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The Effect of Cloud-based IT Architecture on IT Exploration and Exploitation: Enabling Role of Modularity and Virtuality

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ABSTRACT

In today's turbulent business landscape, a firm's ability to explore new IT capabilities and exploit current ones is essential for enabling organizational agility and achieving high organizational performance. We propose IT exploration and exploitation as two critical organizational learning processes that are essential for gaining and sustaining competitive advantages. However, it remains unclear how the emerging cloud-based IT architecture affects an organization's ability to explore and exploit its IT capabilities. We conceptualize modularity and virtuality as two critical dimensions of emerging cloud-based IT architecture and investigate how they affect IT exploration and exploitation. We test our hypotheses using data obtained from our field survey of IT managers. We find that modularity is positively associated with both exploration and exploitation whereas virtuality is positively associated with exploration, but not with exploitation. We also find that the effect of modularity on exploitation is stronger than its effect on exploration.

Keywords: Cloud-based IT Architecture, IT Exploitation, IT Exploration, Modularity, Virtuality

Ⅰ. Introduction

Information technology (IT) enables organizations to operate their businesses effectively and efficiently and create values using digitalized systems, processes, and knowledge (Pang et al., 2014; Sambamurthy et al., 2003). Strategic management of IT capabilities can provide firms with competitive advantages in the market (Bharadwaj, 2000). Hypercompetitive business and dynamic technological environments make a firm's ability to explore new IT capabilities and exploit their existing ones essential to achieve

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superior firm performance (Lee et al., 2007). We view IT exploration and exploitation as important organizational learning processes that help firms experiment with new IT capabilities and optimize current ones.

Previous studies on the impact of IT on competitive advantages have examined various IT capabilities as enablers. For example, IT infrastructure improves a firm's ability to detect, process, and communicate market changes (Chakravarthy et al., 2013; Lu and Ramamurthy, 2011). Technical and managerial IT skills enable firms to successfully deploy required information systems (Chakravarthy et al., 2013; Lu and Ramamurthy, 2011). Strategic IT alignment facilitates business-IT collaborations in organizations (Tallon and Pinsonneault, 2011). In particular, the dual capability to explore and exploit IT capabilities is found to enhance organizational agility and performance (Lee et al., 2007; Lee et al., 2015; Seo et al., 2014). An important gap in the extant literature is that we have little knowledge about how firms build their ability to explore and exploit IT capabilities. We use IT architecture as an underlying perspective to address this research gap. IT architecture is a logical structure that defines and controls how an organization's IT resources are placed, interfaced, and integrated to enable business strategies (Ross, 2003). IT architecture is an organizing framework for a firm's IT management practices to explore emerging IT capabilities and exploit existing IT capabilities in more effective and efficient ways. Furthermore, the importance of IT architecture has increased due to the diversity of technologies available and to the speed of technology development. In this paper, we investigate two critical dimensions of emerging IT architecture, namely *modularity* and *virtuality*, as enablers for IT exploration and exploitation in organizations. Recent advances in cloud computing and open source software among others have increased the modularity and virtuality of IT infrastructure. Especially, cloud computing leveraging modularity and virtuality has potential to transform a firm's IT learning process associated with adopting new IT capabilities and utilizing existing ones for business operations (Lee et al., 2014; Lim and Oh, 2017). Therefore, it is important to understand how these emerging characteristics of IT architecture affect a firm's ability to explore and exploit IT capabilities.

We argue that modularity and virtuality enhance a firm's IT exploration and exploitation by facilitating its organizational activities to experiment with new IT capabilities and continuously improve current IT capabilities. We examine our research model with data obtained from a field survey of IT managers in large organizations in South Korea. Our results show that both IT architecture modularity and virtuality are positively associated with a firm's ability to explore and exploit IT capabilities. Moreover, we find that the positive effect of IT architecture modularity on a firm's IT exploitation is stronger than its effect on IT exploration and that the positive effect of IT architecture virtuality on the firm's IT exploration is larger than its effect on IT exploitation. Our research contributes to the extant literature by revealing the mechanisms by which IT architecture influences IT exploration and exploitation.

In what follows, we provide a theoretical background for our study. We then describe the research model and hypotheses. Subsequently, we present the details of our data collection and analysis methods. We conclude with a discussion of the implications of the study, limitations and future research directions.

Ⅱ. Theoretical Background

2.1. IT Architecture and New Computing Paradigm

A variety of information systems have been introduced and deployed in organizations over the last couple of decades. As the number and variety of information systems has increased, the complexity of IT infrastructure and systems has increased as well, which hampers a firm's efficiency and flexibility in utilizing IT resources and capabilities (Lee et al., 2013; Xia and Lee, 2005). As a result, the importance of IT architecture has grown. IT architecture provides a conceptual and technical platform on which IT resources are allocated, interconnected, and combined into an entire corporate information system (Feeny and Willcocks, 1998). It is a design principle that affects a firm's IT management operations to effectively utilize IT resources and respond to the changing business environment.

One important change to IT architecture has recently emerged. Increasingly, more organizations are adopting cloud computing, a service platform in which configurable IT resources are delivered over the Internet (Ahmed, 2011). Cloud computing presents a new way of utilizing IT resources and configuring corporate IT capability. Using cloud computing from third-party vendors, firms can avoid expensive up-front IT investment and instantly access the latest technologies upon service initiation (Kim and Kim, 2015). The amount and selection of cloud services can be adjusted according to the fluctuation of business needs.

The basic building blocks of cloud computing originate from the latest technologies and concepts such as grid computing, utility computing, and service-oriented architecture are virtuality and modularity. Cloud computing enables firms to rapidly acquire IT resources by virtualizing IT resources to be shared over the Internet (Yoo, 2011). On the other hand, cloud computing also enables firms to deploy a new information system with less time and effort by configuring and reconfiguring software components (Iyer et al., 2003). In what follows, we discuss the concept of modularity and virtuality in greater detail.

2.2. The Modularity of IT Architecture

Modularity is a general design concept that defines the structure and interaction of subsystems within a complex system (Baldwin and Clark, 2000). Simon (1962) proposes the notion of modularity by suggesting that complex technological and organizational systems can be decomposed into distinct subsystems that are interconnected with each other. He suggests modularity as a fundamental structuring rule through which complexity can be managed by reducing the interdependence between modules (subsystems) and increasing interdependence within them.

In a modular system, modules interact with one another through standardized interfaces, which allows loose coupling among modules (Baldwin and Clark, 1997). "Near-decomposability" by loose coupling (Simon, 1962; Weick and Orton, 1990) and standardized interfaces (Baldwin and Clark, 1997) are the significant elements of modularity. Loose coupling refers to the degree to which a module in a complex system can be independently designed to avoid sequential or reciprocal changes of the others (Nambisan, 2002). Standardized interface refers to policies and rules that specify how modules in a system interact with each other (Weil and Ross, 2005).

By dividing a system into a number of subsystems, firms can effectively deal with system-related issues by focusing on one local subsystem at a time, without affecting the entire system (Yoo, 2013). In addition to reducing complexity, modularity also increases the flexibility of the systems. With a modular system, firms can obtain new configurations or replace one component with another without loss of the system's functionality or performance (Baldwin and Clark, 1997; Yoo, 2013). Prior research suggests that such a mix-and-match strategy allows firms to be more flexible and innovative (Baldwin and Clark, 2000; Garud et al., 2003; Schilling, 2000).

2.3. The Virtuality of IT Architecture

Virtuality is a concept of abstracting physical IT resources, such as server, storage, and network, and making them appear as software-based logical resources (Pearce, 2013). It separates the architectural and user-perceived hardware and software resources from their physical implementation (Figueiredo, 2005). Therefore, virtuality allows firms to consolidate multiple networked hardware systems into a single IT resources pool. Virtual resources can be dynamically reallocated to applications depending on the capacity of computing power needed (Pearce, 2013; Yoo, 2011).

The virtuality of IT architecture provides two ways to improve the efficiency of IT services. First, it refines granularity in offering diverse computing services with given resources by providing the ability to run multiple operating systems and applications on the same machine (Yoo, 2011). Thus, virtuality facilitates more efficient use of IT resources by increasing the usage of a hardware system. Second, virtuality enables dynamic allocation of the resources required for running multiple business applications related to a firm's business operations. This capability greatly enhances the flexibility and scalability of IT services.

2.4. Organizational Learning in IT Work

Prior research on the relationship between IT capabilities and organizational learning has explored how IT capabilities improve a firm's ability to achieve competitive advantage through enhanced business agility. Chakravarthy et al. (2013) and Lu and Ramamurthy (2011) examine the role of IT infrastructure in facilitating organizational sensing and responsiveness to market changes. They note that IT infrastructure strengthens organizational learning by improving a firm's ability to detect, process, and communicate market information. IT skills and strategic IT alignment are found to contribute to organizational agility by helping firms implement or deploy necessary information systems (Chakravarthy et al., 2013; Lu and Ramamurthy, 2011) and by facilitating the collaboration between business and IT (Tallon and Pinsonneault, 2011). These studies suggest that the strategic use of IT capabilities can enable organizational agility by facilitating organizational learning. As today's IT solutions and services are becoming more advanced and diverse, firms need to engage in organizational learning to discover new IT-based opportunities and make the best use of current IT resources. In line with this, IT exploration and exploitation have been recognized as fundamental capabilities that enable organizational agility and firm performance (Lee et al., 2007).

IT exploration refers to the experiment with new IT resources and practices whereas IT exploitation refers to the utilization of existing IT resources and practices (Lee et al., 2007). IT exploration requires a firm to devote time and resources to keep track of new ITs in the market, experiment with the most promising ones, and select those technologies that bring positive impacts on current and future business operations (Lee et al., 2015). IT exploitation, in contrast, is related to the ability of a firm to fine-tune the current IT resources and practices, reuse them in different business activities, and seamlessly integrate them with business processes (Lee et al., 2015). IT exploration pays more attention to discovering and adopting emerging technologies, methodologies, and skills whereas IT exploitation focuses on utilizing existing IT resources to reap full benefits. When a firm is engaged in both exploration and exploitation of its IT resources successfully, it can achieve superior performance in both short term and long term.

Ⅲ. Research Model

This section presents our research model that hypothesizes the relationships between two IT dimensions of IT architecture (i.e., modularity and virtuality) and two different modes of organizational learning in IT work (i.e., IT exploration and IT exploitation).

3.1. Effect of IT Architecture Modularity

In a modular IT architecture, sub-systems are loosely coupled by a standard interface. Structural encapsulation of modules allows for a high level of independence of individual modules (Schilling, 2000; Zweben et al., 1995). IT architecture modularity fosters exploration in IT development and deployment as it enables recombination and reconfiguration of loosely-coupled sub-systems. Modularity also makes it less costly and time-consuming for software teams to add new modules or remove existing ones, thus increasing software development agility (Lee and Xia, 2010). As a result, with a modular IT architecture, an IT organization is more likely to experiment with new IT capabilities, and phase out obsolete components of a system. IT architecture modularity lowers the risks associated with major changes. Modularity fosters the user organization's adoption of new technologies as it reduces user concerns about the possible disruption of existing systems due to new technologies (Tiwana and Konsynski, 2010). Increased modularity in IT architecture enables an environment in which both IT organizations and user organizations are more receptive to exploring radical changes in technological capabilities. Therefore, we hypothesize that:

H1a: IT architecture modularity is positively associated with a firm's IT exploration.

Modular IT architecture fosters exploitation in IT development and deployment. A change to one module of an existing system would not affect other modules in the system. This makes it cost-efficient for an IT organization to fine-tune and optimize a module by leveraging a firm's existing IT capabilities and resources. The fine-tuned, optimized IT resources can improve operational excellence (Arthur, 2009). In a tightly integrated architecture, even a small change to one component of a system may require substantial cascading changes to other components of the system (Zweben et al., 1995). As the system becomes increasingly complex, the cost of making a change becomes higher. Modularity significantly reduces this cost by containing the changes within the target module so that it doesn't affect other modules. IT architecture modularity facilitates a firm's exploitative efforts for making incremental changes and optimizing its systems to make the most use of its existing IT resources (Schilling, 2000; Yoo et al., 2013). Thus, we hypothesize that:

H1b: IT architecture modularity is positively associated with a firm's IT exploitation.

As discussed earlier, modularity has a positive effect on both exploration and exploitation in IT development and deployment. However, we argue that the size of its effect on the two different modes of organizational learning may differ. Minimal interdependencies among modules allows for incremental improvement and optimization of individual modules, thus fostering IT exploitation (Tiwana and Konsynski, 2010). On the other hand, we argue that modularity has a relatively limited effect on IT exploration. While modularity allows for adding or removing modules and for recombining and reconfiguring existing modules, it may constrain radical structural changes as it determines a high-level structure of the architecture in terms of how modules are defined and related to one another (Weick and Orton, 1990). If an exploratory effort requires fundamental changes to the current modular structure, modularity may become a barrier to such effort rather than being a facilitator. In other words, the IT organization can explore new technological capabilities only so much within the currently defined modular structure. In summary, while modularity facilitates the optimization of individual modules to a great extent, it provides relatively limited opportunities for radical exploration. Thus, we posit the following hypothesis:

H1c: The effect of IT architecture modularity on a firm's IT exploitation is greater than its effect on the firm's IT exploration.

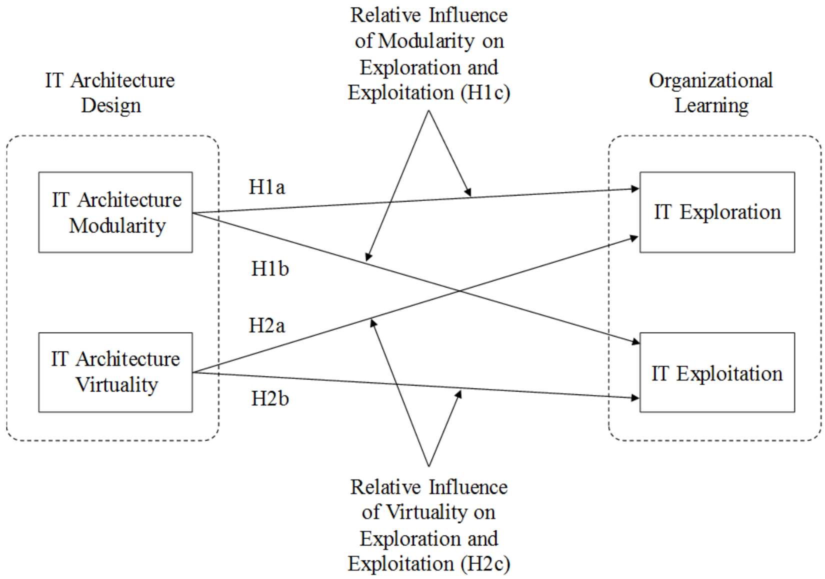
3.2. Effect of IT Architecture Virtuality

Virtuality makes it possible to pool physical IT resources so that they can be shared within and across organizations. For example, server virtuality makes multiple computing devices appear as a single logical instance to developers as well as end users. With virtual IT architecture, an IT organization can allocate pooled IT resources dynamically to respond to changing business and technology requirements (Figueiredo et al., 2005). Virtuality makes a firm's IT architecture flexible and scalable to support the fluctuation of business demands. Virtuality also makes IT investment decisions less path-dependent, providing options for flexibility and reversibility (Etro, 2009). Firms can explore promising IT capabilities with relatively lower risk of IT capital investment if IT resources are virtualized.

Exploratory efforts in IT development and deployment often require mobilizing and reconfiguring of IT resources. Virtuality makes it easy to deploy IT resources on-demand across and within organizational boundaries, allowing firms to rapidly experiment with different strategic initiatives in order to respond to new opportunities (Low et al., 2011). In other words, virtuality helps a firm overcome resource constraints when the firm pursues major changes to its IT systems. Thus, we posit the following hypothesis:

H2a: IT architecture virtuality is positively associated with a firm's IT exploration.

Virtuality fosters the exploitation of existing IT resources and capabilities. IT resources that are virtually consolidated can be used for different systems on-demand. Underutilized resources can be easily mobilized and made available for other uses dynamically. Therefore, virtuality increases the utilization of IT resources (Cafaro and Aloisio, 2011). Furthermore, virtuality makes it easier for the IT



<Figure 1> Research Model

organization to continuously fine-tune and optimize current systems because it allows developers to do their work without having to manage physical systems. Thus, we posit the following hypothesis:

H2b: IT architecture virtuality is positively associated with a firm's IT exploitation.

As discussed earlier, virtuality has a positive effect on both exploration and exploitation in IT development and deployment as it allows a firm to overcome the physical constraints of IT resources. With a virtualized IT architecture, the firm can manage its IT resources at a logical level rather than at a physical level. The pooled resources and the possibility of their dynamic reallocation greatly improve the firm's ability to bring about transformative changes to its IT systems and capabilities (Figueiredo et al., 2005). However, the effect of virtuality on incremental changes to current systems is relatively limited because not all incremental changes require or benefit from the dynamic reallocation of pooled IT resources. Some of the incremental changes (i.e., exploitative efforts) can be accomplished by using currently allocated resources. Therefore, virtuality is critical for exploratory efforts that often require the mobilization of resources, but it only benefits certain types of exploitative efforts that require such resource reallocation. Taken together, we posit the following hypothesis:

H2c: The effect of IT architecture virtuality on a firm's IT exploration is greater than its effect on the firm's IT exploitation.

Ⅳ. Research Method

To test the hypotheses, we conducted a field survey to collect data from senior IT managers in South Korea. In what follows, we discuss our data collection process, the study sample, and the measures.

4.1. Sample

The survey was conducted to the South Korea's top 500 companies published annually by the Daily Economic Newspaper in South Korea. The survey was intended for the IT managers of the target firms. We first contacted the target respondents and then sent the survey questionnaire to them. We sent follow-up messages to encourage the participation of the target respondents. We received 108 usable responses, with a response rate of 21.6% (108/500). <Table 1> shows the characteristics of our sample.

4.2. Measures

We used extant measures from prior literature wherever possible and appropriate, with adaptations if necessary. IT architecture modularity was measured by three items that were adapted from Tiwana and Konsynski (2010). These items capture the extent to which a firm's information systems are structured using independent, loosely-coupled modules. The items for IT architecture modularity are reflective indicators.

We developed a new measure for IT architecture virtuality because no measure was available in prior literature. It was measured by the extent to which IT resources in firms such as network, storage, server, database, operating system, and application are virtualized, which form formative indicators. We checked the face validity of the new measures with industry experts. We also provided a definition of virtuality and a few examples of virtualized IT resources to ensure that the respondents had a clear understanding of the construct. Since there is only one formative construct in our model, we could not use the Inter-item and Item-to-construct Correlation Matrix to validate the formative construct (Loch et

<Table 1> Sample Characteristics (*N* = 108)

Category	Size	Percentage
Industry		
Manufacturing	28	26%
Service	64	59%
Others*	16	15%
Annual Revenue		
Less than $1billion	9	8%
$1billion – $10 billion	32	30%
Over $10 billion	67	62%
Number of Employees		
Less than 1,000	37	34%
1,000 – 10,000	60	56%
Over 10,000	11	10%
Rank of Respondents		
Executive and Senior IT Manager	73	68%
Middle IT Manager	35	32%

Note: *Others include Construction, Education, Healthcare, Transportation, and Utilities.

al., 2003). As a result, we relied mainly on VIF (variance inflator factor) statistic to assess if multi-collinearity among formative indicators could be an issue (Petter et al., 2007). As shown in <Table 2>, the VIF statistics suggest that the formative indicators are valid and acceptable (Diamantopoulos and Siguaw, 2006).

Informed by prior literature (e.g., Lee et al., 2015), we measured IT exploration and IT exploition with three and four items, respectively. The indicators of IT exploration measure the extent to which a firm makes efforts to experiment with new, innovative technologies, infrastructure, applications, IT services, and IT-related business processes. The indicators of IT exploitation measure the extent to which a firm makes efforts to improve the quality and efficiency of existing IT infrastructure, applications, IT services, and IT-related business processes.

Ⅴ. Data Analyses and Results

Since our research model includes both formative indicators and reflective indicators, we use partial least squares (PLS) to test the research model as it can handle formative indicators (Chin et al., 2003; Lohmoller, 1989). Further, PLS is appropriate when the research model is in an early stage of development and has not been tested extensively (Teo et al., 2003). We follow a two-step analytic approach. First, we assess the validity and reliability of the measurement model. Then, we test the structural model to assess the significance and strength of the hypothesized links among the constructs.

5.1. Measurement Model

We model the indicators of IT architecture modularity, IT exploration, and IT exploitation as reflective measures. The properties of reflective measures are assessed in terms of item loadings, internal consistency, and discriminant validity. Our validation shows that the reliability coefficients of all three constructs are above .70, and each AVE is above .50 (see <Table 3>). The results indicate that the measurements are reliable and the item loadings are in an acceptable range. The results shown in <Table 4> suggest that our measurement model demonstrates sufficient discriminant validity of all three constructs as their square root of the AVE is greater than all of the inter-construct correlations (Chin, 1998).

We also construct a cross-loading table as suggested by Gefen et al. (2000) to further assess the validity of our reflective measures. <Table 5> shows that each item loading is higher on its assigned construct than on the other constructs, indicating ad-

<Table 2> VIF Statistics for Formative Indicators

Construct	Indicators	VIF
IT Architecture Virtuality (ITV)	ITVNW	1.84
	ITVST	2.49
	ITVSV	3.43
	ITVOS	3.58
	ITVDB	3.09
	ITVAP	2.31

Note: ITVNW (Network); ITVST (Storage); ITVSV (Server); ITVOS (Operating System); ITVDB (Database); ITVAP (Application)

<Table 3> Reliability for Reflective Constructs

Construct	AVE	Composite Reliability	Cronbach's Alpha
ITM	0.580	0.845	0.757
EXPLR	0.729	0.890	0.814
EXPLT	0.769	0.909	0.850

Note: ITM (IT architecture Modularity); EXPLR (IT Exploration); EXPLT (IT Exploitation)

<Table 4> Discriminant Validity

Construct	ITM	EXPLR	EXPLT
ITM	**0.761**		
EXPLR	0.380	**0.854**	
EXPLT	0.610	0.524	**0.877**

Note: Diagonal elements in bold case are the square root of AVE and other numbers of correlations; ITM (IT Architecture Modularity); EXPLR (IT Exploration); EXPLT (IT Exploitation).

<Table 5> Cross-Loadings for Reflective Constructs

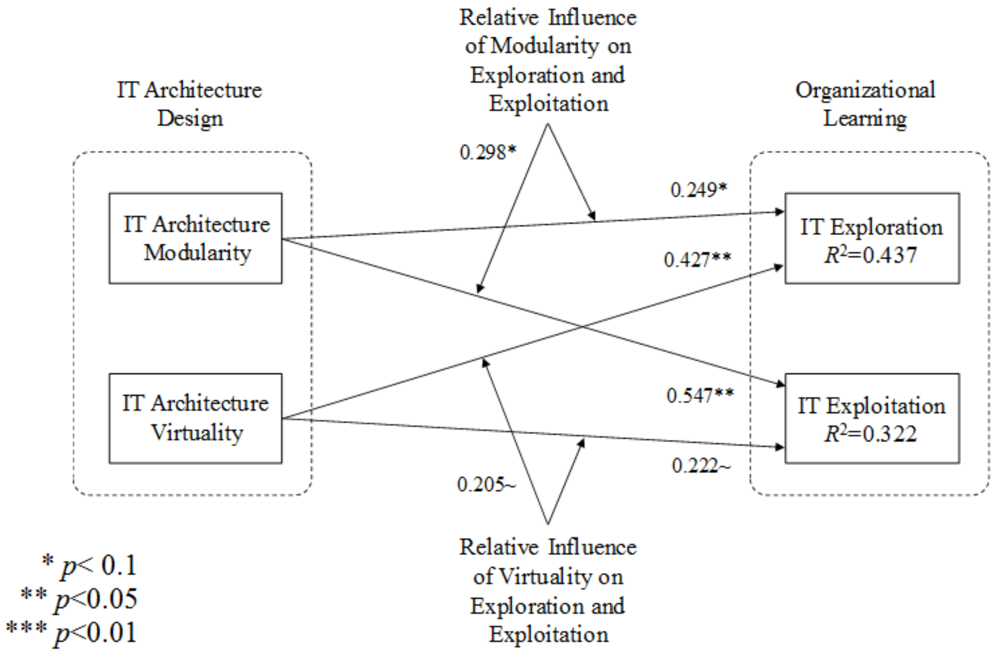
Items	ITM	EXPLR	EXPLT
ITM1	**0.841**	0.321	0.542
ITM2	**0.775**	0.294	0.485
ITM3	**0.768**	0.329	0.452
ITM4	**0.648**	0.195	0.358
EXPLR1	0.279	**0.814**	0.506
EXPLR2	0.311	**0.858**	0.449
EXPLR3	0.380	**0.888**	0.386
EXPLT1	0.467	0.418	**0.855**
EXPLT2	0.598	0.513	**0.921**
EXPLT3	0.528	0.437	**0.853**

Note: ITM (IT Architecture Modularity); EXPLR (IT Exploration); EXPLT (IT Exploitation)

equate convergent and discriminant validity. Thus, the results confirm the discriminant validity of the reflective constructs.

5.2. Hypothesis Testing

<Figure 2> presents our PLS results. The R^2 values of IT exploration (EXPLR) and IT exploitation (EXPLT) are .437 and .322 respectively, indicating that the model explains a substantial amount of variance for IT exploration and exploitation. As shown in <Table 6>, the link between IT architecture modularity (ITM) and IT exploration is significant (b = .249, $p < .05$) at 0.05 significance level. The link between IT architecture modularity and IT exploitation is statistically significant (b = .547, $p < .01$) at 0.01



<Figure 2> PLS Results

<Table 6> Hypothesis Test Results

Hypothesis	Results	Path Statistics			
		Path Coefficient	SE	t	p-value
H1a: ITM → + EXPLR	Supported	0.249	0.105	2.373	< 0.05
H1b: ITM → + EXPLT	Supported	0.547	0.120	4.577	< 0.01
H2a: ITV → + EXPLR	Supported	0.427	0.088	4.838	< 0.01
H2b: ITV → + EXPLT	Not Supported	0.222	0.119	1.863	< 0.1

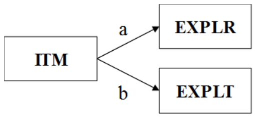
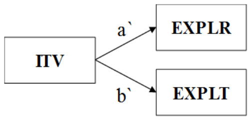
Note: ITM (IT Architecture Modularity); ITV (IT Architecture Virtuality); EXPLR (IT Exploration); EXPLT (IT Exploitation)

level. The results support Hypotheses H1a and H1b.

Our results also indicate that the link between IT architecture virtuality (ITV) and IT exploration is statistically significant (b = .427, p < .01) at 0.01 level. However, the path between IT architecture virtuality and IT exploitation is found to be marginally significant at 0.1 significance level (b = .222, p < .1). The results support Hypothesis H2a but only marginally support Hypothesis H2b.

We also examine the relative influence of IT architecture modularity and virtuality on IT exploration and exploitation. The test results shown in <Table 7> indicate that the coefficient of the path from IT architecture modularity to IT exploitation is significantly greater than the path from IT architecture modularity to IT exploration (t = 1.832, p < .05). It is also shown that the coefficient of the path from IT architecture virtuality to IT exploration is greater than the path from IT architecture virtuality to IT exploitation. But, the difference is only marginally

<Table 7> Comparing Effect Size of Hypothesized Relationships

Hypothesis	Results	Test of Difference			
		Difference of Path Coeff.	SE	t	p-value
H1c: **a < b** 	Supported	0.298	0.163	1.832	0.034 (< 0.05)
H2c: **a` > b`** 	Marginally Supported	0.205	0.153	1.342	0.091 (< 0.1)

Note: ITM (IT Architecture Modularity); ITV (IT Architecture Virtuality); EXPLR (IT Exploration); EXPLT (IT Exploitation)

significant (t = 1.342, p < .1). The results thus provide empirical evidence for supporting Hypothesis H1c but only marginally supporting H2c.

Ⅵ. Discussion

IT architecture plays a critical role in the development and operation of IT systems and services. Recent technological developments of cloud computing enable firms to pursue new forms of IT architecture that are highly scalable and flexible. The emerging cloud-based IT architecture offers potentially transformative possibilities for organizational IT management. This research aims to investigate if cloud-based IT architecture facilitate organizational learning in terms of exploring and exploiting IT resources and practices. More specifically, we focus on investigating two attributes of cloud-based IT architecture: modularity and virtuality.

We find that both modularity and virtuality positively affect IT exploration while modularity also positively affects IT exploitation. However, the hypothesized positive effect of virtuality on IT exploitation is found to be not significant but only marginally significant. We speculate that the effect is not as significant as they posit because although virtuality can increase the utilization of IT resources in theory, resource constraint may not be a major barrier to exploitation in reality. In addition, although virtuality can allow for developers to exploit current technologies without having to manage physical systems, the time and effort saved do not seem to motivate developers to do more exploitation.

Furthermore, we find that the effect of modularity on exploitation is greater than its effect on exploitation and that the effect of virtuality on exploration is marginally greater than its effect on exploitation. These findings significantly advance our current understanding of exploration and exploitation in IT work by revealing the mechanisms by which the modularity and virtuality of IT architecture influence these organizational learning processes in the context of IT. Although modularity has been studied extensively in a variety of domains, our study is the first to investigate its effect on organizational ability to explore and exploit IT capabilities. While virtuality is becoming an important characteristic of IT architecture, little or no research has investigated how virtuality affects IT learning. Therefore, our research makes an important contribution to the literature by conceptualizing modularity and virtuality in the context of cloud-based IT architecture and testing their effects on an IT organization's exploration with new capabilities and its exploitation of existing ones.

It is important to conceptually distinguish IT exploration and exploitation from IS infusion. Although they are related, they refer to different processes. IS infusion is mainly about realizing the full benefit of an information system after it was adopted by users (Saga and Zmud, 1993). IS infusion may involve user training and user learning through use of the system. Although developers play a role in IS infusion process, users are the main driving force. In contrast, IT exploration is a broader concept that includes experimenting or adopting a new system, changing major functionalities of the system, or even removing some parts of the system. IT exploitation is probably more closely related to IS infusion. It involves processes of fine-tuning and optimizing an adopted system. However, exploitation is different from infusion in that the former is carried out by both IS developers and users whereas the latter is mainly driven by users.

Our research findings also have implications for practice. Depending on the relative importance between exploration and exploitation in the IT organization, a firm can make informed decisions about how to design its cloud-based IT architecture and how much it should invest in increasing modularity and virtuality. We suggest that there could be four different archetypes of cloud-based IT architecture based on the level of modularity and virtuality. On one end of the spectrum, there is *traditional enterprise architecture*, which can be characterized by low levels of both modularity and virtuality. On the other end of the spectrum, there is *cellular IT architecture*, which is characterized by high levels of both modularity and virtuality. Such cellular IT architecture allows for the highest degree of operational efficiency and strategic flexibility. Organizations with such cellular IT architecture are well-positioned to pursue an ambidextrous organizational learning strategy (Raish et al., 2009; Tushman and O'Reilly, 1999). Then, there are *modular IT architecture* and *virtual IT architecture*, each of which has a high level of modularity or virtuality, respectively. Our results suggest that these different archetypes of IT architecture are likely to produce different organizational learning outcomes in terms of the exploration and exploitation of IT resources and capabilities.

Although this study makes significant contributions to IS research and practices, there are some limitations. This study treats exploration and exploitation as two mutually exclusive modes of organizational learning that take place in parallel. However, there might be a case where exploration and exploitation take place sequentially and cyclically, in which a firm explores new capabilities, then refines and optimizes them, and then reinitiates another exploration. Another limitation is that our research model does not include control variables that might affect IT exploration and exploitation. Therefore, our findings should be taken with caution. Future research should further validate our findings with important control variables included. Lastly, this study does not consider environmental factors, such as industry turbulence or environmental complexity that may affect the relationship between IT architecture and organizational learning. Future research should address these limitations by incorporating dynamic interactions between exploration and exploitation as well as environmental factors.

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<Appendix A> Measurement Items

Constructs	Items
1. IT Architecture Modularity (1 = strongly disagree; 5 = strongly agree)	Components of IT infrastructure and applications are easy to recombine
	IT infrastructure and applications are highly interoperable.
	Components of IT infrastructure and applications are independent
	Components of IT infrastructure and applications have minimal interdependencies
2. IT Architecture Virtuality	To what extant is each of following IT resources in your company virtualized? (1 = 0%~20%; 2 = 20%~40%; 3 = 40%~60%; 4 = 60%~80%; 5 = 80%~100%) • Network • Storage • Server • Operation system • Data Base • Application
3. IT Exploration IT department in your company makes efforts to… (1 = strongly disagree; 5 = strongly agree)	Build innovative IT infrastructure and applications
	Reengineer IT-related business processes
	Adopt IT innovation of other companies
4. IT Exploitation IT department in your company makes efforts to… (1 = strongly disagree; 5 = strongly agree)	Increase the efficiency of IT services
	Improve current IT-related business processes
	Reduce the lead-time of developing IT infrastructure and applications

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