HOW TO BE GOOD AT SENSING AND RESPONDING: THE ROLES OF THREE TYPES OF IT INFRASTRUCTURE

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Abstract

Business agility has been considered as one of the key organizational capabilities in the modern business environment. The current research indicates that information technologies (IT) can help firms develop agility and in turn agility can improve firm performance, but how IT leads to agility and superior performance and under what circumstances is an ongoing consideration. In particular, while current research has examined higher-order latent capacities of IT resources and capabilities, they haven’t clearly specified what IT factors can enable organizational agility and how. In this study, we investigate the distinct values of two key capabilities of agility, i.e., sensing and responding capabilities, under the different levels of market competition. We also identify three types of IT infrastructure and explore the underlying enabling processes between these three infrastructures and sensing and responding capabilities. The model test results using a large-scale field survey data indicate that responding capability becomes more important as the level of market competition increases. The results also reveal that knowledge infrastructure and data service infrastructure are the key enablers of sensing capability and that standard application infrastructure is the key enabler of responding capability. This study helps understand underlying mechanisms of IT-enabled agile processes within a firm.

Keywords: Business Agility, Sensing and Responding Capability, IT infrastructures, Market Competition
1 INTRODUCTION

Information technologies (IT) are fundamental to the growth of contemporary businesses (Bharadwaj 2000; Mithas et al. 2011; Ravichandran & Lertwongsatien 2005). Researchers argue that the relationship between organizational IT and business performance can be deconstructed through the presence of business competences. Ravichandran and Lertwongsatien (2005), for example, argue that IT supports a firm’s core competences, such as market-access competence, integrity-related competence, and functional-related competence, thus contributing to better firm performance. Mithas et al. (2011) also empirically evidence the positive impacts of IT on firm performance through specific business capabilities, such as customer, process, and performance management capabilities. In this stream of research, business agility; a dynamic capability to sense and respond to market changes with speed and surprise (Overby et al. 2006), has achieved particular attention as an IT-enabled business competence to lead superior performance in today’s dynamic business environments (e.g., Lu & Ramamurthy 2011; Sambamurthy et al. 2003; Tallon & Pinsonneault 2011). However, current studies in this stream of research are still lacking in the following two areas: (1) understanding of underlying mechanisms of agile process within a firm and (2) conceptual distinction among different types of IT investment.

First, business agility has been widely accepted as one of the key organizational capabilities in today’s business. Recent studies have focused on demonstrating that agility can help improve firm performance in various contexts (e.g., Raschke 2010; Tallon & Pinsonneault 2011; Vickery et al. 2010). However, the understanding on how agility leads to superior performance and under which situations is still limited. In line with this, some researchers propose to investigate the values of sensing and responding capabilities separately in leading to firm performance (Nazir & Pinsonneault 2012; Overby et al. 2006; Roberts & Grover 2012). Drawing upon this approach, to understand the underlying mechanisms of agile process within a firm, we investigate the distinct values of the two key capabilities of agility under different environmental conditions.

Second, the extant studies have not clearly specified which IT resources or capabilities are involved in enabling organizational agility. There have been two trends in studying IT impacts on agility. One is to investigate higher-order latent capacities of IT resources or capabilities (e.g., Lu & Ramamurthy 2011). The other is to examine only IT managerial capabilities (e.g., Mithas et al. 2011; Tallon & Pinsonneault 2011). While the former approach fails to explain the values of specific IT investments, the latter approach does not accurately explain the actualized values of IT investment as the results of those IT management capabilities. To address these gaps in existing studies, we investigate specific types of IT infrastructure as the tangible IT-based enablers of the sensing and responding capabilities. Through this study, therefore, we aim to answer the following key research questions:

1. What are the impacts of sensing and responding capabilities on firm performance? Do they have identical or distinct values across various market conditions?

2. How can a firm’s IT infrastructures build its agility, particularly in terms of its sensing and responding capabilities? What kinds of IT infrastructures are involved in the two component capabilities of organizational agility?

The next section describes the conceptual foundations of the study. Next, we describe the study’s primary hypotheses. Subsequently, we present the details of our data gathering methodology and analysis. Finally, the paper discusses the implications of the study with its potential contribution to the relevant literature.

2 CONCEPTUAL DEVELOPMENT

As the overarching theory bases of the study, we adopt Sambamurthy et al.’s (2003) capability-building and digital-options perspectives. First, capability building within a firm refers to the organizational process that integrates, builds, and reconfigures various resources to create its high-
level capabilities which lead to superior performance in its marketplaces (Teece et al. 1997). Drawing upon this capability-building perspective, agility has been proposed as a key driving force of a firm’s competitive actions in a dynamic business environment. In particular, IT has been highlighted as a business platform to enable this high-level organizational capability (Lu & Ramamurthy 2011; Sambamurthy et al. 2003). Second, Sambamurthy et al. (2003) propose digitized process and knowledge platforms, i.e., digital options, as the direct enablers of business agility. Following this perspective, we examine the roles of IT infrastructure to support organizational process and knowledge management in leading to business agility.

2.1 Agility: Sensing and Responding Capabilities

Agility, a firm’s ability to move fast to respond to environmental changes and seize novel opportunities, is considered a significant business capability that enables firms to develop and execute meaningful decisions and effectively respond to predictable and unpredictable changes (Dove 1992; Sambamurthy et al. 2003). Agility embraces other concepts in management literature such as dynamic capabilities, strategic flexibility, and market orientation (Lu & Ramamurthy 2011; Overby et al. 2006).

Researchers have examined various aspects of agility and two capabilities have been considered as fundamentals of agility: environmental sensing capability and responding capability (Overby et al. 2006). Sensing capability is defined as the capability to detect and anticipate market opportunities and environmental changes (Overby et al. 2006). It is the capability that enables a firm to sense and track new customer preferences, competitors’ actions, and advancements in technology. Responding capability is defined as the capability to implement necessary changes efficiently and effectively to seize opportunities and address challenges (Overby et al. 2006). After sensing the changing environment, responding capability is critical to allow the firm to take appropriate business actions. Such responses can range from complex strategic changes to simple price changes. Overby et al. (2006) argue that firms can have different levels of sensing and responding capabilities and highlight the importance of achieving both capabilities in generating competitive actions in a timely manner.¹

2.2 IT Infrastructures

IT infrastructures are the sharable technical and common enterprise-wide platforms to provide various IT services and initiatives (Bharadwaj 2000; Melville et al. 2004). They are the foundation for the delivery of business applications and services at various levels, such as enterprise-wide data and networking services, standardized operation support, and organizational knowledge management (e.g., Alavi & Leidner 1999; Bharadwaj 2000; Broadbent & Weill 1997; Melville et al. 2004; Weill et al. 2002).

According to Sambamurthy et al. (2003), a firm needs to have digitized platforms, i.e., IT infrastructures, for both its process and knowledge management. In addition, Weill and Vitale (2002) conceptualize two distinct components of IT infrastructure: one provides shared data and network services and the other provides standardized application support. Drawing upon these conceptualizations, in this study, we investigate three distinctive types of IT infrastructure, i.e., data service infrastructure, standard application infrastructure, and knowledge infrastructure.

Data service infrastructure refers to the technical platform for enterprise-wide data and network services. This includes IT commodities and shared IT services for the management of large-scale data processing, networking, and firm-wide database (Weill & Vitale 2002). According to Bhatt (2000), this type of IT infrastructure provides access to consistent data about the activities of different departments by increasing the standardization of data definition, codes, and formats. Standard

¹ Roberts and Grover (2012) propose two alternative perspectives on the relationship between the sensing and responding capabilities, i.e., matching and mediating. While the relationship between the two capabilities is not our research focus, these alternative perspectives will be discussed with post-hoc analyses in our discussion section.
application infrastructure refers to the common enterprise application platform and standard IT applications within a firm (Armstrong & Sambamurthy 1999). This type of IT infrastructure supports shared IT applications (e.g., enterprise resource planning) and standard business processes across the firm (Weill et al. 2002). Lastly, it has been widely accepted that IT plays an important role in organizational knowledge management as a digitized platform (Alavi & Leidner 2001; Sambamurthy et al. 2003). Thus, in this study, we define knowledge infrastructure as the IT-enabled platform that promotes organizational knowledge management and sharing (Bharadwaj 2000).

Because the entire business depends on the shared IT capabilities, we argue that these IT infrastructures are crucial to business agility. IT infrastructures are instrumental in implementing common transaction processing among business units and thus expedite business operations. They allow quick access and sharing of business data and knowledge across a firm’s business processes (Sambamurthy et al. 2003). They provide the resources that make feasible innovation and continuous improvement (Bharadwaj 2000). However, the specific roles of these different types of IT infrastructure in enabling the sensing and responding capabilities are not completely understood yet.

3 RESEARCH MODEL AND HYPOTHESES

Figure 1 shows the study’s research model.

Figure 1. Research Model

3.1 Agility and Firm Performance: Sensing and Responding Capabilities

Sensing capability is crucial to firm performance. To be agile, firms must have sensing capability to collect market intelligence and closely monitor environmental changes such as new customer preferences, technical innovations, market upheavals, economic shifts, and political events (Sull 2009b). It embodies the collective knowledge, skills, and resources that a firm needs in order to recognize opportunities and deliver products and services valued by its customers. This capability to scan firm environment allows a firm to stay close to its customers, identify emerging needs quickly, keep up with trends, anticipate challenges, and predict market changes in the future (Ravichandran & Lertwongsatien 2005). Zara, one of the world’s largest clothing retailers, for example, consistently polishes its sensing capability to scan market trends and collect real-time market data every day (Sull 2009a). On the other hand, Woolworth closed all its U.S. stores because it failed to sense the changes in their customers’ shopping behaviors (Roberts & Grover 2012). Based on these arguments, we propose our first hypothesis regarding the relationships between sensing capability and firm performance as follows:

**Hypothesis 1a.** A higher level of sensing capability will lead to a higher level of firm performance.
A firm should not only understand the trends of its marketplace, but also be able to implement changes internally and externally to respond to these trends. Responding capability emphasizes the effectiveness and efficiency of a firm’s actions in response to changes. Sensing capability provides knowledge about current and future markets. Equipped with such knowledge, a firm should act in functional and cross-functional dimensions at the same time (Braganza & Korac-Kakabadse 2000). Aiming at flexible delivery of high-quality products and services with competitive costs, responding ability allows the firm to assemble its activities and resources in different ways when necessary, modify their products and/or services, and make new plans that refocus on new resources and capabilities to allow access to future opportunities and maintain their sustained competitiveness (Teece et al. 1997). Sometimes, to respond to changes and unexpected events, business routines and mobilization of limited resources must be adjusted on short notice. Such agile integration of existing resources and operations into “novel” combinations to better match their market needs helps them respond quickly to external changes, thus, improving firm performance. For example, when Southwest found that its people-oriented services based on having well-trained employees for a personal touch and excellent customer service were no longer adequate, Southwest demonstrated strong responding capability by quickly outlining a new strategy to rely on advanced technologies to help business growth while keeping prices competitive and successfully transforming its business processes as well as IT infrastructures (Ross & Beath 2007). Therefore, its responding capability positively affected firm performance. Based on these arguments, we propose our next hypothesis regarding the relationships between responding capability and firm performance as follows:

**Hypothesis 1b.** A higher level of responding capability will lead to a higher level of firm performance.

### 3.2 Conditional Value of Sensing and Responding Capabilities

Both sensing and responding capabilities are important in today’s businesses. However, their impacts on firm performance vary depending on market competition intensity. Strategy literature has long recognized the importance of aligning business strategies and capabilities with its environment (Porter 1980). Firms who provide substitutable products compete with one another at a given level of the value chain. Competitions can be based on price, quality, brand name, etc. High market competition requires firms to constantly scan their competitors’ actions, customers’ behaviors, and new technologies to keep track of the market. In such case, firms need high sensing capability to collect and process vast amount of information from the market in a short period of time. High market competitions also require firms to be more dynamic in terms of its processes, resources allocation, marketing strategies, and partnership to maintain the fit between the firm and its environment (Teece et al. 1997). Lack of agility implies a lack of responsiveness to the environment and the presence of inappropriate, outdated business activities and processes, thus resulting in poor performance. Therefore, especially in high market competition where uncertainty and unpredictability are normal, the performance of a firm highly depends on its capabilities of sensing and responding.

On the contrary, in stable market where competition is moderate, though firms still need to monitor market and respond to market, changes are usually predictable and much less frequent. When changes are detected, firms usually have more time to respond. In such circumstances, firms are more likely to take defensive actions that seek to maintain secure niches in a stable product area rather than seek innovations (DeSarbo et al. 2005), leading to less challenging actions. Thus, in relative stable market, the positive impacts of sensing and responding capabilities are weaker than those in highly competitive market. This conclusion is consistent with prior findings that predicting market trends is highly correlated with high performance in hostile environment, but such capability plays less important role in benign environment, and that organic structure that allows rapid organizational responses to external changes are more important in hostile environment than in benign environment for small manufacturing firms (Covin & Slevin 1989). Based on these arguments, we propose our next hypotheses regarding the contingency values of sensing and responding capabilities as follows:
Hypothesis 2a. Sensing capability will lead a higher level of firm performance under a higher level of market competition.

Hypothesis 2b. Responding capability will lead a higher level of firm performance under a higher level of market competition.

3.3 IT Infrastructures and Sensing Capabilities

Among the three types of IT infrastructure, we argue that the data service and knowledge infrastructures have positive influences on the sensing capability within a firm. First, data service infrastructure of a firm aims to streamline data integration across different departments, business units, and business partners by providing enterprise-wide data management and access through electronic linkages (e.g., networking and electronic data integration) (Weill et al. 2002; Weill & Vitale 2002). This type of infrastructure supports sharing of business data across as well as within the boundaries of a firm (Bhatt 2000). Therefore, it helps a firm identify important business data and information emerging from its external and internal sides, such as new market trends, customer demand changes, and internal weakness. It also helps the firm quickly share these data and information within the firm and thus improve its overall sensing capability.

Second, according to Sambamurthly et al. (2003), IT-based knowledge infrastructure is a part of the digitized business platform of contemporary business process. Such a digitized platform of business knowledge can improve a firm’s sensing capability by sharing knowledge about emerging market needs and identifying the firm’s needs and the missing resources. Knowledge infrastructure can also influence sensing capability by helping the firm obtain deep insights into the current economic environment, market competition, and future trends through assimilation of its internal and external knowledge sources (Cohen & Levinthal 1990; Joshi et al. 2010). Therefore, it facilitates learning within a firm to better understand its current status among its competitors. Based on these arguments, we propose our hypotheses regarding the relationships between IT infrastructures and sensing capability as follows:

Hypothesis 3a. A higher quality of data service infrastructure will lead to a higher level of sensing capability.

Hypothesis 3b. A higher quality of knowledge infrastructure will lead to a higher level of sensing capability.

3.4 IT Infrastructures and Responding Capabilities

Among the three levels of IT infrastructure, we argue that the data service and application infrastructures have positive influences on the responding capability within a firm. First, data service infrastructure can enhance a firm’s responding capability by facilitating the utilization of organizational available resources. According to Weill et al. (2002), enterprise-wide data management services enabled by the data service infrastructure can help a firm manage data asset independently from the specific applications and department and thus make them available for new initiatives such as new-product development and new marketing channel development (e.g., cross-selling). In addition, this type of IT infrastructure can enable such initiatives as cycle-time improvement and cross-functional processes by facilitating enterprise-wide sharing of operational data (Bharadwaj 2000). Therefore, this infrastructure enhances its overall responding capability to adapt market changes and environmental dynamics.

Second, standard application infrastructure is a cluster of infrastructure applications that are standardized across a firm. From the organizational perspective, the primary reason for employing standard application infrastructure is to enable the standardization of business processes (Weill et al. 2002). While some enterprises choose one ERP package and achieve this infrastructure, others can achieve it by standardizing and consolidating business unit’s applications into a shared standard platform for business applications. Both approaches aim to reduce costs, enable standardization,
increase flexibility, and encourage the integrated operation of multiple business units, thus making the firm agile in responding to its external changes (Weill et al. 2002). By providing standardized technical specifications, interfaces, and criteria, standard application infrastructure makes it easier to integrate new IT components. This allows for easy modification of existing business processes and integration of new technologies with existing platforms, thereby allowing the IT unit to deliver new capabilities and services quickly (Alexandersen et al. 2003). Furthermore, a reusable technology base for integrating systems and making IT applications through such standardized standard application infrastructure make a firm cost effective in their operation and support. Such flexible platform allows both incremental and disruptive modifications of existing business processes for new business models of a firm (Lyytinen & Rose 2003), providing it with more capability to respond to competitive pressure (Armstrong & Sambamurthy 1999). For example, City Bank could both reduce cost and enable faster time-to-market for new banking services by utilizing the standardized applications as a base of its new financial service creations (Weill & Vitale 2002). Based on these arguments, we develop our hypotheses regarding the relationships between IT infrastructures and responding capability as follows:

**Hypothesis 4a.** A higher quality of data service infrastructure will lead to a higher level of responding capability.

**Hypothesis 4b.** A higher quality of standard application infrastructure will lead to a higher level of responding capability.

## 4 RESEARCH METHOD

### 4.1 Measurement Development

Research constructs were operationalized based on the definition of each construct as well as definitions of relevant constructs in the literature. Every attempt was made to use existing measurements that have good psychometric measurement properties. Modifications of existing items were also made to suit the context of the study. Table 1 shows the measurement items of all research constructs and their sources. All survey items were asked using a 7-point Likert Scale (1=Strongly Disagree, 7=Strongly Agree).

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Measurement Items</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm Performance</td>
<td>• Our customer retention rate is high relative to all other direct competitors.</td>
<td>Tippins and Sohi (2003)</td>
</tr>
<tr>
<td></td>
<td>• Our sales growth rate is high relative to all other direct competitors.</td>
<td></td>
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<tr>
<td></td>
<td>• Our profitability is high relative to all other direct competitors.</td>
<td></td>
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<tr>
<td></td>
<td>• Our return on investment rate is high relative to all other direct competitors.</td>
<td></td>
</tr>
<tr>
<td>Sensing Capability</td>
<td>• Our organization’s capability in obtaining real time information about</td>
<td>Overby et al. (2006)</td>
</tr>
<tr>
<td></td>
<td>changes of market is strong.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Our top management team is alert to new trends, challenges, and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>opportunities in the market.</td>
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<td></td>
<td>• Our top management team is capable of identifying our internal</td>
<td></td>
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<tr>
<td></td>
<td>competence.</td>
<td></td>
</tr>
</tbody>
</table>

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² In this study, we do not hypothesize a direct effect of standard application infrastructure on sensing capability. This is because standard application infrastructure mainly aims to streamline the internal processes, rather than to find external opportunities and market information. Likewise, we also do not hypothesize a direct effect of knowledge infrastructure on responding capability. This is because this type of IT infrastructure within a firm focuses on gathering, analyzing, and sharing knowledge about its business while responding capability emphasizes actual implementations of requisite processes.
| Responding Capability | Our organization can quickly reallocate our resources (e.g., technology, human, and process) to deal with emerging changes.  
| | Our organization can effectively combine existing resources to address emerging challenges  
| | Our organization can timely redesign business processes to accommodate emerging challenges.  
| | Our organization can easily reconfigure our processes to handle emerging changes.  
| Pavlou and El Sawy (2006) |
| Data Service Infrastructure | The technology infrastructure needed to electronically link our business units and business partners is present and in place today.  
| | The capacity and speed of our network adequately meets our current business needs.  
| | The speed of corporate data access meets our current business needs.  
| Ravichandran and Lertwongsatien (2005) |
| Standard Application Infrastructure | Our standard application infrastructure allows reuse of application components.  
| | We have modularized the common application components of our enterprise-wide technology infrastructure.  
| | Most common application modules can be easily integrated with other business applications.  
| | The standard application infrastructure is standardized.  
| Knowledge Infrastructure | Our IT systems effectively and efficiently facilitate capturing important business knowledge.  
| | Our IT systems effectively and efficiently support coding (or packaging) important business knowledge.  
| | Our IT systems effectively and efficiently leverage distributing important business knowledge.  
| | Our IT systems effectively and efficiently promote sharing important business knowledge.  
| Kankanhalli et al. (2011) |
| Market Competition | There are many competitors in this market.  
| DeSarbo et al. (2005) |

**Table 1. Measurement Items and Sources of Principal Research Constructs**

The research model also involved two control variables. We controlled a potential effect of firm size on our dependent variable because it would offer either organizational synergy or managerial diseconomies (Tanriverdi 2006). We used the number of employees to measure the size of our samples (Ravichandran & Lertwongsatien 2005). To control the potential effect of industry type (Frohlich & Westbrook 2002), we used a categorical variable of manufacturing vs. service industry.

**4.2 Research Design**

We conducted a large-scale field survey with firms in both manufacturing and service industries in the United States. We applied a series of criteria congruent with the context of the study for selecting the target samples. We focused on industries that rely heavily on IT to support their business operations. Companies with fewer than ten employees were excluded from our sample because such small companies may not provide an appropriate setting for investigating high-level capabilities in their operations, strategic movements, and IT service.

After defining the target samples, we conducted a field survey using a web-based tool. Survey invitations were sent to business executives (e.g., president, chief executive officer, chief operating officer, business director) of sample firms in the target industries. Around 1,000 executives in an industrial respondent pool were invited to participate in this survey. A total of 195 complete data samples were collected, after removing small companies, incomplete data, and other inappropriate data, such as responses from individuals in non-managerial or different managerial positions (e.g., chief information officer).
The final sample represents six manufacturing-industry types \( (n=79) \), including consumer products \( (47) \), communications equipment \( (12) \), chemicals \( (8) \), computers/hi-tech \( (7) \), automotive \( (3) \), and biological products \( (2) \), and five service-industry types \( (n=116) \), including healthcare services \( (59) \), banking/insurance \( (38) \), consulting \( (16) \), marketing \( (2) \), and accounting \( (1) \). The firm sizes include: less than 250 \( (84) \), between 251 and 1,000 \( (22) \), and more than 1,000 employees \( (89) \).

5 RESULTS

Partial least squares (PLS), a structural equation modeling technique, was used to analyze the proposed path model (Chin 1998).

5.1 Measurement Model Evaluation

Convergent validity of the reflective measures is determined in three ways: (1) the item reliability of each measure, (2) the composite reliability of the construct, and (3) the average variance extracted (AVE) by the construct. Results reported in Table 2 indicate that all measures demonstrate adequate convergent validity, i.e., over .70 for reliability and over .50 for AVE (Fornell & Larcker 1981).

<table>
<thead>
<tr>
<th>Construct</th>
<th>Mean (S.D.)</th>
<th>Item Reliability</th>
<th>Composite Reliability</th>
<th>Cronbach’s Alpha</th>
<th>AVE</th>
</tr>
</thead>
<tbody>
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<td>Firm Performance (FP)</td>
<td></td>
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</tr>
<tr>
<td>FP1</td>
<td>5.32 (1.39)</td>
<td>.703</td>
<td></td>
<td>.882</td>
<td>.821</td>
</tr>
<tr>
<td>FP2</td>
<td>4.69 (1.42)</td>
<td>.860</td>
<td></td>
<td></td>
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<tr>
<td>FP3</td>
<td>4.58 (1.42)</td>
<td>.822</td>
<td></td>
<td></td>
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<tr>
<td>FP4</td>
<td>4.56 (1.36)</td>
<td>.839</td>
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<tr>
<td>Sensing Capability (SC)</td>
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<tr>
<td>SC1</td>
<td>4.72 (1.38)</td>
<td>.818</td>
<td></td>
<td>.849</td>
<td>.734</td>
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<tr>
<td>SC2</td>
<td>5.01 (1.37)</td>
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<td>SC3</td>
<td>4.70 (1.43)</td>
<td>.795</td>
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<tr>
<td>Responding Capability (RC)</td>
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<td>.938</td>
<td>.912</td>
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<td>RC1</td>
<td>4.38 (1.50)</td>
<td>.872</td>
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<td>RC2</td>
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<tr>
<td>RC3</td>
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<tr>
<td>RC4</td>
<td>4.39 (1.50)</td>
<td>.903</td>
<td></td>
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<tr>
<td>Data Service Infrastructure (DSI)</td>
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<td></td>
<td></td>
<td>.926</td>
<td>.879</td>
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<td>DSI1</td>
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<td>DSI2</td>
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<td>Standard Application Infrastructure (SAI)</td>
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<td></td>
<td>.924</td>
<td>.891</td>
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<td>SAI1</td>
<td>4.58 (1.20)</td>
<td>.844</td>
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<tr>
<td>SAI2</td>
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<tr>
<td>SAI4</td>
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<td>Knowledge Infrastructure (KI)</td>
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<td></td>
<td>.957</td>
<td>.940</td>
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<tr>
<td>KI1</td>
<td>4.19 (1.44)</td>
<td>.914</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KI2</td>
<td>4.06 (1.39)</td>
<td>.915</td>
<td></td>
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</tr>
<tr>
<td>KI3</td>
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<td>.935</td>
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</tr>
<tr>
<td>KI4</td>
<td>4.13 (1.40)</td>
<td>.917</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** * p < .01, * p < .05

Table 2 Results of Convergent Validity Test for Research Constructs

Discriminant validity is inferred when the square root of each construct’s AVE is higher than the correlation of the construct to other latent variables (Barclay et al. 1995; Fornell & Larcker 1981). As shown in Table 3, all the diagonal values, i.e., the square root of each construct’s AVE, are higher than their correlations with other constructs. This implies that each of the constructs shares greater variance.
with its own block of measures than with other constructs representing a different block of measures (Chin 1998). Therefore, this result indicates that discriminant validity is satisfied for measures used in this study.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>FP</th>
<th>SC</th>
<th>RC</th>
<th>DSI</th>
<th>SAI</th>
<th>KI</th>
<th>MC</th>
<th>IND</th>
<th>SIZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm Performance (FP)</td>
<td>.808</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensing Capability (SC)</td>
<td>.563</td>
<td>.808</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Responding Capability (RC)</td>
<td>.426</td>
<td>.574</td>
<td>.889</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Service Infrastructure (DSI)</td>
<td>.199</td>
<td>.351</td>
<td>.363</td>
<td>.898</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Application Infrastructure (SAI)</td>
<td>.273</td>
<td>.344</td>
<td>.412</td>
<td>.736</td>
<td>.868</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge Infrastructure (KI)</td>
<td>.204</td>
<td>.381</td>
<td>.306</td>
<td>.540</td>
<td>.570</td>
<td>.920</td>
<td></td>
<td></td>
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<tr>
<td>Market Competition (MC)</td>
<td>.129</td>
<td>.086</td>
<td>.046</td>
<td>.017</td>
<td>.071</td>
<td>.096</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry Type (IND)</td>
<td>-.083</td>
<td>.026</td>
<td>-.010</td>
<td>-.043</td>
<td>-.063</td>
<td>.009</td>
<td>.136</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Firm Size (SIZ)</td>
<td>.003</td>
<td>-.044</td>
<td>-.237</td>
<td>.055</td>
<td>.008</td>
<td>-.033</td>
<td>.053</td>
<td>-.041</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Diagonal elements in this correlation matrix of research constructs are the square root of the average variance extracted (AVE).

**Table 3. Results of Discriminant Validity Test for Research Constructs**

### 5.2 Structural Model Analyses

Estimated path effects and associated t-values were calculated using the Bootstrapping routine in SmartPLS 2.0 (Ringle et al. 2005). In particular, the moderation effect by the conditional variable, i.e., market competition, was tested using an standardized interaction term analysis (Chin 1998). Figure 2 shows the results of the model analysis.

**Fig. 2. Results of Model Test (n=195)**

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3 We further conducted supplemental analyses to address potential multicollinearity using the variance inflation factor (VIF). The VIF scores of all the principal constructs are between 1.020 and 2.535. Therefore, we conclude that our model is free from the multicollinearity concern (Thatcher & Perrewe, 2002). We also conducted Harman’s single-factor analysis to test a potential for common-method variance. The exploratory factor analysis (EFA) of our principal constructs reveals six distinct factors (with Eigen value of over 1), which explains similar amounts of the total variance of 76%, ranging from 5% to 18%. This result indicates that our data do not suffer from common-method variance (Podsakoff et al., 2003).
As shown in Figure 2, all proposed paths, except two, were significant. First, sensing capability was found to be a significant determinant of firm performance (at the .01 level). Responding capability was also found to be a significant determinant of firm performance (at the .05 level). The two component capabilities of agility together explained 38.7% of the variances of firm performance. Therefore, H1a and H1b were supported.

Second, market competition showed a significant interaction effect, i.e., moderation effect, on the link between responding capability and firm performance (at the .05 level) while it did not have a significant interaction effect on the link between sensing capability and firm performance. Therefore, H2b was supported while H2a was rejected.

Third, the proposed links, except one, between three types of IT infrastructure and the two capabilities were proved significant (at least at the .05 level) and explained 17.3% of the variance of sensing capability and 17.8% of the variance of responding capability. The control variables, i.e., industry type and firm size, were not significant in determining firm performance.4

6 DISCUSSION AND CONTRIBUTIONS

In this study, we define business agility as sensing and responding capabilities and investigate how these two agile capabilities affect firm performance under various market competitions. In the meantime, this study examine what IT infrastructures help build sensing and responding capabilities and how they influence firm performance through business agility. The results confirmed most of our hypotheses: sensing capability significantly contributes to firm performance; data service and knowledge infrastructures help build sensing capability; responding capability also significantly contributes to firm performance; standard application infrastructure has positive impact on responding capability; and under the high market competition, the role of responding capability is more critical than under the low market competition. However, two of our hypotheses were not supported: (1) the positive impact of sensing capability on firm performance shows no difference between high and low market competition; (2) data service infrastructure is not a significant determinant of responding capability. These unexpected findings need to be further discussed.

Our results show that market competition does not have a conditional effect on the link between sensing capability and firm performance while responding capability is significantly moderated by market competition. This finding implies that under highly competitive market situations, the firms having high responding capability achieve high firm performance. In other words, under the less competitive market situations, their responding activities, e.g., quick reallocation of organizational resources and redesign of business processes are unlikely to be actualized as superior high performance. However, according to our results, sensing capability is important regardless of the levels of market competition. While this finding is counterintuitive to the general perspectives on the contingency value of agility (e.g., Covin & Slevin 1989; DeSarbo et al. 2005; Sambamurthy et al. 2003), there are some potential arguments in the literature. For example, Roberts and Grover (2012) propose that a firm’s sensing capability is actualized through its responding capability, i.e., a

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4 We also conducted alternative (competing) model tests to check the goodness of fit of the proposed structural model. First, the direct effects of the independent variables (three types of IT infrastructure) on the dependent variable (firm performance) were tested. The results show that the direct effect of standard application infrastructure (β=.256, t=2.329) was significant (at the .05 level), while other types of infrastructure were not significant in predicting firm performance. Moreover, they explained only 8.7% of the variances of firm performance. Second, we tested another alternative model including all possible links between the three types of IT infrastructure and the two agility components. The results showed insignificant impacts of knowledge infrastructure on responding capability and of standard application infrastructure on sensing capability, while the results generally confirmed our main model results (except the reduced impact of data service infrastructure on sensing capability). These results confirm the goodness of fit of the proposed structural model.
mediating role of responding capability between sensing capability and firm performance.\textsuperscript{5} Thus, we might find the significant conditional effects of responding capability, but not of sensing capability. Our findings call for further investigations through our future studies.

The proposed relationship between data service infrastructure and responding capability was not supported while all other proposed links were supported. According to these results, a firm’s sensing capability is supported by the data and knowledge IT infrastructures. Since organizational sensing requires the firm’s information processing and integration platform across its departments, business unites, and partners (Nazir & Pinsonneault 2012), such information-based IT infrastructures would be the key enablers of this capability. On the other hand, our results imply that, to timely respond to emerging opportunities and changes, a firm needs to have a high quality of standard application infrastructure, i.e., a standardized technology platform for application services and integrations. We argued that data service infrastructure would be also important for such organizational responding processes, but its importance was relatively lower than standard application infrastructure.

Our study makes several contributions. First, this study contributes to research on agility by examining the conditional value of agility under different market competition. In particular, while agility has been defined as sensing and responding capabilities (Overby et al. 2006), the understanding of how these two capabilities work under different market environment is still limited. We extend the literature by studying moderating effect of market competition on the relationship between sensing and responding capability and firm performance. It helps understand underlying mechanisms of agile processes within a firm. Second, current studies have examined higher-order latent capacities of IT capabilities (e.g., Lu & Ramamurthy 2011) and IT managerial capabilities (e.g., Mithas et al. 2011; Tallon & Pinsonneault 2011) respectively, but haven’t clearly specified what IT capabilities can enable organizational agility and how. Our study contributes to this research gap and identifies three types of IT infrastructure, i.e., data service infrastructure, standard application infrastructure, and knowledge infrastructure. Furthermore, we explore the underlying enabling processes between these three infrastructures and sensing and responding capability.

Our study can be extended to several directions by overcoming its limitations. First, we utilized a cross-sectional research design that would limit study of the causal relationships and time effects among research constructs. A longitudinal setting of data gathering can provide additional insights by involving time-effect among the research constructs. Second, the data used in this study were collected from one respondent of each sample firm. A matched-pair field survey method has been discussed as a comprehensive approach to solve this limitation (e.g., Lee et al. 2007; Tallon & Pinsonneault 2011). With this approach, the questions about organizational capabilities will be sent to the business executives and the questions about IT infrastructures will be sent to the IT executives. In line with this, we want to also highlight an additional value of achieving objective measures of firm performance for our future studies. In this study, third, we did not highlight the relationship between the sensing and responding capabilities. However, some recent researchers propose to investigate the possible relationships between them. Overby et al. (2006) conceptualized four different combinations of the two agile capabilities and their potential impacts on organizational actions and performance. For examples, Roberts and Grover (2012) proposed and tested the positive impact of their alignment (i.e., high sensing and high responding capabilities) on firm performance. Combining with the environmental contingency perspective, this will be an interesting research topic for our future studies. Fourth, this study conceptualized IT infrastructures from shared service for data and network, standardized application platform, and organizational knowledge support. While these categorizations

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\textsuperscript{5} To further validate this mediation effect of responding capability, we conducted Baron and Kenny’s (1986) mediation test and Sobel’s (1982) standard errors test. The results indicate that the mediation path (mediation effect=.098, t=2.020) was significant (at the .05 level) and its mediation types fell on the partial mediation, i.e., when the mediator (responding capability) was included, the strength of the direct effect of sensing capability on firm performance was reduced, but still significant. The results confirm the significant mediating effect of responding capability between sensing capability and firm performance.
are based on well-accepted theoretical bases in the literature, their boundaries in practical settings may not be sharply distinguished because various IT resources are often integrated with each other within a contemporary firm. This issue might cause the high correlations among the three types of IT infrastructure, particularly between data service and standard application infrastructures. Lastly, in our model test, the three types of IT infrastructure explained less than 20% of the variances of the sensing and responding capabilities. Other organizational resources which can complement the value of IT infrastructure, such as operational capabilities (e.g., Lee et al. 2007), may help improve the explanatory power of the model. In line with this, we also need to highlight some emerging technology platforms (e.g., cloud computing, service-oriented architecture, and business intelligence) as alternative forms of IT infrastructure. These new types of IT infrastructure will be further considered for our future studies.

References


