-based systems such as ERP applications.

These findings have enriched the understanding of cloud computing in the context of strategic alliances in the IS literature. The various cloud services offered by the family of cloud computing have their own, distinct effects on different alliance formations. Our study is an informative attempt to theoretically investigate the underlying mechanisms for the relationships between cloud services and strategic alliances and to empirically examine and confirm the existence of such relationships.

4.5.2 Managerial implications, limitations and future work

Collaboration and strategic alliance are becoming more and more necessary nowadays because of the escalated competition in a dynamic global market. Many times, a firm cannot accomplish what it wants to achieve on its own or the price to do so is too enormous to consider. In the current turbulent economic environment, firms want to stay vigilant, swift and flexible to adapt to any changes that may impact their businesses, so that they can achieve a relatively sustainable competitive advantage. To be swift, adaptable and flexible, firms usually want to be lean by keeping only those essential business units or functions that really matters to their business goals and services, and integrate those non-core functions through acquisition or access to the complementary or shareable resources from outside. Cloud computing plays an important role in helping fulfill such a purpose. Cloud computing makes obtaining specific IT resources from outside a firm’s boundary cost-effectively, scalable and flexible. More strategically speaking, it makes firms not worry about possessing IT capabilities but their core business capabilities.

Decision makers and managers in firms should seriously consider the use of cloud computing and its various specific cloud services when considering easier, less risky, and more effective strategic alliances with potential alliance partners. Cloud computing largely reduces the costs and complexity incurred during alliances, so firms can easily form non-equity alliances to achieve their business goals rather than having to form joint ventures. Though managers may think IaaS is a just an affordable, accessible source of IT from outside the firm, they may be seriously underestimating the real power of IaaS. Managers should realize that IaaS actually may be the most versatile and all-purpose cloud resource that can almost improve all kinds of strategic alliances, no matter they are joint ventures, non-equity, collaborative or arm’s-length alliances. IaaS is not only for the sake of cost savings in IT hardware but for the innovation and business transformation that a firm can conduct based on such resource. IaaS is an essential tool for firms to dramatically reduce the costs associated with different alliances and can help firms to achieve their alliance formations flexibly. Senior executive and managers in a firm should take advantage of IaaS to focus on improving their business competitiveness and product/service quality so that the firm will be more successful and possess more resources that valuable to other firms in alliances. PaaS, though not so versatile as IaaS, may still be useful in facilitating non-equity alliances. Managers can consider using PaaS to accelerate application development and ease of connection with other firms. SaaS is most adept at improving market-oriented arm’s-length and non-equity collaborations and alliances, so managers should strategically consider using it to promote their firm’s success in such alliances. Managers should consider taking advantage of KaaS to infuse useful information and knowledge into their internal processes so that they can gain more insights about their customers and the market in a cost-effective, flexible way. With

KaaS, they do not need to form unnecessary joint ventures or collaborative alliances. Instead, they can adopt more market-end contracts to obtain the knowledge and capabilities that they need for their business success. The decision makers and managers should also be aware that business process is the cornerstone of their business and they should consider using BPaaS to enrich their business functions and models so as to promote their collaborative alliances. BPaaS can also be used to improve their internal ERP systems' flexibility and agility to improve the success of arm's-length alliances and the overall effect of various alliances.

This paper is not without limitations. The final sample size of the firms of interest remains just over 100 firms on average in a given year, therefore the models were allowed to include only a limited set of informative controls. This may have narrowed down the explanatory power of the models. The representativeness of the final sample, though is acceptable, might still need to be improved. Thus, caution should be exercised when considering a generalization of the findings in this paper. Though we studied the relationship between cloud computing and strategic alliances, we have not investigated the value that can be derived from such a relationship similar to the second step in the paper by Tafti et al. (2013). It is also very important to understand if such cloud-driven alliances can eventually benefit firm's long-term value and performance. As the extension to this paper, it is a natural follow-up for us to conduct such investigation in the future.

4.6 Figures and Tables

Figure 4.1. Data sample representativeness

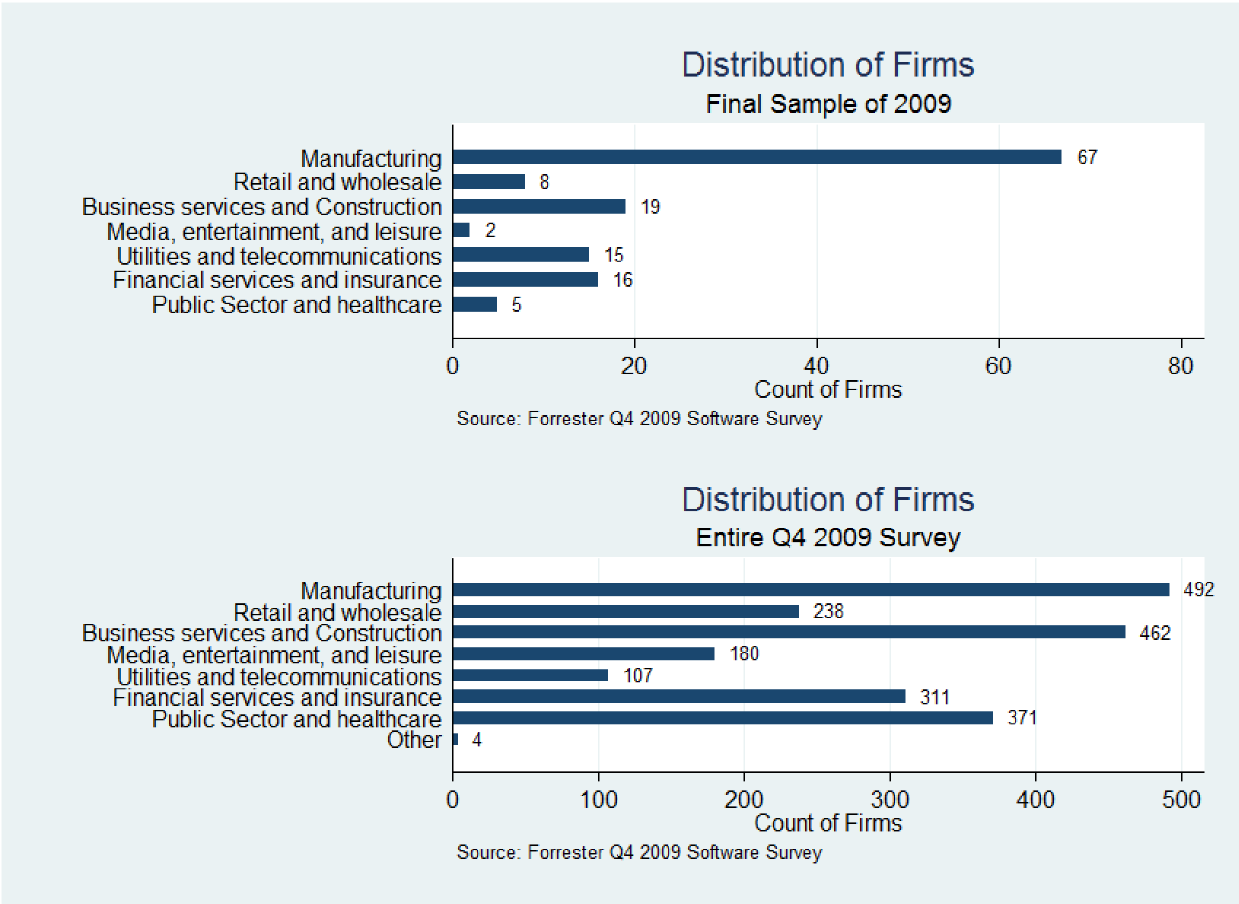

Table 4.1. Correlations and summary statistics (Year of 2009)

	Mean	S.D.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Joint-venture	0.42	0.50	0.00	1.00	1.00						
(2) Collaborative	0.45	0.50	0.00	1.00	-0.00	1.00					
(3) Total no. alliance	3.59	3.06	1.00	11.00	-0.12	0.12	1.00				
(4) No. of joint-vent	1.34	1.83	0.00	7.00	0.51	-0.05	0.32	1.00			
(5) No. of non-equity	2.25	3.01	0.00	11.00	-0.43	0.15	0.82	-0.28	1.00		
(6) No. of collab	1.79	2.28	0.00	7.00	-0.18	0.40	0.86	0.14	0.79	1.00	
(7) No. of arm's-leng	1.80	1.61	0.00	6.00	0.03	-0.34	0.68	0.42	0.44	0.21	1.00
(8) Cloud as a whole	0.02	0.99	-0.83	3.58	-0.13	-0.08	0.15	-0.11	0.22	0.11	0.14
(9) IaaS	1.16	1.98	-0.29	3.92	-0.21	-0.06	0.37	-0.15	0.46	0.24	0.36
(10) PaaS	0.44	1.76	-0.22	5.24	-0.06	0.06	0.05	-0.03	0.07	0.19	-0.17
(11) SaaS	0.92	1.37	-0.49	2.44	-0.08	-0.21	0.28	-0.04	0.31	0.02	0.51
(12) KaaS	0.26	1.48	-0.22	5.80	0.00	-0.14	-0.17	-0.07	-0.14	-0.19	-0.07
(13) BPaaS	0.44	1.64	-0.22	5.45	-0.06	0.03	-0.06	-0.05	-0.03	0.01	-0.14
(14) SOA	0.85	1.09	-0.76	1.90	-0.09	0.03	0.37	-0.03	0.39	0.36	0.19
(15) ERP systems	-0.11	0.96	-0.77	2.51	0.09	0.09	-0.10	0.01	-0.11	-0.03	-0.16
(16) Herfindahl index	0.09	0.09	0.02	0.54	0.11	-0.06	0.00	0.25	-0.15	0.01	-0.00
(17) Indus Tobin's q	0.90	0.50	0.02	2.21	-0.27	0.17	-0.07	-0.41	0.18	0.10	-0.26
(18) Regulation	0.27	0.44	0.00	1.00	0.14	-0.09	-0.02	0.16	-0.11	-0.07	0.07
(19) log(Employees)	4.09	1.66	-1.26	6.01	0.07	-0.09	0.54	0.27	0.39	0.41	0.45
(20) Advertising	0.04	0.12	0.00	0.96	0.17	0.06	-0.19	-0.07	-0.15	-0.12	-0.20
(21) Ind-Manufact	0.53	0.50	0.00	1.00	-0.24	0.20	0.28	-0.24	0.43	0.34	0.05
(22) Ind-Retail&Wh	0.07	0.25	0.00	1.00	-0.05	-0.18	-0.19	-0.13	-0.11	-0.19	-0.10
(23) Ind-Services	0.39	0.49	0.00	1.00	0.26	-0.12	-0.16	0.33	-0.37	-0.23	0.02

	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(8)	1.00											
(9)	0.66	1.00										
(10)	0.62	0.15	1.00									
(11)	0.53	0.49	0.02	1.00								
(12)	0.68	0.22	0.24	0.18	1.00							
(13)	0.79	0.21	0.58	0.14	0.67	1.00						
(14)	0.42	0.47	0.28	0.39	0.01	0.20	1.00					
(15)	-0.04	-0.24	0.25	-0.05	-0.14	0.06	0.00	1.00				
(16)	-0.20	-0.17	-0.08	-0.23	-0.07	-0.11	-0.16	-0.13	1.00			
(17)	0.27	0.33	0.34	-0.07	-0.05	0.20	0.08	0.11	0.05	1.00		
(18)	0.20	-0.22	0.25	0.17	0.23	0.32	0.29	0.19	-0.30	-0.32	1.00	
(19)	0.16	0.20	0.01	0.23	0.08	0.02	0.22	-0.06	0.17	-0.24	0.04	1.00
(20)	-0.14	-0.15	-0.02	-0.16	-0.06	-0.05	-0.25	-0.06	-0.06	0.02	-0.05	-0.21
(21)	0.25	0.42	0.14	0.19	-0.07	0.07	0.23	0.32	-0.37	0.41	-0.16	0.06
(22)	-0.00	-0.04	0.09	-0.15	0.10	-0.01	-0.14	-0.05	0.59	0.26	-0.16	-0.05
(23)	-0.23	-0.38	-0.18	-0.08	0.03	-0.05	-0.13	-0.31	0.03	-0.56	0.26	-0.04

	(20)	(21)	(22)	(23)
(20)	1.00			
(21)	-0.07	1.00		
(22)	-0.03	-0.29	1.00	
(23)	0.09	-0.84	-0.21	1.00

N = 132 firms. Dependent variables are joint-venture alliance (dummy), collaborative alliance (dummy), total number of alliance, number of joint venture, number of non-equity alliance, number of collaborative alliance, and number of arm's-length alliance.

Table 4.2. Panel random-effects logistic regression results for specific cloud services and alliance type

Panel random-effects logistic model	Model 1 Joint-venture alliance		Model 1 Collaborative alliance
H2B: IaaS	0.183	**H2D**	0.071
	(0.146)		(0.108)
H3B: PaaS	-0.155		-0.052
	(0.139)		(0.110)
H4A: SaaS	-0.267	**H4B**	-0.205
	(0.162)*		(0.120)*
H5B: KaaS	-0.049	**H5C**	-0.155
	(0.161)		(0.129)
H6B: BPaaS	-0.036	**H6C**	0.134
	(0.169)		(0.130)
SOA	-0.212		0.034
	(0.184)		(0.140)
ERP systems	0.278		0.072
	(0.214)		(0.167)
BPaaS x ERP systems	-0.047	**H7B**	-0.023
	(0.164)		(0.115)
Herfindahl index	1.404		-2.023
	(2.409)		(2.417)
Industry Tobin’s q	-1.048		0.558
	(0.452)**		(0.383)
Regulated industry	1.150		-1.218
	(0.478)**		(0.383)***
log(Employees)	0.168		0.048
	(0.116)		(0.089)
Advertising	1.886		0.037
	(1.071)*		(0.304)
Industry-Manufacturing	-0.315		-0.132
	(1.468)		(1.241)
Industry-Retail&Wholesale	0.460		-3.478
	(1.552)		(1.618)**
Industry-Services	-0.025		-0.165
	(1.475)		(1.240)
Year 2009	0.699		0.202
	(0.323)**		(0.276)
Year 2010	1.437		-0.707
	(0.388)***		(0.352)**
Year 2011	0.923		-0.525
	(0.299)***		(0.270)*
Constant	-0.739		-0.374
	(1.656)		(1.407)
Wald χ^2	43.43***		41.38***
Observations	536		536
Number of firms	126		126

Notes. The Hausman tests are insignificant at 10%, which indicates that the random-effects models are efficient comparing to the fixed-effects models. The likelihood-ratio tests are significant, which means the panel logistic models are more appropriate comparing to the pooled models. Standard errors are in parentheses. * p<0.1; ** p<0.05; *** p<0.01.

Table 4.3. Panel random-effects count regression results for specific cloud services and number of alliance

Panel random-effects count model	Model 2.1 Poisson		Model 2.1 Poisson		Model 2.1 Poisson
	Total no. of alliance		No. of joint-venture alliance		No. of non-equity alliance
H2A: IaaS	0.114	**H2B**	0.170	**H2C**	0.073
	(0.038)***		(0.064)***		(0.065)
H3A: PaaS	-0.024		-0.084	**H3B**	0.013
	(0.036)		(0.066)		(0.060)
SaaS	0.019	**H4A**	-0.020		0.048
	(0.043)		(0.068)		(0.070)
H5A: KaaS	-0.103	**H5B**	-0.067		-0.110
	(0.045)**		(0.072)		(0.075)
H6A: BPaaS	0.056		0.013	**H6B**	0.094
	(0.046)		(0.077)		(0.078)
SOA	0.028		-0.124		0.135
	(0.052)		(0.083)		(0.083)
ERP systems	0.007		0.108		-0.049
	(0.060)		(0.092)		(0.100)
H7A: BPaaS x ERP systems	0.089		0.075		0.113
	(0.043)**		(0.077)		(0.069)
Herfindahl index	0.585		1.539		-0.702
	(0.729)		(1.002)		(1.268)
Industry Tobin's q	0.003		-0.428		0.008
	(0.023)		(0.216)**		(0.025)
Regulated industry	0.255		0.603		-0.216
	(0.129)**		(0.204)***		(0.218)
log(Employees)	0.174		0.205		0.094
	(0.035)***		(0.057)***		(0.052)*
Advertising	0.027		0.054		-0.752
	(0.069)		(0.069)		(0.532)
Industry-Manufacturing	0.814		0.574		0.805
	(0.539)		(0.779)		(0.827)
Industry-Retail&Wholesale	0.402		0.562		0.427
	(0.563)		(0.820)		(0.862)
Industry-Services	0.690		0.625		0.496
	(0.539)		(0.786)		(0.826)
Year 2009	-0.276		0.084		-0.479
	(0.119)**		(0.201)		(0.154)***
Year 2010	-0.618		0.041		-1.140
	(0.144)***		(0.216)		(0.214)***
Year 2011	-0.118		0.397		-0.455
	(0.113)		(0.184)**		(0.153)***
Constant	-0.698		-1.627		-0.545
	(0.570)		(0.870)*		(0.867)
Wald χ^2	81.24***		50.26***		68.12***
Observations	260		260		260
Number of firms	126		126		126

Table 4.3 (cont.)

Panel random-effects count model	Model 2.1 Poisson	Model 2.2 Negative Binomial		Model 2.1 Poisson
	No. of collaborative alliance	No. of collaborative alliance		No. of arm's-length alliance
H2D: IaaS	0.142	0.139	**H2E**	0.096
	(0.070)**	(0.069)**		(0.045)**
PaaS	-0.034	-0.032		-0.023
	(0.073)	(0.072)		(0.041)
SaaS	-0.110	-0.103	**H4B**	0.091
	(0.081)	(0.083)		(0.048)*
H5C: KaaS	-0.214	-0.191		-0.048
	(0.094)**	(0.093)**		(0.051)
H6C: BPaaS	0.138	0.142		0.025
	(0.087)	(0.082)*		(0.053)
SOA	0.068	0.071		-0.008
	(0.096)	(0.096)		(0.060)
ERP systems	0.054	0.035		-0.004
	(0.115)	(0.117)		(0.067)
BPaaS x ERP systems	0.054	0.062	**H7B**	0.117
	(0.078)	(0.078)		(0.048)**
Herfindahl index	-0.159	-0.505		1.069
	(1.588)	(1.710)		(0.784)
Industry Tobin's q	0.036	0.035		-0.062
	(0.027)	(0.026)		(0.086)
Regulated industry	-0.467	-0.583		0.589
	(0.258)*	(0.279)**		(0.147)***
log(Employees)	0.212	0.199		0.143
	(0.065)***	(0.067)***		(0.040)***
Advertising	0.005	0.015		0.016
	(0.356)	(0.327)		(0.070)
Industry-Manufacturing	0.850	0.690		0.817
	(0.842)	(0.828)		(0.725)
Industry-Retail&Wholesale	-2.070	-2.114		0.986
	(1.296)	(1.279)*		(0.740)
Industry-Services	0.554	0.412		0.749
	(0.838)	(0.823)		(0.727)
Year 2009	-0.217	-0.217		-0.325
	(0.182)	(0.197)		(0.158)**
Year 2010	-1.084	-1.010		-0.354
	(0.259)***	(0.274)***		(0.175)**
Year 2011	-0.397	-0.486		0.053
	(0.188)**	(0.214)**		(0.141)
Constant	-1.438	0.502		-1.293
	(0.916)	(1.081)		(0.762)*
Wald χ^2	61.60***	55.59***		62.43***
Observations	260	260		260
Number of firms	126	126		126

Notes. The Hausman tests are insignificant at 10%, which indicates that the random-effects models are efficient comparing to the fixed-effects models. Panel random-effects Poisson and negative binomial regression results are available but only the Poisson results are shown unless there is any significant coefficient estimate difference between the two types of results such as the ones for collaborative alliance. The likelihood-ratio tests are significant (except Model 2.1 Poisson for arm's-length alliance), which means the panel logistic models are more appropriate comparing to the pooled models. Standard errors are in parentheses. * p<0.1; ** p<0.05; *** p<0.01.

Table 4.4. Propensity score matching (PSM) results using the nearest neighbor (NN) matching method

Dependent Variable	Hypothesis and Treatment Variable	Propensity Score Matching (PSM) Result				
		Number of Treated	Number of Control	Average Treatment Effect on the Treated (ATT)	Standard Error	T Value
Joint-venture	**H1**: AnyCloud	143	52	-0.196***	0.072	-2.704
Total no. of alliance	**H2A**: AnyIaaS	64	28	0.719*	0.455	1.578
No. of non-equity	**H2C**: AnyIaaS	64	28	0.844**	0.448	1.884
No. of arm's length	**H2E**: AnyIaaS	64	28	0.484**	0.286	1.693
Total no. of alliance	**H3A**: AnyPaaS	34	19	0.618*	0.449	1.377
No. of non-equity	**H3B**: AnyPaaS	34	19	0.794**	0.460	1.727
No. of arm's length	**H4B**: AnySaaS	109	51	0.376*	0.243	1.547
No. of joint venture	**H5B**: AnyKaaS	21	16	-0.381*	0.254	-1.499
Total no. of alliance	**H6A**: AnyBPaaS	31	23	0.742*	0.459	1.617
No. of non-equity	**H6B**: AnyBPaaS	31	23	1.065***	0.412	2.583
No. of collaborative	**H6C**: AnyBPaaS	31	23	0.645**	0.276	2.341

Notes. A bootstrapped method with 20 replications was used. Only statistically significant PSM results are shown. Results are based on the pooled sample data of 2009-2012. The details of the treatment and control variables can be found in Table C.3 in Appendix C. * p<0.1; ** p<0.05; *** p<0.01.

CHAPTER 5: CONCLUSION

Information technology (IT) is an indispensable cornerstone for modern organizations to conduct daily operations and businesses. Technologies evolve fast and cloud computing is undoubtedly one of the most successful applications in the newest wave of technology commercialization in the past decade. Today cloud computing is widely accepted and utilized in industries to facilitate firms to access IT resources, develop applications and achieve their business goals.

With its commercial success, more and more attention has been drawn on studying the phenomena around cloud computing application. As cloud computing is a multifaceted paradigm that synthesizes and advances several previous disruptive technologies such as the Internet, utility computing and virtualization (Armbrust et al. 2010; Marston et al. 2011; Zhang et al. 2010), its applications can be very diversified and its certain characteristics can be salient and amplified in a certain situation. For example, if one firm emphasizes the utility billing feature of cloud computing, the firm is very likely to utilize cloud computing from the cost-saving point of view. Indeed, many firms started using cloud computing from this point – they adopted Software as a Service (SaaS) applications to help justify their IT costs in software such as email systems. Meanwhile another firm is probably more interested in using cloud computing to innovate its IT systems and business models to achieve more strategic goals and server its consumers better. For instance, Netflix utilized Amazon's cloud services to dramatically improve the response time and speed to its massive customers' demands on the online streaming services so as to promote its customer service quality and brand reputation.

In particular, cloud computing provides an unprecedented, affordable opportunity for the relatively small businesses and firms to access and utilize various IT resources that would have not been possible for them before, thus enabling them with a relatively equal footing in IT resources to quickly innovate and achieve their strategic goals and compete with those large, market-leading companies. In other words, cloud computing has fundamentally improved the possibility and chance for those small firms to survive and thrive, promoting innovation and creativity.

Like many other previous novel technologies, cloud computing is not without risks and limitations. During the usage of cloud computing, many firms have expressed their concerns about the inherent risks incurred by outsourcing data and applications to third-party cloud vendors such as data security and privacy issues and others. Those concerns are particularly salient in large organizations since they have to consider protecting their customers' data and their own reputation and company image very carefully before adopting any new technology – they have to thoroughly study the impact of the new technology within and beyond their organizational boundary. When considering adopting cloud computing, firms also need to evaluate and adapt their cloud computing strategies to suit their own business needs and make sure cloud computing is properly used and generates strategic values for their businesses. Oftentimes this is not an easy task because there are various cloud services that firms can choose from such as the three basic service models of Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) and a variety of extended service models such as Knowledge as a Service (KaaS) and Business Process as a Service (BPaaS). Each of the cloud services present its own characteristics and serving purposes, and may be more beneficial when applied in certain specific situations. Firms need to reasonably understand each of the cloud services before applying them in their own businesses so as to utilize cloud computing in an optimal way and to avoid unnecessary chaos and loss.

This dissertation serves as an academic investigation to shed lights on unraveling the complexity around cloud computing and understanding cloud computing as a whole and its various service models in the sense of how to prepare firms to mitigate the cloud risks on their own side such as by modularizing their internal IT systems to better adopt cloud computing and whether cloud computing can help them achieve company goals such as firm performance and strategic alliance formation.

Given the inherent risks and uncertainties in the current cloud services provided by third-party cloud vendors, how to make those cloud services as safe as possible is probably one of the most important issues and factors for the cloud firm users to evaluate and determine whether a cloud service is suitable for them hence to adopt the cloud service. In fact, according to the IDC survey (2009), there are eight main factors that affect the firms' adoption decision of cloud computing and some of the most significant cloud risks and concerns are security, availability and vendor lock-in. Those concerns seriously deter the use of cloud computing in certain companies, especially those large companies that have many factors to consider in order to make a right IT strategy decision. We believe the cloud risks can be addressed and mitigated from two sides. One obvious side is to address them directly in the provided cloud systems by the cloud vendors, in which there have already been numerous academic articles to enhance cloud safety, especially from the technical point of view. The other side, which may be less obvious, is that we can also address the cloud risks from the users' point of view. That is, we believe cloud firm users themselves can also proactively act within their firm boundaries to help improve their experience and immunity to the cloud risks. In our research findings, we find that, one of the things firms can do is probably that they can internally modularize their IT systems to mitigate the cloud risks and to better adopt different cloud services such as application-level (i.e., SaaS) and server-level cloud services (i.e., IaaS and PaaS). More specifically, we find that, for the small and medium-sized enterprises (SMEs), if they internally modularize their IT systems in a very strategic way such as to deploy a companywide service-oriented architecture (SOA) strategy, they will have an easier time to adopt more application-level cloud services; if they tend to only modularize their internal IT systems locally within some specific IT projects and have no a holistic modularization strategy for the entire company, it is likely that they will use less application-level cloud services but more server-level cloud services to power up their local projects' IT resource needs. For large firms, they also tend to use more application-level cloud services if they adopt a companywide strategy in internal IT system modularization, or to use less such cloud services if they only make a non-strategic modularization decision in certain localized IT projects. In other words, modularization in internal IT systems either in a strategic or non-strategic way tend to have a very similar effect on adoption of applications-level or SaaS cloud services for all firms, regardless of their firm sizes. This may reflect the fact that SaaS applications are the easiest and most convenient cloud services to be accepted and adopted by all firms since the applications are ready for immediate use and there are countless function-rich SaaS applications that can be applied and complied to the purpose of internal strategic planning in firms. For instance, internal email and collaboration systems can be readily replaced by cloud-based ones such as Gmail and Microsoft SharePoint since they are quite standardized processes and risks are low especially when firms modularize their internal IT systems such as using an SOA approach. Nevertheless, internal IT modularity (strategic and nonstrategic) seems to have no effect on adoption of server-level cloud services for large firms, unlike the result for the SMEs. This reflects the fact that large firms usually already have sufficient internal raw IT resources (e.g., servers, databases and platforms) and their decisions to use external server-level cloud services are based on much more factors that they have to consider such as compatibility, regulation and reputation rather than only raw IT resource accessibility. Unlike application-level cloud services which may directly provide novel and advanced functionality to all firms, server-level cloud services only provide relatively homogenous raw IT resources. Since large firms have a much more leeway in terms of raw IT resource availability, they do not have to rely on such external resources from the cloud very much. Therefore, from our study, we show that internal IT modularity is one of the important antecedents that can affect firms' decision to adopt external cloud services. The study can be enriched to include other possible antecedents of modularity in the future. For example, IT modularity representations other than SOA (e.g., module-based enterprise systems such as ERP systems or component applications such as CRM and SCM) can be incorporated into the study when data allow the relevant proxies to broaden the inclusiveness of the construct. More generally speaking, modularity constructs not limited in IT can also be valuable targets for investigation. For instance, Sanchez and Mahoney (1996) point out the possible association between product modularity and organizational structure modularity, so another possible path could be to examine the causal effect of IT modularity on adoption of cloud computing with firm structure modularity as the mediator.

Once a firm decides and is ready to adopt cloud services, it must also understand the important consequences of adoption of cloud services and how different cloud services (e.g., IaaS, PaaS, SaaS, KaaS and BPaaS) can be optimally utilized to achieve desired goals for its business, be it firm performance or formation of strategic alliances for example, since different specific cloud services are very likely to present different characteristics in different situations. For one of the important consequences, firm performance, we find that cloud computing as an overall concept can directly generate long-term and intangible strategic values for firms rather than having to complement other internal resources such as ERP systems to generate such values, confirming the direct view of IT as a strategic resource for firm performance in the debate about whether IT is a commodity or not (Bharadwaj et al. 1999). As to the specific cloud services, SaaS many not generate direct strategic values for firms but can do so when complemented with internal ERP systems. As strategic internal IT modularity in SOA leads to more SaaS adoption, we can see that the outsourced SaaS applications alone are usually commodity-like, but they can be strategically considered, complemented and integrated with firms' other internal resources to create strategic values. For example, a firm may outsource its email system to Google by using Gmail as its enterprise email system to save IT costs and dedicate those saved resources to other more valuable areas. Gmail alone may not generate long-term strategic values for the firm because every firm can easily adopt and access this SaaS email service in the cloud. However, if a firm integrates Gmail with its other internal systems such as ERP systems and collaborative systems in a very strategic, firm-specific way, Gmail can significantly help improve the efficiency of the other internal systems so as to generate a competitive advantage for the firm. IaaS and especially PaaS are found to have a direct effect on firm performance measured by Tobin's q. These are two more fundamental and server-level cloud services compared to SaaS. In other words, the server-level cloud services are not commodity from the perspective of cloud users, even though this may be true from the standpoint of cloud vendors. A cloud user firm can utilize the commodity-price IaaS and PaaS cloud services from cloud vendors to design, develop and implement strategic IT infrastructures, functionalities and applications that can directly generate strategic values for the firm (Bharadwaj 2000). The most basic cloud service in the server-level cloud services, IaaS, though can generated direct strategic values for a firm as described, might undermine the value of a firm's internal ERP systems if inappropriately used to develop duplicated, substitute components or functions in the ERP systems. Therefore, managers in a firm need to carefully consider how to strategically utilize IaaS to develop new functions or applications to complete rather than to substitute the existing ERP systems. One extended cloud service, BPaaS which provide relatively generic business processes in the cloud, might still be able to directly improve firm performance if used properly to promote the flexibility and efficiency of business processes in the firm. These findings about the effects of adoption of cloud computing on firm performance can be enriched in the future by, for example, investigating the complementary effect of cloud computing with other possible strategic internal resources such as human IT resources (Bharadwaj 2000) when data are available. Cloud services may dramatically change the nature and requirements of human IT resources including technical and managerial IT skills in a firm. For example, by using more cloud services, the IT skills required in a firm may shift from developing and maintaining IT systems to more IT strategic thinking. The effects of such fundamental shifts should be considered in the subsequent research in the future.

For another important consequence of adoption of cloud computing, formation of strategic alliances, we find that the overall effect of cloud computing is to shift the governance structure of a firm from hierarchy-based to market-based from the point of view of inter-firm transaction costs. Therefore, the holistic representation of various cloud services has a direct effect to facilitate non-equity alliances rather than joint ventures. Cloud computing also enables firms to generate strategic resources and become more attractive and valuable to other firms in alliances. Firms tend to use more convenient non-equity alliances to access and exchange resources with the help of cloud computing. As to the specific cloud services, comparing to all the other ones, IaaS is the most versatile cloud service that can almost facilitate all kinds of alliance formations such as joint ventures, non-equity alliances, collaborative alliances and arm's-length alliances. Similar to the effect of IaaS on firm performance, IaaS is a set of convenient raw IT resources that can be flexibly utilized by cloud firm users to develop necessary IT functionalities, processes and applications to help form various types of strategic alliances. PaaS, as the middle layer in the basic three-tier cloud services (i.e., IaaS, PaaS and SaaS), on one hand resembles some of the characteristics of IaaS, on the other hand is more heterogeneous in terms of provided IT resource types. Therefore, from the perspective of cloud users, PaaS is less versatile than IaaS and may only facilitate formation of non-equity alliances. SaaS, as the top layer in the basic three-tier cloud services, can reduce the transaction costs associated with end product or service exchanges so that it mainly helps formation of arm's-length and non-equity alliances. The extended cloud service, KaaS, can help firms reduce the needs to form joint ventures or collaborative alliances since it is more cost-effective and convenient for firms to obtain knowledge-based resources from KaaS than from such alliances. Another extended cloud service, BPaaS, can facilitate formation of collaborative alliances as well as non-equity alliances because BPaaS can reduce inter-organizational transaction costs in business processes that are common in such alliances. BPaaS can also reduce the rigidity of the traditional process-based systems such as ERP systems to promote arm's-length alliances by putting the governance structure from hierarchy-like to market-like. Though it is evident that cloud computing and it various services can promote different types of formation of strategic alliances directly or complementarily, it is also important to understand and study the created values from such alliances for firms in the future.

The findings in the dissertation indicate that firms need to consider adoption of cloud computing in an informative, strategic way to avoid unnecessary risks and to utilize different cloud services to help them better achieve different goals such as long-term firm performance improvement and different types of formation of strategic alliances. Firms can proactively act to modularize their internal IT systems to reduce the risks exposed in the cloud and to better adopt different cloud services according to their needs. Different cloud services, in turn, can help firms improve their firm performance and formation of strategic alliances in different ways. When firms understand these roles and effects cloud computing may play better, they will utilize cloud computing in a much more efficient and effective way to help them grow and thrive in business.

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APPENDIX A

Details Regarding Measures

Dependent Variables – Cloud Computing Adoption

The measures of cloud computing adoption are based on the prior literature about the taxonomy of cloud computing (Hoefer and Karagiannis 2010; Mell and Grance 2011; Youseff et al. 2008). Starting from consolidating all relevant keywords of cloud computing, the following can be identified: 1) Virtual server (at hosting), 2) Cloud, 3) Software-as-a-Service and SaaS, 4) Platform-as-a-Service and PaaS, 5) Infrastructure-as-a-Service and IaaS, 6) Pay-per-use, 7) Utility, 8) Information-as-a-Service and I-aaS, 9) Knowledge-as-a-Service and KaaS, 10) Business process-as-a-Service and BP-aaS, 11) Compute-as-a-Service, 12) Database-as-a-Service and DaaS, 13) Network-as-a-Service and NaaS, and 14) Communication as a Service and CaaS. Mapping these keywords to the questions in the dataset yields the following matched keywords: 1) Business process-as-a-Service and BP-aaS, 2) Cloud, 3) Compute-as-a-Service, 4) Database-as-a-Service and DaaS, 5) Information-as-a-Service and I-aaS, 6) Infrastructure-as-a-Service and IaaS, 7) Knowledge-as-a-Service and KaaS, 8) Platform-as-a-Service and PaaS, 9) Software-as-a-Service and SaaS, and 10) Virtual server. By further validating the matched questions' context and relevance to cloud computing, the following finalized keywords for cloud computing are identified: 1) Software-as-a-Service / SaaS and 2) Virtual server. SaaS represents the application-level cloud services and virtual server represents the server-level cloud services.

Independent Variables – IT Modularity

Duncan (1995) uses the following survey questions as measurement instruments when operationalizing the construct of IT modularity within the context of IT infrastructure flexibility.

The author identifies that modularity comprises two components: data and applications. The questions for data are: 1) In our major systems, data rules and relations are not hard coded into applications, 2) Our firm has formally and sufficiently identified data to be shared across business units, and 3) What percentage of corporate data is currently shareable across organizational boundaries? The questions for applications are: 1) Generally speaking, business rules such as tax regulations are hard coded into the relevant application module, 2) Our firms have adequately identified those business process components which are shareable, and 3) The complexity of current applications software seriously restricts our ability to develop systems of single-process, reusable modules.

Byrd and Turner (2000) discuss the measures for IT infrastructure flexibility. As a dimension of IT flexibility, IT modularity consists of two components: application functionality and data transparency. They also use Likert-style questions for measuring IT modularity. The measures for applications functionality are: 1) The applications used in our organization are designed to be reusable, 2) Reusable software modules are widely used in new systems development, 3) End users utilize object-oriented tools to create their own applications, 4) IT personnel utilize object-oriented technologies to minimize the development time for new applications, 5) Legacy systems within our organization restrict the development of new applications, 6) Data processing (e.g., batch job, key entry time, etc.) does NOT restrict normal business operations or functions, 7) We have a backlog of IT design work for new applications, and 8) Our organization uses enterprise-wide application software. The measures for data transparency are: 1) Our organization utilizes online analytical processing (OLAP), 2) Our corporate database is able to communicate through many different protocols (e.g., SQL, ODBC), 3) Mobile users have ready access to the same data used at desktops, 4) A common view of our organization's customer is available to everyone in the organization, 5) Our organization easily adapts to various vendors' database management systems protocols and standards, 6) Data captured in one part of our organization are immediately available to everyone in the organization, 7) Our IT organization handles variances in corporate data formats and standards, and 8) Data rules and relations (e.g., tax regulations) are hard-coded into applications. Chung et al. (2005) and Fink and Neumann (2009) also adopt the measures from Byrd and Turner (2000) when measuring modularity in the context of IT infrastructure flexibility.

Tiwana and Konsynski (2010) identify two dimensions for IT architecture modularity: IT architecture loose coupling and IT standardization. IT architecture loose coupling contains the characteristics of 1) plug-and-play, 2) highly interoperable, 3) well-understood interdependencies, 4) minimal unnecessary interdependencies, 5) loosely coupled, and 6) highly modular. IT standardization contains the characteristics of 1) IT standards, 2) IT policies, 3) IT architecture, 4) compliance guidelines for line function IT applications, 5) compliance guidelines for line function IT infrastructure, and 6) dedicated IT liaisons for each line function.

Tafti et al. (2013) identify services-based IT architecture as a proxy for modular architecture and consider whether a services-based IT architecture has been widely deployed within the firm. The relevant survey question is: Has your IT department developed and deployed a company-wide services-based IT architecture? Tiwana and Konsynski (2010) identify SOA as the typical modular IT architecture.

Consolidated from these IT modularity measures, the following keywords can be identified: 1) Service-Oriented Architecture and SOA, 2) module, 3) loosely-coupled, 4) object-oriented, 5) reusable and reusability, 6) standard, 7) open source, 8) enterprise service bus, and 9) component and componentization. Mapping these keywords to the questions in the survey dataset yields the following matched keywords: 1) Service-Oriented Architecture and SOA, 2) module, 3) standard, 4) open source, 5) enterprise service bus, and 6) component and componentization. By further validating the matched questions' context and relevance to IT modularity, the following pertinent keywords for IT modularity is finally identified: Service-Oriented Architecture and SOA.

Table A.1. Definitions and Constructions of Variables

Variable Type - Dependent/ Independent/ Control	**Variable Name**	**Related Survey Question**	**Variable Definition/Construction**	**Data Source**
Dependent Variable	*PerVirSer*	QSS3. What percentage of your firm's applications are/will be deployed in the following ways, now and two years from now? - QSS3X_4. Virtual server at hosting or cloud service provider , Today	QSS3X_4 is a numeric measure ranging from 0 to 100 (percentage).	Forrester Q4 2008 Software Survey
Dependent Variable	*PerSaaS*	QSS3. What percentage of your firm's applications are/will be deployed in the following ways, now and two years from now? - QSS3X_6. Software-as-a-Service (SaaS) , Today	QSS3X_6 is a numeric measure ranging from 0 to 100 (percentage).	Forrester Q4 2008 Software Survey
Independent Variable	*BizTranSOA*	QSS8. [QSS5=3,4] How is your firm currently using SOA?- QSS8_4. [QSS5=3,4] Strategic business transformation	QSS8 has five sub-questions of which all are binary: 1) QSS8_1. [QSS5=3,4] Internal integration (i.e., application integration within your firm), 2) QSS8_2. [QSS5=3,4] External integration (i.e., integration with other companies), 3) QSS8_3. [QSS5=3,4] Pure data or information access (i.e., no business logic), 4) QSS8_4. [QSS5=3,4] Strategic business transformation, and 5) QSS8_5. [QSS5=3,4] Other (Please specify). However, we only take Sub-question QSS8_4 into account since only this one indicates SOA adoption significantly and it is a dummy measure.	Forrester Q4 2008 Software Survey

Table A.1 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Survey Question	Variable Definition/Construction	Data Source
Independent Variable	*ProjSOA*	QSS9. [QSS5=3,4] Including projects for both new applications and changes to existing applications, approximately how much of your firm's solution delivery projects use SOA?	QSS9 is a numeric measure which has the range from 0 to 4. The number 0 to 4 indicates the magnitude of SOA usage by projects. The numbers are converted from the original options for the question: 1) Less than 10% of projects, 2) 10% to 24% of projects, 3) 25% to 50% of projects, 4) More than 50% of projects, and 5) Don't know. Option 1) to 4) gets 1 to 4 points respectively while Option 5) gets 0 point.	Forrester Q4 2008 Software Survey
Control Variable	*WSCApp*	QSD5. What types of new custom applications are your firm's developers building?- QSD5_5. SOAP or REST based Web services	QSD5_5 is a dummy measure. Yes gets 1 and No gets 0. A missing value is imputed with 0.	Forrester Q4 2008 Software Survey

Table A.1 (cont.)

Variable Type - Dependent/ Independent/ Control	**Variable Name**	**Related Survey Question**	**Variable Definition/Construction**	**Data Source**
Control Variable	*ImGoal_Out*	QSS1. Thinking of your firm's current planning cycle, how important are each of the following goals?	QSS1 is a set of 12 sub-questions which are about the goals of 1) QSS1_1. Reduce IT costs, 2) QSS1_2. Use information technologies to increase innovation, 3) QSS1_3. Support regulatory requirements, 4) QSS1_4. Increase ability to meet unmet demands for IT services, 5) QSS1_5. Address IT staffing and skills challenges, 6) QSS1_6. Reduce the number of (major) software vendors that we work with, 7) QSS1_7. Move some/more enterprise applications to off-premise providers, 8) QSS1_8. As quality control test, please select the second option for this row, 9) QSS1_9. Improve integration between applications, 10) QSS1_10. Improve communication to business of IT value, 11) QSS1_11. Expand our use of open source software, and 12) QSS1_12. Expand use of Software-as-a-Service (SaaS is an application which you don't own, it is hosted remotely, and a monthly usage fee is paid). The options for each sub-question range from "1 - Not at all important" to "5 - Very important" to "Don't know". The options are converted to a dummy variable which gives 1 point to Option 5 and otherwise gives 0 point. Using PCA to reduce dimensions, the following one variable is finally used. ImGoal_Out (which represents 7 and 12) is about shifting out IT applications to external providers.	Forrester Q4 2008 Software Survey
Control Variable	*PDepSaaS*	QPA1. When implementing a major application, which of the following best describes the type of deployment option your firm prefers?	QPA1 has 8 options: 1) A custom-developed application, 2) A packaged application or application modules, 3) A pre-integrated application suite, 4) A tailored solution assembled from existing-custom and..., 5) Software-as-a-Service, 6) Hosted solution (multi-instance or ASP), 7) Other, and 8) Don't know. The question is converted to a dummy variable with 1 point for Option 5 and otherwise 0 point.	Forrester Q4 2008 Software Survey

Table A.1 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Survey Question	Variable Definition/Construction	Data Source
Control Variable	*NoSaaS_Qual*	QPA6A. [QPA6=98] Why aren't you interested in Software-as-a-Service?	QPA6A is a set of 9 sub-questions which are about the reasons for indifference in SaaS: 1) QPA6A_1. [QPA6=98] We're locked in with our current vendor, 2) QPA6A_2. [QPA6=98] Total cost concerns (i.e., total cost of ownership), 3) QPA6A_3. [QPA6=98] Complicated pricing models, 4) QPA6A_4. [QPA6=98] Application performance (i.e., downtime, speed), 5) QPA6A_5. [QPA6=98] Security concerns, 6) QPA6A_6. [QPA6=98] Integration issues, 7) QPA6A_7. [QPA6=98] Lack of customization, 8) QPA6A_8. [QPA6=98] We can't find the specific application we need, and 9) QPA6A_9. [QPA6=98] Other reason (Please specify). Each sub-question is a dummy variable with 1 point for Yes and 0 point for No. Option 9 is dropped. Using PCA to reduce dimensions, the following one variable is finally used. NoSaaS_Qual (which represents 4, 5 and 6) is about poor SaaS quality and performance.	Forrester Q4 2008 Software Survey

Table A.1 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Survey Question	Variable Definition/Construction	Data Source
Control Variable	*AdSaaS_FlexAgi*	QPA6B. [QPA6=2,3,4,5] How important were the following in your firm's decision to adopt Software-as-a-Service (SaaS)?	QPA6B is a set of 6 sub-questions which are about the influencing factors for the decision of SaaS adoption: 1) QPA6B_1. [QPA6=2,3,4,5] Ability to substitute upfront costs with regular monthly payments, 2) QPA6B_2. [QPA6=2,3,4,5] Lower overall costs, 3) QPA6B_3. [QPA6=2,3,4,5] Speed of implementation and deployment, 4) QPA6B_4. [QPA6=2,3,4,5] Gaining a feature or functionality that is not available in a traditional, licensed software package, 5) QPA6B_5. [QPA6=2,3,4,5] Lack of in-house IT staff to maintain a traditional software solution, and 6) QPA6B_6. [QPA6=2,3,4,5] To support a large number of mobile and remote users. The options for each sub-question range from "1 - Not at all important" to "5 - Very important" to "Don't know / Does not apply to me". The options are converted to a dummy variable which gives 1 point to Option 5 and otherwise gives 0 point. Using PCA to reduce dimensions, the following one variable is finally used. AdSaaS_FlexAgi (which represents 1, 2, 3, 4, 5 and 6) is about the various aspects of flexibility and agility that SaaS offers.	Forrester Q4 2008 Software Survey
Control Variable	*ENT*	SME/Enterprise indicator	A dummy variable with 1 indicating large enterprise and 0 indicating SME.	Forrester Q4 2008 Software Survey
Control Variable	*ITSpend_ln*	IT Spending	IT Spending is a numeric variable, in which missing values are imputed with the sample median values for SME and large enterprise separately. Eventually, the values of natural logarithm (log) are used.	Forrester Q4 2008 Software Survey

Table A.1 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Survey Question	Variable Definition/Construction	Data Source
Control Variable	*Ind_Man* *Ind_RnW* *Ind_Ser* *Ind_Pub*	Industry	INDUSTRY7 has 8 options: 1) Manufacturing, 2) Retail & Wholesale, 3) Services, 4) Media, Entertainment, & Leisure, 5) Utilities & Telecom, 6) Finance & Insurance, 7) Public Sector, and 8) other. Option 8 is dropped. Four dummies are used. Ind_Man is for Option 1 Manufacturing. Ind_RnW is for Option 2 Retail & Wholesale. Ind_Ser is for Option 3, 4, 5 and 6 which all can be grouped into services. Ind_Pub is for Option 7 Public Sector. The categorization uses 2012 NAICS as a reference.	Forrester Q4 2008 Software Survey

Table A.2. The effect of IT modularity on server-level cloud service adoption (pooled data of SMEs and large enterprises) and the related Chow test

Server-level cloud	**Model 1**
Strategic SOA	1.733
	(1.739)
Non-strategic SOA for projects	1.955
	(0.785)**
Custom application by Web service	-2.436
	(1.421)*
Goal of outsourcing	0.923
	(0.470)*
SaaS as preferred deployment option	-2.910
	(3.315)
SaaS quality concerns	-0.141
	(0.261)
SaaS flexibility	-0.206
	(0.293)
Firm size-SME/large firm	2.437
	(2.521)
IT expenditure	0.290
	(0.234)
Industry-Manufacturing	-7.243
	(10.198)
Industry-Retail&Wholesale	-7.565
	(10.301)
Industry-Services	-6.827
	(10.170)
Industry-Public Sector	-7.856
	(10.233)
Biz Trans SOA x Firm size	-0.375
	(2.262)
Project SOA x Firm size	-2.587
	(1.086)**
Constant	4.567
	(10.703)
R^2	0.05
F-stat	1.64*
Observations	457
Chow test F-stat	3.52**

Notes. Chow test is significant so that the pooled data cannot be used for Model 1. Instead, Model 3 is used separately for SMEs and large enterprises (see the Model 3 columns in Table 2.4). Standard errors are in parentheses. * p<0.1; ** p<0.05; *** p<0.01.

Table A.3. Lindell-Whitney marker-variable tests for Model 2 and Model 3

Model 2			Model 3 for SMEs only		
	(1)	**(2)**		**(1)**	**(2)**
(1) region_na	1.00		**(1) region_na**	1.00	
(2) age	-0.01	1.00	**(2) age**	-0.06	1.00
(3) BizTranSOA	0.02	0.05	(3) BizTranSOA	-0.01	0.02
(4) ProjSOA	0.02	-0.06	(4) ProjSOA	0.04	0.00
(5) WSCApp	0.07	-0.07	(5) WSCApp	0.08	-0.03
(6) ImGoal_Out	-0.08	-0.09	(6) ImGoal_Out	-0.02	-0.08
(7) PDepSaaS	0.05	-0.02	(7) ITSpend_ln	0.03	0.04
(8) NoSaaS_Qual	0.09	0.07	(8) Ind_Man	0.06	0.17
(9) AdSaaS_FlexAgi	0.01	-0.08	(9) Ind_RnW	0.04	-0.15
(10) ENT	-0.08	0.12	(10) Ind_Ser	-0.06	-0.12
(11) ITSpend_ln	-0.06	0.10	(11) Ind_Pub	-0.01	0.05
(12) Ind_Man	0.01	0.15			
(13) Ind_RnW	-0.03	-0.05			
(14) Ind_Ser	-0.02	-0.13			
(15) Ind_Pub	0.03	0.03			

Notes. Marker variables are highlighted in bold. It can be seen that they are not highly correlated with the principle constructs used in the models, which dismisses the possibility of common method bias in the study.

APPENDIX B

Table B.1. Definitions and data sources of variables for (panel) OLS models

Variable Type - Dependent/ Independent/ Control	**Variable Name**	**Related Question/Explanation**	**Variable Definition/Construction**	**Data Source**
Dependent Variable	*TQ*	Tobin's q	Tobin's q = (MVE + PS + DEBT) / TA MVE = (Closing price of share at the end of the financial year) × (Number of common shares outstanding); PS = Liquidating value of the firm's outstanding preferred stock; DEBT = (Current liabilities - Current assets) + (Book value of inventories) + (Long-term debt); TA = Book value of total assets.	Compustat
Independent Variable	*IaaS*	SS.8: What are your firm's plans to adopt the following software technologies? - SS.8_1: Cloud infrastructure-as-a-service (Iaas)	SS.8_1 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of IaaS usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Independent Variable	*SaaS*	SS.8: What are your firm's plans to adopt the following software technologies? - SS.8_2: Software-as-a-service (SaaS)	SS.8_2 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of SaaS usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey

Table B.1 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Independent Variable	*PaaS*	SS.8: What are your firm's plans to adopt the following software technologies? - SS.8_3: Platform-as-a-service (PaaS)	SS.8_3 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of PaaS usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Independent Variable	*KaaS*	SS.8: What are your firm's plans to adopt the following software technologies? - SS.8_4: Information/Knowledge-as-a-service (I-aaS/KaaS)	SS.8_4 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of I-aaS/KaaS usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Independent Variable	*BPaaS*	SS.8: What are your firm's plans to adopt the following software technologies? - SS.8_5: Business process-as-a-service (BP-aaS)	SS.8_5 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of BP-aaS usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized. Please note, BPaaS is not a standalone cloud service model variable, instead, it is an inherent interaction variable that represents the complementarity between business process and cloud computing.	Forrester Q4 2009 Software Survey

Table B.1 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Independent Variable	*cloud*	Cloud computing as a whole	A composite variable calculated by IaaS + PaaS + SaaS + KaaS + BPaaS. The value is normalized.	Forrester Q4 2009 Software Survey
Independent Variable	*cloud_bas*	Basic cloud computing as a whole	A composite variable for the three basic types of cloud computing (IaaS, PaaS and SaaS) generated using principal component analysis (PCA). The value is normalized.	Forrester Q4 2009 Software Survey
Independent Variable	*cloud_ext*	Extended cloud computing as a whole	A composite variable for the two extended types of cloud computing (KaaS and BPaaS) generated using principal component analysis (PCA). The value is normalized.	Forrester Q4 2009 Software Survey
Control Variable – Industry	*hhi_ind*	Herfindahl–Hirschman Index (HHI)	The Herfindahl-Hirschman Index (HHI) is to measure industry concentration (a proxy for industry competitiveness). The HHI for an industry j is given as $HHI_j = \Sigma_i s_{ij}^2$ where s_{ij} is the market share of firm i in industry j.	Compustat
Control Variable – Industry	*Q_ind*	Weighted industry average Tobin's q	Market share weighted average Tobin's q for all firms within the same industry categorized by three-digit NAICS codes.	Compustat
Control Variable – Industry	*CapInt_ind*	Weighted industry capital intensity	Market share weighted average capital intensity, defined as physical capital / net income. Physical capital is the book value of Property, Plant, and Equipment - Total (Net).	Compustat
Control Variable – Industry	*Regu*	Industry regulation	A dummy variable that indicates whether a firm is in a regulated industry such as airlines, banking, pharmaceuticals, and utilities.	Compustat
Control Variable – Firm	*Emp (Log)*	Employees	Emp is a numeric measure that represents the number of employees in the firm. If the value is missing in Compustat, the alternative value from Forrester Q4 2009 Software Survey is used. Natural logarithm of the number is used.	Compustat
Control Variable – Firm	*Adv*	Advertising intensity	Advertising intensity is defined as advertising divided by sales.	Compustat
Control Variable – Firm	*RnD*	R&D intensity	R&D intensity is defined as research and development expense divided by sales.	Compustat
Control Variable – Firm	*MarketShare*	Market share of the firm	Market share of the firm is defined as the firm's sales divided by the total sales of the industry categorized by three-digit NAICS codes.	Compustat

Table B.1 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Control Variable – Firm	*CapInt*	Capital intensity	Capital intensity is defined as physical capital divided by net income.	Compustat
Control Variable - Firm	*ERPsys*[46]	ERP systems as a whole	A composite variable of various ERP components (ERP, FA, HCM, IKM, CRM, OM, SRM, PLM, EAM, SCM, PPM and ISP) generated using principal component analysis (PCA). The value is normalized.	Forrester Q4 2009 Software Survey
Control Variable - Firm	*FirmAge*	Firm age	An integer proxy that indicates the age of the firm. It is calculated as current year – begin of stock data (BEGDAT) + 1.	The Center for Research in Security Prices (CRSP) Stock Header Database
Control Variable - Firm	*Ind_Man* *Ind_RnW* *Ind_Ser* *Ind_Pub*	Industry	INDUSTRY7 has 8 options: 1) Manufacturing, 2) Retail & Wholesale, 3) Services, 4) Media, Entertainment, & Leisure, 5) Utilities & Telecom, 6) Finance & Insurance, 7) Public Sector, and 8) other. Option 8 is dropped. Four dummies are used. Ind_Man is for Option 1 Manufacturing. Ind_RnW is for Option 2 Retail & Wholesale. Ind_Ser is for Option 3, 4, 5 and 6 which all can be grouped into services. Ind_Pub is for Option 7 Public Sector. The categorization uses 2012 NAICS as a reference.	Forrester Q4 2009 Software Survey
Control Variable - Firm	*y09* *y10*	Year	Dummy variables for years 2009-2011.	Compustat

[46] See Table B.3 in Appendix B for the details about how the ERP component variables are constructed.

Table B.2. Definitions and data sources of variables for propensity score models

Variable Type - Dependent/ Independent/ Control	**Variable Name**	**Related Question/Explanation**	**Variable Definition/Construction**	**Data Source**
Dependent Variable	*TQ*	Tobin's q	Tobin's q = (MVE + PS + DEBT) / TA MVE = (Closing price of share at the end of the financial year) × (Number of common shares outstanding); PS = Liquidating value of the firm's outstanding preferred stock; DEBT = (Current liabilities - Current assets) + (Book value of inventories) + (Long-term debt); TA = Book value of total assets.	Compustat
Treatment Variable	*AnyCloud*	Any use of various cloud services in the firm	A dummy variable with 1 indicating any use of cloud services of IaaS, PaaS, SaaS, KaaS or BPaaS in the firm.	Forrester Q4 2009 Software Survey
Treatment Variable	*AnyCloud_bas*	Any use of basic cloud services in the firm	A dummy variable with 1 indicating any use of basic cloud services of IaaS, PaaS or SaaS in the firm.	Forrester Q4 2009 Software Survey
Treatment Variable	*AnyCloud_ext*	Any use of extended cloud services in the firm	A dummy variable with 1 indicating any use of extended cloud services of KaaS or BPaaS in the firm.	Forrester Q4 2009 Software Survey
Treatment Variable	*AnyIaaS*	Any use of IaaS in the firm	A dummy variable with 1 indicating any use of IaaS in the firm.	Forrester Q4 2009 Software Survey
Treatment Variable	*AnyPaaS*	Any use of PaaS in the firm	A dummy variable with 1 indicating any use of PaaS in the firm.	Forrester Q4 2009 Software Survey
Treatment Variable	*AnySaaS*	Any use of SaaS in the firm	A dummy variable with 1 indicating any use of SaaS in the firm.	Forrester Q4 2009 Software Survey
Treatment Variable	*AnyKaaS*	Any use of KaaS in the firm	A dummy variable with 1 indicating any use of KaaS in the firm.	Forrester Q4 2009 Software Survey
Treatment Variable	*AnyBPaaS*	Any use of BPaaS in the firm	A dummy variable with 1 indicating any use of BPaaS in the firm.	Forrester Q4 2009 Software Survey

Table B.2 (cont.)

Variable Type - Dependent/ Independent/ Control	**Variable Name**	**Related Question/Explanation**	**Variable Definition/Construction**	**Data Source**
Control Variable - Firm	*SOA*	SS.6: Which of the following best describes your firm's approach to, or use of, service-oriented architecture (SOA)?	SS.6 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of SOA usage in the firm. The numbers are converted from the original options for the question: 1) We are not pursuing SOA, and no immediate plans to do so, 2) We will pursue SOA within 12 months, 3) We use SOA but we do not have an enterprise-level strategy for SOA, 4) We use SOA and we do have (or are building) an enterprise-level strategy and commitment for SOA, and 5) Don't know. Option 3 and 4 get 1 and 2 points respectively while the others get 0 point. The value is normalized.	Forrester Q4 2009 Software Survey
Control Variable - Firm	*ERPsys*	ERP systems as a whole	A composite variable of various ERP components (ERP, FA, HCM, IKM, CRM, OM, SRM, PLM, EAM, SCM, PPM and ISP) generated using principal component analysis (PCA). The value is normalized.	Forrester Q4 2009 Software Survey
Control Variable – Firm	*MarketShare*	Market share of the firm	Market share of the firm is defined as the firm's sales divided by the total sales of the industry categorized by three-digit NAICS codes.	Compustat
Control Variable – Firm	*CapInt*	Capital intensity	Capital intensity is defined as physical capital divided by net income.	Compustat
Control Variable - Firm	*Ind_Man* *Ind_RnW* *Ind_Ser*	Industry	INDUSTRY7 has 8 options: 1) Manufacturing, 2) Retail & Wholesale, 3) Services, 4) Media, Entertainment, & Leisure, 5) Utilities & Telecom, 6) Finance & Insurance, 7) Public Sector, and 8) other. Option 8 is dropped. Four dummies are used. Ind_Man is for Option 1 Manufacturing. Ind_RnW is for Option 2 Retail & Wholesale. Ind_Ser is for Option 3, 4, 5 and 6 which all can be grouped into services. Ind_Pub is for Option 7 Public Sector. The categorization uses 2012 NAICS as a reference. (Notes. Ind_Pub is redundant thus dropped.)	Forrester Q4 2009 Software Survey

Table B.2 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Control Variable – Industry	*hhi_ind*	Herfindahl–Hirschman Index (HHI)	The Herfindahl-Hirschman Index (HHI) is to measure industry concentration (a proxy for industry competitiveness). The HHI for an industry j is given as $HHI_j = \Sigma_i s_{ij}^2$ where s_{ij} is the market share of firm i in industry j.	Compustat
Control Variable – Industry	*Q_ind*	Weighted industry average Tobin's q	Market share weighted average Tobin's q for all firms within the same industry categorized by three-digit NAICS codes.	Compustat
Control Variable – Industry	*Regu*	Industry regulation	A dummy variable that indicates whether a firm is in a regulated industry such as airlines, banking, pharmaceuticals, and utilities.	Compustat

Table B.3. Definitions and data sources of component variables for the composite variable of ERP systems

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Control Variable – Component of ERPsys	*ERP*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_1: Enterprise resource planning (ERP) software	PA.1_1 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of ERP usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Control Variable – Component of ERPsys	*FA*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_2: Finance and accounting software	PA.1_2 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of finance and accounting software usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Control Variable – Component of ERPsys	*HCM*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_3: Human capital management software	PA.1_3 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of human capital management software usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey

Table B.3 (cont.)

Variable Type - Dependent/ Independent/ Control	**Variable Name**	**Related Question/Explanation**	**Variable Definition/Construction**	**Data Source**
Control Variable – Component of ERPsys	*IKM*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_4: Information and knowledge management	PA.1_4 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of information and knowledge management software usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Control Variable – Component of ERPsys	*CRM*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_5: Customer relationship management (CRM) software	PA.1_5 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of CRM usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Control Variable – Component of ERPsys	*OM*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_6: Order management software	PA.1_6 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of order management software usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey

Table B.3 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Control Variable – Component of ERPsys	*SRM*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_7: Spend management or supplier relationship management (SRM) software	PA.1_7 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of SRM usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Control Variable – Component of ERPsys	*PLM*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_8: Product life-cycle management (PLM) software	PA.1_8 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of PLM usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Control Variable – Component of ERPsys	*EAM*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_9: Enterprise asset management (EAM) software	PA.1_9 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of EAM usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey

Table B.3 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Control Variable – Component of ERPsys	*SCM*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_10: Supply chain management (SCM) software	PA.1_10 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of SCM usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Control Variable – Component of ERPsys	*PPM*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_11: Project portfolio management (PPM) software	PA.1_11 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of PPM usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Control Variable – Component of ERPsys	*ISP*	PA.1: What are your firm's plans to adopt the following business applications? - PA.1_12: Software that supports an industry-specific process	PA.1_12 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of usage of software that supports an industry-specific process in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey

APPENDIX C

Table C.1. Examples of collaborative and arm's-length alliances

Collaborative alliance
Example 1: Emerson Network Power, a unit of Emerson, and Sun Microsystems Inc have announced a global sales alliance to provide businesses and organizations with roadmaps and technologies to increase the productivity and energy efficiency of their datacenters. The alliance will be formed through the interaction of Sun's datacenter consultants with Emerson's local Liebert power, cooling, and services specialists throughout the world to evaluate, develop and provide solutions to a variety of customer datacenter problems. The companies will deliver products and services for data center productivity and efficiency.
Example 2: Accenture PLC (Accenture) and GE Aviation Systems LLC (GE) planned to form a joint venture named Taleris(TM) to provide airline intelligent operations services. The JV will offer analytics dashboard, operations workbench, mobile-enabled access, integration architectures, and complementary technology and services such as business process redesign, systems integration, data analysis and customer decision support. This integrated service from Accenture and GE will improve efficiency by leveraging aircraft performance data, prognostics, recovery and planning optimization solutions.
Example 3: Broadcom Corp (BC) and Adobe Systems Inc (AS) formed a strategic alliance to provide integrated high definition Web-based video on television platform services in the United States. The alliance combined AS' Flash platform into BC's digital television and set top box system-on-a-chip platform.
Arm's-length alliance
Example1: Novo Nordisk A/S (NN) and Caisson Biotech LLC (CB) formed a strategic alliance wherein NN was granted license for CB's heparosan-based drug delivery technology. Under the agreement, CB will receive and contract research manufacturing payments as well as milestone payments upon the achievement of certain predefined clinical, regulatory and commercial targets as well as royalties on the global sales of the therapeutic products developed under the agreement, representing a total deal value potentially in excess of USD 100 mil.
Example 2: Dell Inc (DE) and Ramco Systems Ltd (RS) plan to form a strategic alliance to provide enterprise resource planning (ERP) solutions to middle market businesses. The alliance will distribute RS' ERP cloud which includes planning of production; asset management and analytics; supply chain management; corporate functions of human resource; customer relationship management and financial management. The alliance aims to lessen business cost and increase its revenue. The alliance will be included in DE's portfolio of solutions, particularly in Software-as-a-Service (SaaS) tools.
Example 3: Citigroup Inc and Sumitomo Mitsui Financial Group Inc planned to form a strategic alliance to provide Sumitomo Mitsui Financial Group an access to Citigroup's global networks in corporate and investment banking, including M&A and sales and trading services.

Source. All the listed examples are direct quotes from the "deal text" column in the SDC Platinum database.

Table C.2: Definitions and data sources of variables for panel logistic and count models

Variable Type - Dependent/ Independent/ Control	**Variable Name**	**Related Question/Explanation**	**Variable Definition/Construction**	**Data Source**
Dependent Variable – Panel Logistic Model	*jvtype*	Joint venture alliance	A binary measure. An alliance is coded with 1 if it is classified as joint venture or 0 if otherwise by reviewing its joint venture flag, activity description, deal text and other relevant information.	SDC Platinum Database
Dependent Variable – Panel Logistic Model	*collatype*	Collaborative alliance	A binary measure. An alliance is coded with 1 if it is classified as collaborative or 0 if arm's-length by reviewing its activity description, deal text and other relevant information. Please note, those joint-venture records are also further classified into either collaborative or arm's-length for this variable.	SDC Platinum Database
Dependent Variable – Panel Count Models	*cttotal*	Total number of various types of alliances for the firm in a year	A positive integer count measure. The total number of all alliances regardless of their types is calculated for each firm in each year.	SDC Platinum Database
Dependent Variable – Panel Count Models	*ctjv*	Number of joint ventures for the firm in a year	A positive integer count measure. The total number of all joint-venture alliances is calculated for each firm in each year.	SDC Platinum Database
Dependent Variable – Panel Count Models	*ctnoneq*	Number of non-equity alliances for the firm in a year	A positive integer count measure. The total number of all non-equity alliances is calculated for each firm in each year.	SDC Platinum Database
Dependent Variable – Panel Count Models	*ctcolla*	Number of collaborative alliances for the firm in a year	A positive integer count measure. The total number of all collaborative alliances is calculated for each firm in each year, excluding those joint-venture records.	SDC Platinum Database
Dependent Variable – Panel Count Models	*ctarmslen*	Number of arm's-length alliances for the firm in a year	A positive integer count measure. The total number of all arm's-length alliances is calculated for each firm in each year, excluding those joint-venture records.	SDC Platinum Database

Table C.2 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Independent Variable	*IaaS*	SS.8: What are your firm's plans to adopt the following software technologies? - SS.8_1: Cloud infrastructure-as-a-service (Iaas)	SS.8_1 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of IaaS usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Independent Variable	*SaaS*	SS.8: What are your firm's plans to adopt the following software technologies? - SS.8_2: Software-as-a-service (SaaS)	SS.8_2 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of SaaS usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Independent Variable	*PaaS*	SS.8: What are your firm's plans to adopt the following software technologies? - SS.8_3: Platform-as-a-service (PaaS)	SS.8_3 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of PaaS usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey

Table C.2 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Independent Variable	*KaaS*	SS.8: What are your firm's plans to adopt the following software technologies? - SS.8_4: Information/Knowledge-as-a-service (I-aaS/KaaS)	SS.8_4 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of I-aaS/KaaS usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized.	Forrester Q4 2009 Software Survey
Independent Variable	*BPaaS*	SS.8: What are your firm's plans to adopt the following software technologies? - SS.8_5: Business process-as-a-service (BP-aaS)	SS.8_5 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of BP-aaS usage in the firm. The numbers are converted from the original options for the question: 1) Not interested, 2) Interested but no plans, 3) Planning to implement in a year or more, 4) Planning to implement in the next 12 months, 5) Implemented, not expanding, 6) Expanding/upgrading implementation, and 7) Don't know. Option 5 and 6 get 1 and 2 points respectively while the others get 0 point. The points are normalized. Please note, BPaaS is not a standalone cloud service model variable, instead, it is an inherent interaction variable that represents the complementarity between business process and cloud computing.	Forrester Q4 2009 Software Survey
Independent Variable	*cloud*	Cloud computing as a whole	A composite variable calculated by IaaS + PaaS + SaaS + KaaS + BPaaS. The value is normalized.	Forrester Q4 2009 Software Survey
Control Variable – Industry	*hhi_ind*	Herfindahl–Hirschman Index (HHI)	The Herfindahl-Hirschman Index (HHI) is to measure industry concentration (a proxy for industry competitiveness). The HHI for an industry j is given as $HHI_j = \Sigma_i s_{ij}^2$ where s_{ij} is the market share of firm i in industry j.	Compustat
Control Variable – Industry	*Q_ind*	Weighted industry average Tobin's q	Market share weighted average Tobin's q for all firms within the same industry categorized by three-digit NAICS codes.	Compustat

Table C.2 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Control Variable – Industry	*Regu*	Industry regulation	A dummy variable that indicates whether a firm is in a regulated industry such as airlines, banking, pharmaceuticals, and utilities. The following NAICS codes are used to determine if a firm is in a regulated industry: 481, 52, 325, 424 and 22.	Compustat
Control Variable – Firm	*Emp (Log)*	Employees	Emp is a numeric measure that represents the number of employees in the firm. If the value is missing in Compustat, the alternative value from Forrester Q4 2009 Software Survey is used. Natural logarithm of the number is used.	Compustat
Control Variable – Firm	*Adv*	Advertising intensity	Advertising intensity is defined as advertising divided by sales.	Compustat
Control Variable - Firm	*SOA*	SS.6: Which of the following best describes your firm's approach to, or use of, service-oriented architecture (SOA)?	SS.6 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of SOA usage in the firm. The numbers are converted from the original options for the question: 1) We are not pursuing SOA, and no immediate plans to do so, 2) We will pursue SOA within 12 months, 3) We use SOA but we do not have an enterprise-level strategy for SOA, 4) We use SOA and we do have (or are building) an enterprise-level strategy and commitment for SOA, and 5) Don't know. Option 3 and 4 get 1 and 2 points respectively while the others get 0 point. The value is normalized.	Forrester Q4 2009 Software Survey
Control Variable - Firm	*ERPsys*[47]	ERP systems as a whole	A composite variable of various ERP components (ERP, FA, HCM, IKM, CRM, OM, SRM, PLM, EAM, SCM, PPM and ISP) generated using principal component analysis (PCA). The value is normalized.	Forrester Q4 2009 Software Survey

[47] See Table B.3 in Appendix B for the details of how the ERP component variables are constructed.

Table C.2 (cont.)

Variable Type - Dependent/ Independent/ Control	**Variable Name**	**Related Question/Explanation**	**Variable Definition/Construction**	**Data Source**
Control Variable - Firm	*Ind_Man* *Ind_RnW* *Ind_Ser*	Industry	INDUSTRY7 has 8 options: 1) Manufacturing, 2) Retail & Wholesale, 3) Services, 4) Media, Entertainment, & Leisure, 5) Utilities & Telecom, 6) Finance & Insurance, 7) Public Sector, and 8) other. Option 8 is dropped. Three dummies are used. Ind_Man is for Option 1 Manufacturing. Ind_RnW is for Option 2 Retail & Wholesale. Ind_Ser is for Option 3, 4, 5 and 6 which all can be grouped into services. Ind_Pub is for Option 7 Public Sector. The categorization uses 2012 NAICS as a reference. Ind_Pub is eventually dropped for multicollinearity.	Forrester Q4 2009 Software Survey
Control Variable - Firm	*y09* *y10* *y11*	Year	Year dummy variables for years 2009-2012.	Compustat

Table C.3. Definitions and data sources of variables for propensity score matching (PSM) models

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Dependent Variable	*jvtype*	Joint venture alliance	A binary measure. An alliance is coded with 1 if it is classified as joint venture or 0 if otherwise by reviewing its joint venture flag, activity description, deal text and other relevant information.	SDC Platinum Database
Dependent Variable	*cttotal*	Total number of various types of alliances for the firm in a year	A positive integer count measure. The total number of all alliances regardless of their types is calculated for each firm in each year.	SDC Platinum Database
Dependent Variable	*ctjv*	Number of joint ventures for the firm in a year	A positive integer count measure. The total number of all joint-venture alliances is calculated for each firm in each year.	SDC Platinum Database
Dependent Variable	*ctnoneq*	Number of non-equity alliances for the firm in a year	A positive integer count measure. The total number of all non-equity alliances is calculated for each firm in each year.	SDC Platinum Database
Dependent Variable	*ctcolla*	Number of collaborative alliances for the firm in a year	A positive integer count measure. The total number of all collaborative alliances is calculated for each firm in each year, excluding those joint-venture records.	SDC Platinum Database
Dependent Variable	*ctarmslen*	Number of arm's-length alliances for the firm in a year	A positive integer count measure. The total number of all arm's-length alliances is calculated for each firm in each year, excluding those joint-venture records.	SDC Platinum Database
Treatment Variable	*AnyCloud*	Any use of various cloud services in the firm	A dummy variable with 1 indicating any use of cloud services of IaaS, PaaS, SaaS, KaaS or BPaaS in the firm.	Forrester Q4 2009 Software Survey
Treatment Variable	*AnyIaaS*	Any use of IaaS in the firm	A dummy variable with 1 indicating any use of IaaS in the firm.	Forrester Q4 2009 Software Survey
Treatment Variable	*AnyPaaS*	Any use of PaaS in the firm	A dummy variable with 1 indicating any use of PaaS in the firm.	Forrester Q4 2009 Software Survey
Treatment Variable	*AnySaaS*	Any use of SaaS in the firm	A dummy variable with 1 indicating any use of SaaS in the firm.	Forrester Q4 2009 Software Survey
Treatment Variable	*AnyKaaS*	Any use of KaaS in the firm	A dummy variable with 1 indicating any use of KaaS in the firm.	Forrester Q4 2009 Software Survey

Table C.3 (cont.)

Variable Type - Dependent/ Independent/ Control	**Variable Name**	**Related Question/Explanation**	**Variable Definition/Construction**	**Data Source**
Treatment Variable	*AnyBPaaS*	Any use of BPaaS in the firm	A dummy variable with 1 indicating any use of BPaaS in the firm.	Forrester Q4 2009 Software Survey
Control Variable - Firm	*SOA*	SS.6: Which of the following best describes your firm's approach to, or use of, service-oriented architecture (SOA)?	SS.6 is a numeric measure which has the range from 0 to 2. The number 0 to 2 indicates the magnitude of SOA usage in the firm. The numbers are converted from the original options for the question: 1) We are not pursuing SOA, and no immediate plans to do so, 2) We will pursue SOA within 12 months, 3) We use SOA but we do not have an enterprise-level strategy for SOA, 4) We use SOA and we do have (or are building) an enterprise-level strategy and commitment for SOA, and 5) Don't know. Option 3 and 4 get 1 and 2 points respectively while the others get 0 point. The value is normalized.	Forrester Q4 2009 Software Survey
Control Variable – Firm	*Emp (Log)*	Employees	Emp is a numeric measure that represents the number of employees in the firm. If the value is missing in Compustat, the alternative value from Forrester Q4 2009 Software Survey is used. Natural logarithm of the number is used.	Compustat
Control Variable – Firm	*Adv*	Advertising intensity	Advertising intensity is defined as advertising divided by sales.	Compustat
Control Variable – Firm	*CapInt*	Capital intensity	Capital intensity is defined as physical capital divided by net income.	Compustat
Control Variable - Firm	*Ind_Man* *Ind_RnW* *Ind_Ser*	Industry	INDUSTRY7 has 8 options: 1) Manufacturing, 2) Retail & Wholesale, 3) Services, 4) Media, Entertainment, & Leisure, 5) Utilities & Telecom, 6) Finance & Insurance, 7) Public Sector, and 8) other. Option 8 is dropped. Four dummies are used. Ind_Man is for Option 1 Manufacturing. Ind_RnW is for Option 2 Retail & Wholesale. Ind_Ser is for Option 3, 4, 5 and 6 which all can be grouped into services. Ind_Pub is for Option 7 Public Sector. The categorization uses 2012 NAICS as a reference. (Notes. Ind_Pub is redundant thus dropped.)	Forrester Q4 2009 Software Survey

Table C.3 (cont.)

Variable Type - Dependent/ Independent/ Control	Variable Name	Related Question/Explanation	Variable Definition/Construction	Data Source
Control Variable – Industry	*hhi_ind*	Herfindahl–Hirschman Index (HHI)	The Herfindahl-Hirschman Index (HHI) is to measure industry concentration (a proxy for industry competitiveness). The HHI for an industry j is given as $HHI_j = \Sigma_i s_{ij}^2$ where s_{ij} is the market share of firm i in industry j.	Compustat
Control Variable – Industry	*Q_ind*	Weighted industry average Tobin's q	Market share weighted average Tobin's q for all firms within the same industry categorized by three-digit NAICS codes.	Compustat
Control Variable – Industry	*Regu*	Industry regulation	A dummy variable that indicates whether a firm is in a regulated industry such as airlines, banking, pharmaceuticals, and utilities.	Compustat