The Effect of IT Modularity on Adoption of Cloud Computing

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[Anonymized for review]

[Note: A graduate student has done the bulk of this work.]

Abstract

Companies with substantial extant in-house IT investments are still hesitant to use cloud computing, as they have concerns about the uncertainty, costs and risks associated with this new paradigm. Studies have noted risks from the perspective of cloud providers and have also indicated an association between service-based modularization and cloud computing. However, few have considered addressing the issues from the perspective of enterprises that will use cloud services and the theoretical and empirical support for the association. In this paper, we focus on IT modularity and how it facilitates the adoption of cloud computing. The paper empirically tests the relationship between IT modularity and cloud computing adoption using a firm-level dataset pertaining to IT services decisions and trends. We also present research questions for future research based on our findings.

Keywords: IT modularity, cloud computing, service-oriented, transaction costs, outsourcing, alliances, small and medium-sized business, SMB, enterprise

1. Introduction

Modularity has been posited to reduce system complexity (Baldwin and Clark, 2000; Langlois, 2002; Parnas, 1972; Simon, 1962), and promote flexibility and agility (Baldwin and Clark, 2003; Floreano et al., 1999; Lau Antonio, Yam and Tang, 2007; Sanchez, 2004; Sanchez and Mahoney, 2002; Schilling, 2000; Watanabe and Ane, 2004; Worren, Moore and Cardona, 2002). For example, Amtrak had difficulty linking its online reservation systems to third-party travel sites until it adopted a more modular and flexible service-oriented architecture (SOA) (Information Week, 2006). This is one among many cases that testify to the benefits of IT systems modularity (IBM, 2010). With the emergence of the 'cloud computing' and related service-based technological paradigms, the landscape of IT modularity has broadened. Notwithstanding the wide acceptance by many startups, companies with substantial in-house IT resources seem to have different experiences with cloud computing. Some enterprises have been hesitant to adopt cloud computing with concerns about the uncertainty, costs and risks associated with this new paradigm related to availability, lock-in, security and privacy (Armbrust et al., 2010). The risks and challenges of cloud computing affect cloud users, those who use services from cloud providers and also provide their own cloud services to end users, as well as end users. Prior studies have focused on addressing the risks from the perspective of cloud providers (Bernstein et al., 2009; Bertino et al., 2009; Catteddu, 2010; Chow et al., 2009; Gopalakrishnan, 2009; Jensen et al., 2009; Jansen and Grance, 2011; and more), but not from the perspective of cloud users. In this paper, we focus on the use of cloud computing by enterprises with substantial internal IT investments. We posit the question: How can enterprises prepare their IT infrastructure and organization to be ready for adoption of cloud computing, given the major risks and challenges in cloud computing?

In spite of successful demonstrations of service-oriented architecture (SOA) and cloud computing synergy in the real-world cases (Mohawk Fine Papers, 2012; SearchSOA, 2001; ZDNet, 2009) and research literature (Feuerlicht, 2010; Mircea, 2010; Namjoshi and Gupte, 2009; Sedayao, 2008; Tsai, Sun and Balasooriya, 2010; Wei and Blake, 2010), prior research does not provide much empirical evidence about the relationship between IT modularity and adoption of cloud computing. Therefore, the purpose of this study is to empirically examine this relationship. We submit that IT modularization in an enterprise, especially those with significant in-house IT assets, may help the firm adopt and utilize cloud computing.

This paper presents the findings of a survey-based empirical study about the relation of two constructs: IT modularity and cloud computing adoption. We examine the association between the two constructs through multivariate regression models. We also examine the magnitude of differences in cloud computing adoption between small and medium-sized businesses and large enterprises. In the following sections, we present a theoretical framework for our hypotheses. We then examine whether IT modularity is associated with increases in firms' level of adoption of cloud services at two distinct levels, server and application, by controlling for firms' cloud experience and preferences, among other industrial and firm-specific variables. We theorize that this association is driven by various transaction cost reductions that reduce the risks of cloud computing offered by IT modularity. We also present and discuss the primary results and suggest limitations and future work.

2. Theoretical Framework

In this section, we present the theoretical arguments for the link between IT modularity and adoption of cloud computing. The broad relationship between IT modularity and adoption of cloud computing can be summarized as in Figure 1. We draw from prior transaction-cost economics (TCE)-based literature on outsourcing and alliances to posit an association between IT modularity and the adoption of cloud computing.

---Insert Figure 1 about here---

Before proposing hypotheses for cloud computing adoption, we discuss taxonomies of cloud computing services and IT modularity, and the role of company size in the adoption decision for cloud services.

2.1 Taxonomy of Cloud Services

The services provided by cloud computing can be grouped into several conceptual layers which are called service models. Mell and Grance (2011), and Hoefer and Karagiannis (2010) summarize the three most widely recognized and used service models: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). More concisely, the three service models can be classified into two fundamental groups: application-level services and server-level services. This is because the two groups have an essential difference: application-level services typically provide end user services directly, while server-level services typically only provide foundational hardware or software resources that end-users and vendors can deploy to build cloud products or services. Application-level services mainly include SaaS, while server-level services mainly include PaaS and IaaS.

2.2 IT Modularity Taxonomy

Prior literature suggests that IT modularity is an interchangeable term used for both IT infrastructure modularity and IT architecture modularity. 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 IT modularity consists of application functionality and data transparency (Dakin, 1993;

Gibson, 1994). Ulrich (1995, p. 422) defines a modular architecture as one that includes “one-to-one mapping from functional elements to physical components of the product, and specifies decoupled interfaces between components”. Tiwana and Konsynski (2010) identify Web services and SOA as typical modular IT architectures.

2.3 Firm Size

Company size may play an important role in cloud computing adoption. Specifically, small firms and large enterprises are likely to have different considerations, attitudes and strategies toward 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 company size and extant IT resources and overhead. Companies can be generally divided into at least two major groupings according to number of employees: *small and medium-sized businesses* (SMBs) and *enterprises*. SMBs (or small and medium-sized enterprises, SMEs) are companies whose personnel numbers fall below certain limits. Here, we adopt the standard from Forrester Research Inc. that an SMB is a company whose number of employees is between 2 and 999 inclusive. An enterprise is a company whose number of employees is equal to or greater than 1,000. We posit that, all other factors being equal, SMBs are more likely to adopt cloud computing than large enterprises. One particular reason is that cloud computing can act to level the playing field when it comes to IT and computing resources available at a firm’s disposal. Small firms can utilize cloud-computing resources to overcome disadvantages in resources, by more easily accessing IT resources otherwise restricted to larger firms.

2.4 IT Modularity and Adoption of Cloud Computing

We argue that TCE, through its insights on the risks of opportunism in a transaction (Teece, 1977; Williamson, 1983), enables better understanding of cloud computing adoption. Prior work has established asset specificity as an influential transaction attribute (e.g., Williamson, 1983, Rindfleisch and Heide, 1997). Asset specificity can be 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 (McGuinness 1994). We submit that IT modularity can reduce asset specificity, coordination costs and opportunism from the perspective of transaction cost economics (TCE), and hence alleviate some risks associated with a public cloud. In addition, IT modularity can facilitate vertical dis-intermediation, outsourcing and alliances.

Modular systems can lower the transaction costs (through reductions in asset specificity, coordination costs, reduced delegation effort, and decreased need for monitoring effort) and generate economies of scale while assembling the offering for a consumer (e.g., Langlois and Robertson, 1992). Kumar and Van Dissel (1996) claim that software characteristics such as reusability and modularity may reduce transaction risk (or the cost associated with the exposure to being exploited) in inter-firm relationships. Transaction risk could be a direct cause of the risk of opportunism and lead to conflict in inter-organizational systems alliances. By enhancing the modularity of their internal IT systems, cloud users can reduce the risk of opportunistic behavior by cloud providers.

Along similar lines, modular IT may help a firm tackle availability concerns and vendor lock-in situations that are prevalent in current public clouds. For instance, modularization may reduce the risk of opportunism by making a firm easier to switch suppliers and hence less vulnerable to lock-in (i.e., hold-up) by a particular supplier (e.g., Hoetker 2006). Similarly, IT modularity can potentially help mitigate the concerns of privacy, security and data ownership in cloud computing. Sanchez and Mahoney (2002) argue that a modular product architecture implies that the engineering interfaces are standardized. Shared standards reduce specificity and provide a form of embedded control that reduces search, monitoring, and enforcement costs. By reducing the amount of required communication, modular architectures with standardized interfaces mitigate the hazard of proprietary information being leaked between product components (Teece, 1996). Component standardization, by definition, reduces asset specificity and information leakage hazards, thereby reducing the sum of production and transaction costs (e.g., Riordan and Williamson 1985). Clemons and Hitt (2004) also 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.

IT modularity can facilitate outsourcing of internal IT components to external cloud computing. Clemons, Reddi and Row (1993) argue that IT can reduce coordination costs without increasing the associated risks, which lead to more outsourcing and less vertical integration. 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*. The terminology of outsourcing is described as buying a good or service from another company rather than making or doing it yourself (Womack, 1990). Combining these viewpoints, 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. Similarly, Schilling and Steensma (2001) notice that modular designs facilitate outsourcing via contracts and/or alliances. They clarify that a standard interface makes assets non-specific. Mikkola (2003) argues that successful outsourcing can only be realized when a system can be modularized with well-specified and standardized interfaces for the modules. Camuffo (2000) observes that modularization and outsourcing are becoming increasingly inseparable particularly when producing a ‘world car’. Fixson, Ro and Liker (2005) say that modularizing product architecture may help reduce the size of a firm boundary, and thus result in the outsourcing of components and processes.

As Mikkola and Skjoett-Larsen (2003) and Sako (2003) indicate, one of the motives for outsourcing is to shift initial investment costs and the risk of demand uncertainty to a supplier. This is exactly what many companies are doing through cloud-computing adoption. In doing so, they usually first put their non-core functions or applications into public clouds, which can take advantage of the clouds’ capabilities and save IT costs. At the same time, they take steps to mitigate the risks that cloud computing entails for their core businesses. 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. Armbrust et al. (2010) suggest that a major benefit of IT modularity is to facilitate use of multiple cloud providers’ services to increase access to IT resources and reduce the risk of vendor lock-in.

Building on prior theory, we posit that more modularity in a firm’s internal IT assets may facilitate adoption of cloud computing (See Figure 1) by reducing various transaction costs and promoting outsourcing and alliances. Because cloud computing can be grouped into two major types (as noted earlier) — server-level cloud services and application-level cloud services —

and since the capabilities required for and generated from these two major types of services are different, we test this proposition for both types of cloud computing:

Hypothesis 1A (H1A): *IT modularity is associated with adoption of server-level cloud computing for SMBs and large enterprises combined.*

Hypothesis 1B (H1B): *IT modularity is associated with adoption of application-level cloud computing for SMBs and large enterprises combined.*

As Talukder and Zimmerman (2010), and Kushida, Breznitz and Zysman (2008) have observed, company size may play an important role in whether and how much a company will adopt a certain cloud computing service. Thus, we posit four relevant hypotheses separately for SMBs and large enterprises as follows:

Hypothesis 2A (H2A): *IT modularity is associated with adoption of server-level cloud computing for SMBs.*

Hypothesis 2B (H2B): *IT modularity is associated with adoption of application-level cloud computing for SMBs.*

Hypothesis 3A (H3A): *IT modularity is associated with adoption of server-level cloud computing for large enterprises.*

Hypothesis 3B (H3B): *IT modularity is associated with adoption of application-level cloud computing for large enterprises.*

Finally, as posited by Talukder and Zimmerman (2010), and Kushida, Breznitz and Zysman (2008), cloud computing adoption may be easier and more attractive to SMBs than to large enterprises. Thus, we consider whether SMBs are more likely to adopt the two levels of cloud-computing services:

Hypothesis 4A (H4A): *SMBs have a more adoption of server-level cloud computing services than large enterprises.*

Hypothesis 4B (H4B): *SMBs have a more adoption of application-level cloud computing services than large enterprises.*

3. Research Design and Methodology

3.1 Data

To test the hypotheses, we use data from Forrester Research Inc., which is an independent technology and market research company that provides advice impacts of technology to clients and the public. The dataset is based upon a comprehensive online and telephone survey about adoption trends in software technology conducted by Forrester. The survey was administered 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). The survey was administered in the period from December 2008 to February 2009 (Q4 2008). The independent variables about IT modularity, control variables and dependent variables about cloud computing all can be identified and linked to specific questions in the dataset.

3.2 Variables

We drew from prior literature to develop our measures of IT modularity and adoption of cloud computing (Byrd and Turner, 2000; Chung et al., 2005; Duncan, 1995; Hoefer and Karagiannis, 2010; Mell and Grance, 2011; Tafti, Mithas and Krishnan, 2013; Tiwana and Konsynski, 2010; Youseff, Butrico and Da Silva, 2008). Keywords for the construct measures from the survey questions in the literature are consolidated. By validating the IT modularity keywords in the dataset, the following pertinent keywords are finally identified: 1) Service-

Oriented Architecture and SOA, and 2) Web service(s). In a similar way, mapping the consolidated cloud computing keywords to the questions in the dataset yields the following finalized keywords: 1) Software-as-a-Service / SaaS and 2) Virtual server.

Among the control variables, Satisfaction with SOA (*SatisSOA*) controls the variation of the level of satisfaction of SOA between different firms. A greater satisfaction with SOA might intrinsically encourage a firm to try and adopt more cloud computing services. Similarly, we control for organizational software selection criteria (*ImCriSW*), specific important organizational goals (*ImGoal*), and important pre-adoption organizational decision factors when adopting SaaS (*ImAdSaaS*) as well. These variables represent the variations of the firms' perceptions on the importance of IT-related activities, which might affect the firms' overall attitudes toward cloud computing adoption. Furthermore, a firm's development platforms for custom-developed applications (*CustAppPlat*) might also have an impact on whether cloud computing will be adopted due to the platforms' intrinsic traits and compatibility with cloud computing. Additionally, if a firm prefers the SaaS deployment option when implementing a major application (*PDepSaaS*), it might influence the firm's use of cloud computing. Likewise, firms' reasons for indifference toward SaaS (*IndiffSaaS*) could also serve well as control variables because they might have an impact on the adoption of cloud computing. Finally, company size (*ComSize*), revenue (*Rev*), IT spending (*ITSpend*), and industry (*Ind*) are other firm-level control variables that need to be accounted for as well because these variables might affect whether and how much a firm will use cloud computing.

The corresponding names, questions, constructions and definitions, and data sources for all the independent, dependent and control variables used in the hypothesis tests are listed in Table 7.

——Insert Table 7 about here——

Table 1, 2, and 3 show summary statistics and correlations for the entire data of Q4 2008 combined with SMBs and Enterprises, only Small and Medium Businesses (SMBs, 2-999 employees), and only Enterprises (1,000+ employees) respectively.

——Insert Table 1 about here——

——Insert Table 2 about here——

——Insert Table 3 about here——

3.3 Estimation Models

3.3.1 Models for Adoption of Cloud Computing

Our dependent variables *PerVirSer* and *PerSaaS* are numeric measures ranging from 0 to 100 (in percentage). The Q4 2008 dataset contains combined SMBs and enterprises data with 2,227 records in total, among which there are 1,232 records for the SMBs and 995 records for the enterprises. We perform several tests: 1) An overall multivariate OLS regression for the entire dataset combining SMB and Enterprise data, 2) An OLS regression for the SMB firms alone, 3) An OLS regression for large enterprise firms alone, and 4) Pairwise comparison (mean) tests for cloud computing adoption (both server-level services and application-level services) across SMBs and enterprises. In addition, for each of the OLS regressions, corresponding descriptive statistics and pairwise correlations are shown. For each of the sub samples, the following two OLS regressions are used to test the hypotheses on the aforementioned two types of cloud computing adoption: server-level cloud services and application-level cloud services in the following models 1 and 2 respectively.

OLS model 1:

$$PerVirSer = Constant + \beta_1 \times ApprToSOA + \beta_2 \times BizTranSOA + \beta_3 \times ProjSOA + \beta_4 \times WSCApp + \beta_5 \times Controls + \varepsilon \quad (1)$$

OLS model 2:

$$PerSaaS = Constant + \beta_1 \times ApprToSOA + \beta_2 \times BizTranSOA + \beta_3 \times ProjSOA + \beta_4 \times WSCApp + \beta_5 \times Controls + \varepsilon \quad (2)$$

Please note the term *Controls* in the two models represents all control variables (See Table 7). The results for 1), 2), and 3) are shown in Table 4, 5 and 6 respectively. The results for 4) are discussed in the section of Results.

——Insert Table 4 about here——

——Insert Table 5 about here——

——Insert Table 6 about here——

4. Results

Table 4, 5 and 6 present the OLS regression results for our set of hypotheses linking IT modularity with cloud computing adoption. The main proposition, that predicts that IT modularity is associated with a greater likelihood of cloud computing adoption, is supported fully in the sub-sample of Small-Medium Business firms, and to some degree for the sub-sample of large enterprises. Specifically, across the entire dataset, for H1A, the overall F test is significant at the 1% level, and the coefficient estimates of *ProjSOA* and *WSCApp* are significant at the 5% level and the 10% level respectively. For H1B, the overall F test is significant at the 1% level, and the coefficient estimate of *WSCApp* is significant at the 10% level.

For the Small-Medium Business sub-sample, for H2A, the overall F test is significant at the 1% level, and the coefficient estimates of *ProjSOA* and *WSCApp* are significant at the 10% level and the 5% level respectively. For H2B, the overall F test is significant at the 1% level, and the coefficient estimate of *ProjSOA* is significant at the 10% level.

In the Enterprise test, for H3A, the overall F test is not significant (though it is close to the 10% level), and no coefficient estimates of *ApprToSOA*, *BizTranSOA*, *ProjSOA* and *WSCApp* are significant at the 10% level. For H3B, the overall F test is significant at the 1% level, and the coefficient estimate of *WSCApp* is significant at the 5% level.

One-sided Student's t-tests are done for comparing the means of cloud computing adoption on server-level cloud services and application level cloud services respectively between SMBs and large enterprises. The hypothesis of H4A, SMBs adopt more server-level cloud services than large enterprises, is supported at the significant level of 10% (Right-tailed t = 1.5861, Pr(T > t) = 0.0564). The hypothesis of H4B, SMBs adopt more application-level cloud services than large enterprises, is supported at the significant level of 1% (Right-tailed t = 3.0068, Pr(T > t) = 0.0013). This shows that SMBs are indeed more likely to use cloud computing than large enterprises at the moment, which confirms the arguments of Talukder and Zimmerman (2010), and Kushida, Breznitz and Zysman (2008).

5. Discussion

5.1 Main Findings and Research Implications

To our knowledge this is one of the first studies to empirically examine the quantitative effects of IT modularity in cloud computing adoption for both small and medium-sized businesses (SMBs) and large enterprises. First, we find that IT modularity is associated with greater adoption of both server-level and application-level cloud computing for the SMBs and large enterprises. This finding documents support for the notion that IT modularity reduces various transaction costs and risks, promotes outsourcing and alliances, and therefore enables more adoption of external cloud computing. Second, we find that IT modularity is associated with greater adoption of both server-level and application-level cloud computing for the SMBs.

Third, while we find that IT modularity is associated with greater adoption of application-level cloud computing, we did not find a statistically significant association between IT modularity and server-level cloud computing. We also find that the average use of both server-level and application-level cloud computing is higher in SMBs than in large enterprises, though the difference is more significant on the application level than on the server level. In other words, the positive association between IT modularity and adoption of cloud computing appears to be stronger in the context of SMB companies than in large enterprises. These findings complement the proposition raised by Talukder and Zimmerman (2010), and Kushida, Breznitz and Zysman (2008) that, since SMBs have a more urgent need for ample affordable IT resources and have much fewer factors to consider than most of the large enterprises, they tend to use more cloud computing on both server and application levels. On the other hand, since large enterprises have to consider many more factors when adopting cloud computing, they tend to first use some external cloud-based applications (i.e., SaaS) to run their non-critical tasks on a trial basis. As to the more complicated server-level services (i.e., PaaS and IaaS), large enterprises are still quite reluctant to use these as they are probably concerned with deeper data ownership, security and privacy issues, reputation, and regulation requirements that will affect the ways they deal with their sensitive data. Large enterprises also typically have sufficient internal IT resources already at their disposal which make them less driven to use external cloud resources.

5.2 Managerial Implications

Cloud computing, as an appealing new IT consumption model, is becoming more accepted by companies. Cloud computing can help a company to achieve not only cost savings, but also flexible and agile business innovations. Our results suggest that strategic internal IT modularity should be considered as an important factor when a company considers adoption of cloud computing in the near future. The infrastructure and architecture of internal IT systems play an important role in whether a company can successfully transfer some of its processes to new businesses in a public cloud. Flexible IT architecture also helps ensure that existing internal processes synchronize effectively with cloud-based processes. Managers should identify the specific candidate processes that might be migrated to an external cloud and consider their interactions and relations with other internal processes. In doing so, managers can better modularize IT processes that are likely to be moved to the cloud.

SMB companies may find themselves to be in a better position to modularize their internal IT systems by developing projects using SOA and building new custom applications using Web services or standards-based architectures. This will help diminish the risks as well as maximize the benefits of cloud computing at both the server level and the application level. Large enterprises may find that modularizing their internal IT systems, by building new custom applications using Web services, can lead to better risk-prevention, adoption and utilization of SaaS-based cloud computing.

This study is not without limitations that can be overcome in future work. In particular, new empirical models can be devised for greater insight into alternative explanations. The difference between the IT modularity effects on SMBs versus large enterprises is interesting and merits further exploration. Further, it would be valuable to study how factors other than IT modularity can affect adoption of cloud computing, yielding greater insight into how firms can better leverage cloud computing in the future.

Appendix

Table 1: Summary statistics and correlations for the entire dataset of Q4 2008

	Mean	S.D.	Min	Max	PerVirSer	PerSaaS	ApprToSOA	BizTranSOA	ProjSOA	WSCApp
PerVirSer	3.034	8.799	0.000	100.000	1.000					
PerSaaS	2.907	8.580	0.000	100.000	0.145	1.000				
					(0.000)					
ApprToSOA	0.357	0.652	0.000	2.000	0.018	0.028	1.000			
					(0.406)	(0.186)				
BizTranSOA	0.073	0.260	0.000	1.000	**0.037***	0.027	0.523	1.000		
					(0.081)	(0.206)	(0.000)			
ProjSOA	0.492	0.959	0.000	4.000	**0.044****	**0.045****	0.853	0.486	1.000	
					(0.037)	(0.032)	(0.000)	(0.000)		
WSCApp	0.056	0.230	0.000	1.000	-0.021	-0.027	0.237	0.097	0.196	1.000
					(0.324)	(0.204)	(0.000)	(0.000)	(0.000)	

*Note. *Significant at 10%, **Significant at 5%, ***Significant at 1%.*

Table 2: Summary statistics and correlations for the SMBs of Q4 2008

	Mean	S.D.	Min	Max	PerVirSer	PerSaaS	ApprToSOA	BizTranSOA	ProjSOA	WSCApp
PerVirSer	3.291	9.880	0.000	100.000	1.000					
PerSaaS	3.378	9.882	0.000	100.000	0.101	1.000				
					(0.000)					
ApprToSOA	0.210	0.504	0.000	2.000	**0.088*****	**0.079*****	1.000			
					(0.002)	(0.006)				
BizTranSOA	0.044	0.205	0.000	1.000	**0.076*****	**0.061****	0.540	1.000		
					(0.008)	(0.032)	(0.000)			
ProjSOA	0.341	0.862	0.000	4.000	**0.107*****	**0.066****	0.884	0.495	1.000	
					(0.000)	(0.021)	(0.000)	(0.000)		
WSCApp	0.037	0.188	0.000	1.000	-0.024	-0.001	0.211	0.106	0.204	1.000
					(0.397)	(0.963)	(0.000)	(0.000)	(0.000)	

*Note. *Significant at 10%, **Significant at 5%, ***Significant at 1%.*

Table 3: Summary statistics and correlations for the enterprises of Q4 2008

	Mean	S.D.	Min	Max	PerVirSer	PerSaaS	ApprToSOA	BizTranSOA	ProjSOA	WSCApp
PerVirSer	2.716	7.232	0.000	70.000	1.000					
PerSaaS	2.325	6.581	0.000	80.000	0.251	1.000				
					(0.000)					
ApprToSOA	0.540	0.759	0.000	2.000	-0.039	0.012	1.000			
					(0.223)	(0.715)				
BizTranSOA	0.109	0.311	0.000	1.000	0.009	0.009	0.497	1.000		
					(0.781)	(0.781)	(0.000)			

ProjSOA	0.678	1.038	0.000	4.000	-0.024	0.050	0.834	0.466	1.000	
					(0.447)	(0.117)	(0.000)	(0.000)		
WSCApp	0.080	0.272	0.000	1.000	-0.013	-0.051	0.228	0.075	0.170	1.000
					(0.684)	(0.111)	(0.000)	(0.018)	(0.000)	

*Note. *Significant at 10%, **Significant at 5%, ***Significant at 1%.*

Table 4: OLS results for the entire dataset of Q4 2008 (for PerVirSer and PerSaaS)

For PerVirSer		For PerSaaS	
Name	Value	Name	Value
ApprToSOA	-0.975	ApprToSOA	-0.709
	(0.655)		(0.632)
BizTranSOA	0.979	BizTranSOA	0.484
	(0.844)		(0.815)
ProjSOA	0.872	ProjSOA	-0.176
	(0.423)**		(0.408)
WSCApp	-1.691	WSCApp	-1.495
	(0.913)*		(0.882)*
Constant	2.569	Constant	3.567
	(2.424)		(2.34)
F statistic	2.14	*F statistic*	2.93
Prob > F	0.0000***	*Prob > F*	0.0000***
R^2 *(overall)*	0.05	R^2 *(overall)*	0.07
Observations	2,227	*Observations*	2,227

* $p<0.1$; ** $p<0.05$; *** $p<0.01$
Standard error in parentheses

Table 5: OLS results for the SMB records of Q4 2008 (for PerVirSer and PerSaaS)

For PerVirSer		For PerSaaS	
Name	Value	Name	Value
ApprToSOA	-1.563	ApprToSOA	-0.376
	(1.433)		(1.423)
BizTranSOA	1.721	BizTranSOA	2.019
	(1.636)		(1.625)
ProjSOA	1.487	ProjSOA	-1.301
	(0.774)*		(0.769)*
WSCApp	-3.329	WSCApp	-0.893
	(1.669)**		(1.657)
Constant	-0.398	Constant	2.832
	(3.117)		(3.094)
F statistic	1.97	*F statistic*	2.3
Prob > F	0.0000***	*Prob > F*	0.0000***
R^2 *(overall)*	0.09	R^2 *(overall)*	0.1
Observations	1,232	*Observations*	1,232

** p<0.1; ** p<0.05; *** p<0.01*

Standard error in parentheses

Table 6: OLS results for the Enterprise records of Q4 2008 (for PerVirSer and PerSaaS)

For PerVirSer		For PerSaaS	
Name	Value	Name	Value
ApprToSOA	-0.654	ApprToSOA	-0.827
	(0.653)		(0.588)
BizTranSOA	0.714	BizTranSOA	0.042
	(0.87)		(0.782)
ProjSOA	0.045	ProjSOA	0.219
	(0.466)		(0.419)
WSCApp	-0.732	WSCApp	-2.168
	(0.993)		(0.894)**
Constant	6.171	Constant	6.521
	(5.577)		(5.018)
F statistic	1.24	*F statistic*	1.63
Prob > F	0.1149	*Prob > F*	0.0025***
R^2 *(overall)*	0.07	R^2 *(overall)*	0.09
Observations	995	*Observations*	995

** p<0.1; ** p<0.05; *** p<0.01*

Standard error in parentheses

Table 7: Definitions and Data Sources of Variables

IV/DV/CV	Variable Name	Related Question	Variable Construction/Definition	Data Source
Independent Variable	*ApprToSOA*	QSS5. Which of the following best describes your firm's approach to, or use of, service-oriented architecture (SOA)? (SOA is a method of conceptualizing, designing, and building applications by assembling reusable building blocks, each of which is…)	A numeric measure which has the range from 0 to 2. The number 0, 1, or 2 indicates the magnitude of SOA usage by the company. The numbers are converted from the original options for the question: 1) Not pursuing, 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, 4) We use SOA and we do have (or are building) an enterprise-level strategy, and 5) Don't know. Option 3) and 4) get 1 and 2 points respectively, all the other options get 0 point. Because we only consider the current adoption of cloud computing, Option 2) still gets 0 point.	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 binary dummy measure.	Forrester Q4 2008 Software Survey
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
Independent 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 binary measure. Yes gets 1 and No gets 0.	Forrester Q4 2008 Software Survey
Dependent Variable	*PerVirSer*	QSS3. What percentage of your firm's applications are/will be deployed in the following	QSS3X_4 are numeric measures ranging from 0 to 100 (percentage). If the answer is left blank, it will be replaced with 0.	Forrester Q4 2008 Software Survey

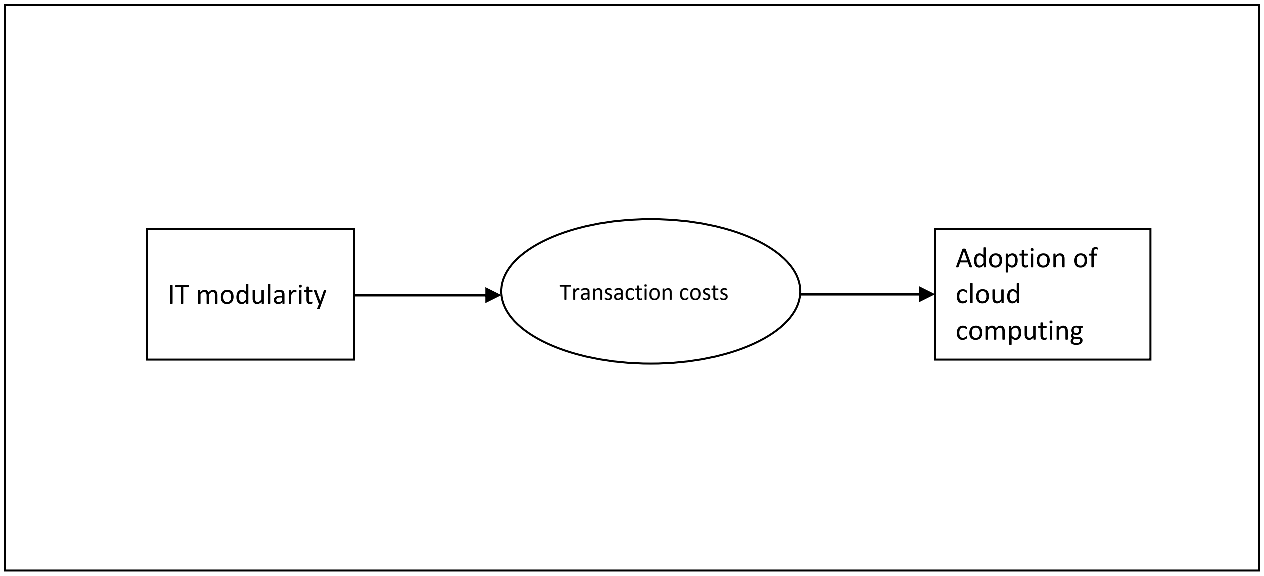
		ways, now and two years from now? - QSS3X_4. Virtual server at hosting or cloud service provider , Today		
Dependent Variable	*PerSaaS*	QSS3. What percentage of your firm's applications are/will be deployed in the following ways, now and two years from now? - QSS3X_6. Software-as-a-Service (SaaS) , Today	QSS3X_6 are numeric measures ranging from 0 to 100 (percentage). If the answer is left blank, it will be replaced with 0.	Forrester Q4 2008 Software Survey
Control Variable	*SatisSOA*	QSS7. [QSS5=3,4] Which of the following best describes your firm's level of satisfaction with SOA?	QSS7 is a numeric variable ranging from 0 to 5. The numbers indicate the magnitude of satisfaction with SOA by the company. The numbers are converted from the original options for the question: 1) SOA has delivered most or all the benefits we expected..., 2) SOA has delivered less benefit than expected, but enough..., 3) We struggle to get the benefits we expected, and we won't..., 4) We have seen little or no benefit, and we will cut back on.., and 5) It's too early to tell. Option 1) gets 5 points, and Option 5) gets 1 point. The options between them have deceasing points by 1. There are also records that have missing values for this question in which case 0 is assigned.	Forrester Q4 2008 Software Survey
Control Variable	*ImCriSW*	QP2. How important are the following criteria to your firm when selecting software?	QP2 is a set of 7 sub-questions which are about the criteria of 1) QP2_1. Overall functionality, 2) QP2_2. Overall system cost (including software licenses, hardware costs, and implementation costs), 3) QP2_3. Software pricing/licensing model (e.g., licensed, subscription, open source), 4) QP2_4. References from other companies, 5) QP2_5. Availability of service and support, 6) QP2_6. Application's ability to integrate with your firm's other systems, and 7) QP2_7. Software brand (e.g., Microsoft, Oracle, etc.). The options for each sub-question range from "1 - Not at all important" to "5 - Very important" to "Don't know / NA". The options are converted into a binary dummy variable which gives 1 point to Option 5 and otherwise gives 0 point.	Forrester Q4 2008 Software Survey
Control Variable	*ImGoal*	QSS1. Thinking of your firm's current planning cycle, how important are each of the following	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)	Forrester Q4 2008 Software Survey

		goals?	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 binary dummy variable which gives 1 point to Option 5 and otherwise gives 0 point.	
Control Variable	*CustAppPlat*	QSD1. For custom-developed applications, which development platforms does your firm use?	QSD1 is a set of 9 sub-questions which are about the platforms of 1) QSD1_1. Microsoft .NET, 2) QSD1_2. Java, Java EE, J2EE, 3) QSD1_3. Open source frameworks like Spring or Hibernate, 4) QSD1_4. Proprietary 4GLs (e.g., Cold Fusion, Magic Software, PowerBuilder, etc.), 5) QSD1_5. Rich interface in a browser (e.g., AJAX, Flash or Flex, etc.), 6) QSD1_6. Mainframe or midrange platforms (e.g., IBM mainframes, Unisys mainframes, AS/400, iSeries, NonStop, VMS, etc.), 7) QSD1_7. Lightweight Web Frameworks (e.g., Ruby on Rails, Zend Framework, Cake PHP), 8) QSD1_8. Other (Please specify), and 9) QSD1_98. Don't know. Each sub-question is a binary dummy variable with 1 point for Yes and 0 point for No.	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 binary dummy variable with 1 point for Option 5 and otherwise 0 point.	Forrester Q4 2008 Software Survey
Control Variable	*IndiffSaaS*	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 of 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.	Forrester Q4 2008 Software Survey

			[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 binary dummy variable with 1 point for Yes and 0 point for No.	
Control Variable	*ImAdSaaS*	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 decision of SaaS adoption: 1) QPA6B_1. [QPA6=2,3,4,5] Ability to substitute upfront costs with regular monthly payments - How important were the following in your firm’s decision to adopt Software-as-a-Service (SaaS)?, 2) QPA6B_2. [QPA6=2,3,4,5] Lower overall costs - How important were the following in your firm’s decision to adopt Software-as-a-Service (SaaS)?, 3) QPA6B_3. [QPA6=2,3,4,5] Speed of implementation and deployment - How important were the following in your firm’s decision to adopt Software-as-a-Service (SaaS)?, 4) QPA6B_4. [QPA6=2,3,4,5] Gaining a feature or functionality that is not available in a traditional, licensed software package - How important were the following in your firm’s decision to adopt Software-as-a-Service (SaaS)?, 5) QPA6B_5. [QPA6=2,3,4,5] Lack of in-house IT staff to maintain a traditional software solution - How important were the following in your firm’s decision to adopt Software-as-a-Service (SaaS)?, and 6) QPA6B_6. [QPA6=2,3,4,5] To support a large number of mobile and remote users - How important were the following in your firm’s decision to adopt Software-as-a-Service (SaaS)? 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 binary dummy variable which gives 1 point to Option 5 and otherwise gives 0 point.	Forrester Q4 2008 Software Survey
Control Variable	*ComSize*	Company Size	Companysize is an ordinal variable ranging from 1 to 7 for Options 1) Very Small (2-5 employees), 2) Small (6-99 employees), 3) Small-Medium (100-499 employees), 4) Medium-Large (500-999 employees), 5) Large (1,000-4,999 employees), 6) Very Large (5,000-19,999 employees), and 7) Global 2000 (20,000 or more employees)	Forrester Q4 2008 Software Survey

			respectively.	
Control Variable	*Rev*	Revenue	Revenue is a numeric variable, in which missing values are replaced with 0.	Forrester Q4 2008 Software Survey
Control Variable	*ITSpend*	IT Spending	IT Spending is a numeric variable, in which missing values are replaced with 0.	Forrester Q4 2008 Software Survey
Control Variable	*Ind*	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. It is converted to a set of 8 binary dummy variables ind1_cv to ind8_cv with 1 indicates which industry a company is in.	Forrester Q4 2008 Software Survey

Figure 1: Logical structure of framework for the proposition: IT modularity and adoption of cloud computing



References

Amtrak's SOA Offers Better Connections -- InformationWeek [WWW Document], n.d. Informationweek. URL http://www.informationweek.com/news/software/bi/196603075

Armbrust, M., A. Fox, R. Griffith, A. D. Joseph, R. Katz, A. Konwinski, G. Lee, D. Patterson, A. Rabkin, and I. Stoica. "A View of Cloud Computing," *Communications of the ACM* (53:4), 2010, pp. 50-58.

Baldwin, C. Y., and K. B. Clark. *Managing in an Age of Modularity*, Blackwell: Malden, MA2003.

Baldwin, C. Y., and K. B. Clark. *Design Rules: The Power of Modularity*, MIT Press2000.

Bernstein, D., E. Ludvigson, K. Sankar, S. Diamond, and M. Morrow. "Blueprint for the Intercloud-Protocols and Formats for Cloud Computing Interoperability," 2009, pp. 328-336.

Bertino, E., F. Paci, R. Ferrini, and N. Shang. "Privacy-Preserving Digital Identity Management for Cloud Computing," *IEEE Data Eng.Bull* (32:1), 2009, pp. 21-27.

Byrd, T. A., and D. E. Turner. "Measuring the Flexibility of Information Technology Infrastructure: Exploratory Analysis of a Construct," *Journal of Management Information Systems* (17:1), 2000, pp. 167-208.

Camuffo, A. "Rolling Out a 'World Car': Globalization, Outsourcing and Modularity in the Auto Industry," *Department of Business Economics and Management Ca'Foscari University of Venice, Italy*2000.

Catteddu, D. *Cloud Computing: Benefits, Risks and Recommendations for Information Security*, Springer2010.

Chow, R., P. Golle, M. Jakobsson, E. Shi, J. Staddon, R. Masuoka, and J. Molina. "Controlling Data in the Cloud: Outsourcing Computation without Outsourcing Control," 2009, pp. 85-90.

Chung, S. H., T. A. Byrd, B. R. Lewis, and F. N. Ford. "An Empirical Study of the Relationships between IT Infrastructure Flexibility, Mass Customization, and Business Performance," *ACM SIGMIS Database* (36:3), 2005, pp. 26-44.

Clemons, E. K., and L. M. Hitt. "Poaching and the Misappropriation of Information: Transaction Risks of Information Exchange," *Journal of Management Information Systems* (21:2), 2004, pp. 87-107.

Clemons, E. K., S. P. Reddi, and M. C. Row. "The Impact of Information Technology on the Organization of Economic Activity: The" Move to the Middle" Hypothesis," *Journal of Management Information Systems*1993, pp. 9-35.

Dakin, G. "Shaping the Future: Business Design through Information Technology," *Journal of the Operational Research Society* (44:12), 1993, pp. 1249-1250.

Duncan, N. B. "Capturing Flexibility of Information Technology Infrastructure: A Study of Resource Characteristics and their Measure," *Journal of Management Information Systems*1995, pp. 37-57.

Feuerlicht, G. *"Next Generation SOA: Can SOA Survive Cloud Computing?" Advances in Intelligent Web Mastering-2,* Anonymous Springer, 2010, pp. 19-29.

Fink, L., and S. Neumann. "Exploring the Perceived Business Value of the Flexibility Enabled by Information Technology Infrastructure," *Information & Management* (46:2), 2009, pp. 90-99.

Fixson, S. K., Y. Ro, and J. K. Liker. "Modularisation and Outsourcing: Who Drives Whom? A Study of Generational Sequences in the US Automotive Cockpit Industry," *International Journal of Automotive Technology and Management* (5:2), 2005, pp. 166-183.

Floreano, D., J. Godjevac, A. Martinoli, F. Mondada, and J. Nicoud. *"Design, Control, and Applications of Autonomous Mobile Robots," Advances in Intelligent Autonomous Systems,* Anonymous Springer, 1999, pp. 159-186.

Forrester VP Jeffrey Hammond explains software architecture trends [WWW Document], n.d. SearchSOA. URL http://searchsoa.techtarget.com/news/2240181143/Forrester-VP-Jeffrey-Hammond-explains-software-architecture-trends

Gibson, R. "Global Information Technology Architectures," *Journal of Global Information Management (JGIM)* (2:1), 1994, pp. 28-38.

Gomes, P. J., and N. R. Joglekar. "Linking Modularity with Problem Solving and Coordination Efforts," *Managerial and Decision Economics* (29:5), 2008, pp. 443-457.

Gopalakrishnan, A. "Cloud Computing Identity Management," *SETLabs Briefings* (7:7), 2009, pp. 45-54.

Halldorsson, A., H. Kotzab, J. H. Mikkola, and T. Skjøtt-Larsen. "Complementary Theories to Supply Chain Management," *Supply Chain Management: An International Journal* (12:4), 2007, pp. 284-296.

Hoefer, C., and G. Karagiannis. "Taxonomy of Cloud Computing Services," 2010, pp. 1345-1350.

Hoetker, G. "Do Modular Products Lead to Modular Organizations?" *Strategic Management Journal* (27:6), 2006, pp. 501-518.

IBM - City University London cuts student registration time by over 95 percent (11/17/2010) [WWW Document], 2010. URL http://www-01.ibm.com/software/success/cssdb.nsf/cs/STRD-8BAH55

Jansen, W., and T. Grance. "Guidelines on Security and Privacy in Public Cloud Computing," *NIST Special Publication*2011, pp. 800-144.

Jensen, M., J. Schwenk, N. Gruschka, and L. L. Iacono. "On Technical Security Issues in Cloud Computing," 2009, pp. 109-116.

Kumar, K., and H. G. Van Dissel. "Sustainable Collaboration: Managing Conflict and Cooperation in Interorganizational Systems," *Mis Quarterly*1996, pp. 279-300.

Kushida, K. E., D. Breznitz, and J. Zysman. 2008. *Cutting through the Fog: Understanding the Competitive Dynamics in Cloud Computing*, Berkeley Roundtable on the International Economy, University of California, Berkeley.

Langlois, R. N. "Modularity in Technology and Organization," *Journal of Economic Behavior & Organization* (49:1), 2002, pp. 19-37.

Langlois, R. N., and P. L. Robertson. "Networks and Innovation in a Modular System: Lessons from the Microcomputer and Stereo Component Industries," *Research Policy* (21:4), 1992, pp. 297-313.

Lau Antonio, K., R. Yam, and E. Tang. "The Impacts of Product Modularity on Competitive Capabilities and Performance: An Empirical Study," *International Journal of Production Economics* (105:1), 2007, pp. 1-20.

McGuinness, T. "Markets and Managerial Hierarchies," *Markets, Hierarchies and Networks*1994, pp. 66-81.

Mell, P., and T. Grance. "The NIST Definition of Cloud Computing (Draft)," *NIST Special Publication* (800:2011, pp. 145.

Mikkola, J. H., and T. Skjoett-Larsen. "Early Supplier Involvement: Implications for New Product Development Outsourcing and Supplier-Buyer Interdependence," *Global Journal of Flexible Systems Management* (4:4), 2003, pp. 31-41.

Mikkola, J. H. "Modularity, Component Outsourcing, and inter-firm Learning," *R&d Management* (33:4), 2003, pp. 439-454.

Mircea, M. "SOA, BPM and Cloud Computing: Connected for Innovation in Higher Education," 2010, pp. 456-460.

Mohawk Fine Papers builds integration-in-the-cloud [WWW Document], 2011. . Computerworld. URL http://www.computerworld.com/s/article/9222208/Mohawk_Fine_Papers_builds_integration_in_the_cloud

Namjoshi, J., and A. Gupte. "Service Oriented Architecture for Cloud Based Travel Reservation Software as a Service," 2009, pp. 147-150.

Parnas, D. L. "On the Criteria to be used in Decomposing Systems into Modules," *Communications of the ACM* (15:12), 1972, pp. 1053-1058.

Rindfleisch, A., and J. B. Heide. "Transaction Cost Analysis: Past, Present, and Future Applications," *The Journal of Marketing*1997, pp. 30-54.

Riordan, M. H., and O. E. Williamson. "Asset Specificity and Economic Organization," *International Journal of Industrial Organization* (3:4), 1985, pp. 365-378.

Sako, M. "Modularity and Outsourcing: The Nature of Co-Evolution of Product Architecture and Organisation Architecture in the Global Automotive Industry," *The Business of Systems Integration*2003, pp. 229-253.

Sanchez, R. "Creating Modular Platforms for Strategic Flexibility," *Design Management Review* (15:1), 2004, pp. 58-67.

Sanchez, R. "Strategic Flexibility in Product Competition," Strategic Management Journal (16:S1), 1995, pp. 135-159.

Sanchez, R., and J. T. Mahoney. "Modularity, Flexibility and Knowledge Management in Product and Organization Design," *Managing in the Modular Age: Architectures, Networks, and Organizations*, 2002, pp. 362.

Schilling, M. A. "Toward a General Modular Systems Theory and its Application to Interfirm Product Modularity." *Academy of Management Review* (25:2), 2000, pp. 312-334.

Schilling, M. A., and H. K. Steensma. "The use of Modular Organizational Forms: An Industry-Level Analysis," *Academy of Management Journal*2001, pp. 1149-1168.

Sedayao, J. "Implementing and Operating an Internet Scale Distributed Application using Service Oriented Architecture Principles and Cloud Computing Infrastructure," 2008, pp. 417-421.

Simon, H. A. "The Architecture of Complexity," *Proceedings of the American Philosophical Society* (106:6), 1962, pp. 467-482.

Tafti, A., S. Mithas, and M. Krishnan. "The Effect of Information Technology–Enabled Flexibility on Formation and Market Value of Alliances," *Management Science* (59:1), 2013, pp. 207-225.

Talukder, A. K., and L. Zimmerman. 2010. *"Cloud Economics: Principles, Costs, and Benefits," Cloud Computing*, Anonymous Springer, pp. 343-360.

Teece, D. J. "Firm Organization, Industrial Structure, and Technological Innovation," *Journal of Economic Behavior & Organization* (31:2), 1996, pp. 193-224.

Teece, D. J. "Technology Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-how," *The Economic Journal* (87:346), 1977, pp. 242-261.

Tiwana, A., and B. Konsynski. "Complementarities between Organizational IT Architecture and Governance Structure," *Information Systems Research* (21:2), 2010, pp. 288-304.

Tsai, W., X. Sun, and J. Balasooriya. "Service-Oriented Cloud Computing Architecture," 2010, pp. 684-689.

Ulrich, K. "The Role of Product Architecture in the Manufacturing Firm," *Research Policy* (24:3), 1995, pp. 419-440.

Watanabe, C., and B. K. Ane. "Constructing a Virtuous Cycle of Manufacturing Agility: Concurrent Roles of Modularity in Improving Agility and Reducing Lead Time," *Technovation* (24:7), 2004, pp. 573-583.

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

Why SOA really, really matters in a cloud computing world | ZDNet [WWW Document], n.d. ZDNet. URL http://www.zdnet.com/blog/service-oriented/why-soa-really-really-matters-in-a-cloud-computing-world/2179

Williamson, O. E. "Credible Commitments: Using Hostages to Support Exchange," *The American Economic Review* (73:4), 1983, pp. 519-540.

Womack, J. P. *Machine that Changed the World*, Scribner1990.

Worren, N., K. Moore, and P. Cardona. "Modularity, Strategic Flexibility, and Firm Performance: A Study of the Home Appliance Industry," *Strategic Management Journal* (23:12), 2002, pp. 1123-1140.

Youseff, L., M. Butrico, and D. Da Silva. "Toward a Unified Ontology of Cloud Computing," 2008, pp. 1-10.