December 2003

Understanding Organizational Impact of Complex IT Infrastructure through Agility: The Case of Enterprise Resources Planning Systems

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UNDERSTANDING ORGANIZATIONAL IMPACT OF COMPLEX IT INFRASTRUCTURE THROUGH AGILITY: THE CASE OF ENTERPRISE RESOURCES PLANNING SYSTEMS

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Abstract

This paper reports the progress of an attempt to examine how and why complex integrated IT infrastructures, such as ERP systems, impact firm performance. Based on emerging literature on agility, IT management and organizational theories, a conceptual model that describes a nomological network linking IT infrastructure characteristics, organizational culture, agility and firm performance is presented. In particular, we argue that a firm's IT infrastructure technical characteristics, IT function skills, infrastructure complexity, and its external orientation will contribute to its potential for agility, which ultimately improves firm performance through various effective competitive actions. The proposed research methodology is also described.

Keywords: IT infrastructure, ERP, agility, complexity, IT function

Introduction

The development and management of a responsive and flexible information technology infrastructure continues to be a dominating concern of organizations in the 21st century (Byrd and Weil 2000; Chatterjee et al. 2002). In 1997, Broadbent and Weill (1997) reported that more than 58 percent of organizational Information Technology (IT) budgets were on IT infrastructure related expenses with a 11 percent annual increase in average. Recent *ComputerWorld* surveys to IT leaders (Melymuka 2002) show that the development of a sense-and-respond infrastructure is still a top priority in IT management, particularly in integrating old legacy applications through enterprise wide systems. A latest report from AMR Research (Scott et al. 2002) confirms this trend by reporting that despite the sluggish economy, many companies are still buying Enterprise Resources Planning (ERP) systems, which in fact tops organizations' IT budgets.

This evidence implies that an integrated IT infrastructure is widely believed to bring value to contemporary firms that are facing unpredictable and rapid changes. However, the investment of time, money and internal resources for IT infrastructure implementation is substantial. The business benefits of such investments are often ambiguous and hardly visible (Chatterjee et al. 2002). There is possibility for both large successes and failures. For instance, along with numerous ERP success stories (e.g., Cisco, Elf Atochem, Compaq, etc.), there are also cases of ERP failures, some even with disastrous results (e.g., Hershey, Fox Myer, Geneva Steel, etc.).

In addition, within the last 10 years, the scope and complexity of technologies at the organizational level have increased significantly. In fact, ERP qualifies as such a complex integrated technology, which is hard to learn (Boudreau et al. 2001), understand (Gattiker and Goodhue 2000), and manage (Hitt et al. 2002). Research shows that the increasing complexity of large-scale technologies such as ERP creates knowledge barriers to organizations trying to leverage the potential technology-driven benefits (Boudreau and Robey 2001; Robey et al. 2002).

Therefore, it is important to investigate and understand the impact of IT infrastructure on firm performance. Recent IS research (Bharadwaj 2000; Bharadwaj et al. 1999; Brynjolfsson et al. 2000; Chatterjee et al. 2002) has provided empirical evidence that

IT infrastructure investments have significant impacts on stock market value and/or financial performance of firms. Hitt et al. (2002) demonstrate that ERP adopters show higher performance across a wide range of organizational productivity metrics. However, how and why these investments enhance firm performance is still unclear. There are growing calls from both IS scholars and professionals for better understanding of this relationship (Sambamurthy et al. 2003).

Sambamurthy et al. (2003) and Chatterjee et al. (2002) have proposed re-conceptualizing IT as a platform for generating agility (Goldman et al. 1995), or a comprehensive ability to respond to competitive challenges. These are viewed as core competence affecting firm performance. Drawing upon this emerging literature on competitive agility, as well as IT management literature and organizational theories, this research is an attempt to open the black box to see the relationship between the IT infrastructure investment and firm performance by developing and testing a theory that explains how and why complex integrated IT infrastructure impacts firm performance. Because ERP is a prime example of a complex IT infrastructure, this work focuses on the above theoretical questions in the context of ERP systems.

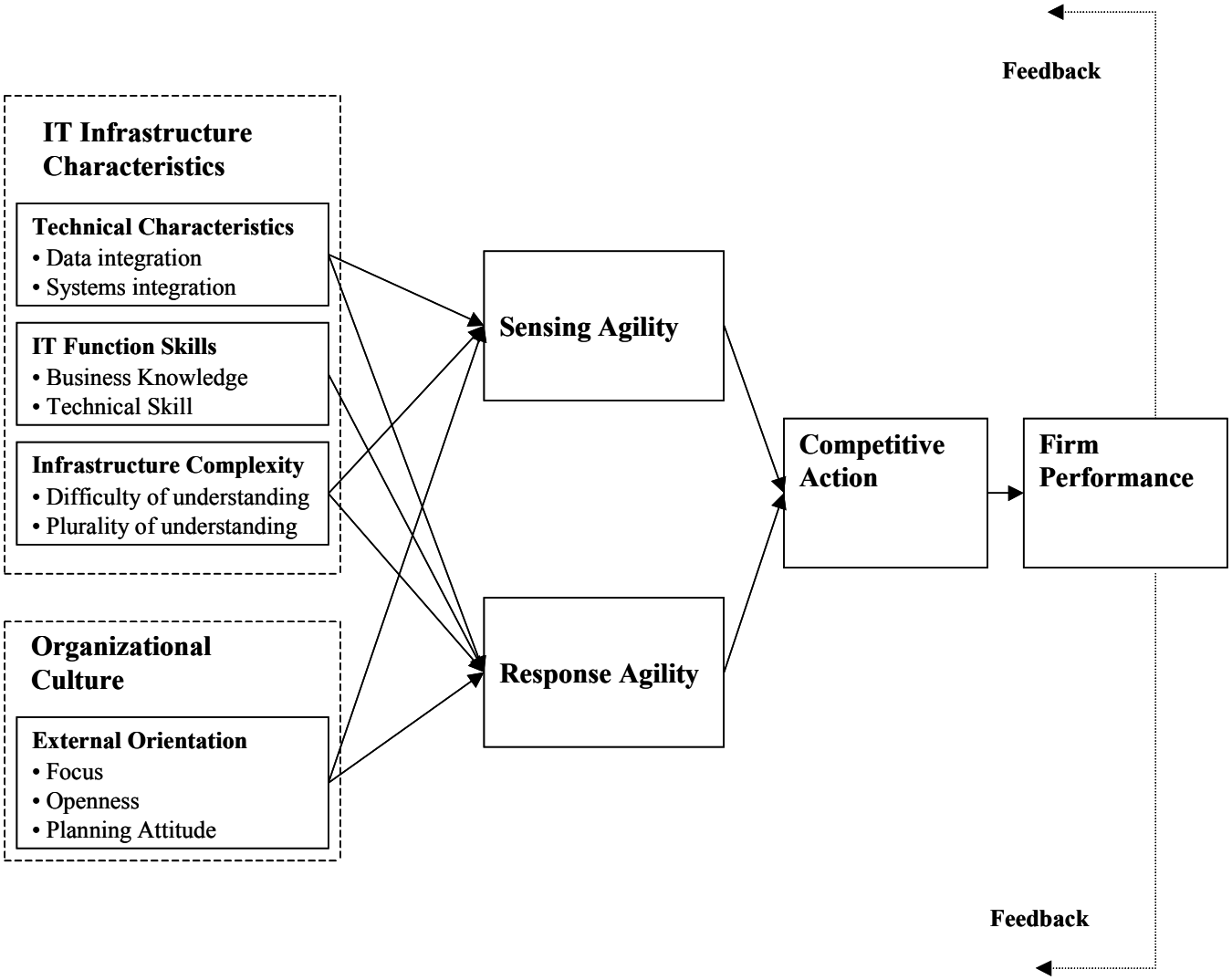

Figure 1. Conceptual Model

Conceptual Model

The resourced-based view (Barney 1991) of firms suggests that a firm can gain sustainable competitive advantages when it owns resources, which are valuable and idiosyncratic (i.e. rare, hard to copy, and imperfect substitutable). Recent IT management literature (e.g., Duncan 1995; Bharadwaj 2000) has suggested that though information systems alone are imitable, the unique characteristics of IT infrastructure, which is not only a complex set of technological systems and managerial IT skills but also developed over time, are firm specific and difficult to emulate. Similarly, though an ERP package per se may not be, we can argue that a successful implementation of ERP system linking the packaged software to different components of the IT infrastructure and to critical business processes is idiosyncratic and therefore potentially a unique source of prolonged competitive advantage.

In addition, while resources serve as a foundation for firms to compete, these resources must be combined synergistically to create organizational capabilities. For firms competing in the current fast-moving and hypocompetitive environments, recent strategic management literature reveals that agility (Goldman et al. 1995), can be such a valuable capability. Benefiting from the above perspectives, we develop our conceptual model (Figure 1). The core of this model is that IT infrastructure characteristics along with an external-oriented organizational culture increase firms' agility, and thus their performance.

Sensing Agility and Response Agility

The unpredictability of the market turbulence calls for a corporate strategy to be adaptive to changes. Hence, an organization's ability to adapt depends on how it processes information. To understand the business value of IT better, Sambamurthy et al. (2003) and Chatterjee et al. (2002) contend that IT needs to be viewed as a platform for agility, a key contributor to innovation and competitive actions, which further lead to firm performance. In this study, agility refers to the organizational ability to quickly assemble requisite assets, knowledge, and relationships via a communication and information infrastructure and to make a deliberate, effective, and coordinated response to changing demands (Amos 1998; Goldman et al. 1995; Sambamurthy et al. 2003).

Haeckel (1999) argues that an adaptive enterprise is a sense-and-respond organization, rather than the traditional make-and-sell model. His view receives extensive support from other strategy researchers (e.g., Zaheer and Zaheer 1997; Bradley et al. 1998). This perspective suggests the two dimensions of a firm's agility, namely, sensing agility and response agility.

We define *sensing agility* as a firm's capacity to rapidly discover and interpret the market opportunities through its information systems. It implies not only an ability to distinguish information from noise quickly, but also to transform apparent noise into meaning faster (Haeckel, 1999). *Response agility* relates to the organizational capability to transform knowledge into action in respond to the environmental signals with speed (Haeckel 1999; Zaheer and Zaheer 1997), such as marshal and reallocate resources to capture the opportunities.

IT Infrastructure Characteristics

It is widely agreed (e.g., Broadbent and Weill 1997; Henderson and Venkatraman 1994) that IT infrastructure consists of two components: technical IT infrastructure, and human IT infrastructure. Duncan (1995) indicates the technical aspects of the IT infrastructure feature as: connectivity, compatibility, and modularity. Lee et al. (1995) find the human IT infrastructure needs four types of knowledge and skills: technology management, business functional, interpersonal, and technical.

In addition, integrated IT infrastructures such as ERP systems have become more and more complex just like the organizational environment to which they are modeling. For example, SAP releases new versions of their ERP systems every 12-16 months to enhance their functional performance. Based on the above facts, we identify three categories of key characteristics of integrated IT infrastructures that impact agility from IT management literature. These three categories are: IT infrastructure technical characteristics, IT function skill, and IT infrastructure complexity.

Technical Characteristics

The technical aspect of IT infrastructure describes a set of basic shared technology components of which it is comprised, including "platform technology" (i.e., hardware and operating systems), network and telecommunication technologies, key data, and data-

processing applications (Duncan 1995). Among numerous attributes of such infrastructure, two primary characteristics that closely relate to agility building are data integration (Goodhue et al. 1992) and systems integration (Markus 2000).

As illustrated by Goodhue et al. (1992), *data integration* means the extent to which data definitions and structures are standardized across organizational data sources. *Systems integration* relates to the degree of tighter connections are created between different computer-based information systems and databases (Markus 2000). These technical characteristics are both perceived to contribute to firms' potential of agility. Considering ERP, two most promising technology driven benefits, as summarized by Gattiker and Goodhue (2002), are unprecedented levels of business integration among business processes and better coordination across diverse business functions. Such a unified business process and high level of coordination are essential for creating agility at the electronic commerce age (Markus, 2000). More interestingly, their impacts on sensing and response agility could be different.

As to sensing agility, a variety of case studies provide anecdotal evidence that the technology-driven attributes of IT infrastructure have positive impact on both information flow and knowledge sharing among organizational members. As a result, a holistic view is likely to be fostered across organizational units, which in turn enhances a firm's sensing agility. On the other hand, whether and how an integrated IT infrastructure increases a firm's response agility is less understood. Organization change itself is complex. Goodhue et al. (1992) contend that high level of data integration is not a panacea to all organizational situations. In fact, besides the benefits brought by integration, we also need to consider both the interdependence and differentiation between organizational subunits, the complexity of the tasks, and the nature of environmental turbulence. Therefore, the effect of the infrastructure technical characteristics on response agility is worth of investigation.

IT Function Skills

Following Bryd and Turner (2000), we argue that the two most important aspects of IT functional skill are the business knowledge and technical skills of IT personnel. Particularly within an ERP environment, unless there is a high quality team of IT professionals who well understand the existing business process, the expected consequences of process change, and the built-in ERP configuration rationale, a prompt ERP-driven process change as per changing business needs is hardly achieved. In other words, IT function skill is a necessary predecessor of response agility.

Infrastructure Complexity

On the other hand, *IT infrastructure complexity*[1] constraints both sensing and response agility. This view comes from the existing ERP literature (e.g., Gattiker and Goodhue 2000; Boudreau and Robey 2001; Robey et al. 2002). For example, Gattiker and Goodhue (2000) report from their plant-level case studies that the ERP-driven process is too complex to understand, especially when it is far different from the one being replaced. This difficulty of understanding had a negative impact on ERP designed information flow as well as knowledge transferring. Boudreau and Robey (2001) and Robey et al. (2002) also suggest that complexity is a source of "knowledge barriers", both for the acquisition of new knowledge and the refutation of obsolete knowledge (Boudreau and Robey 2001).

The above observations are supported by systems theorists (e.g., Flood and Carson 1993; Warfield 1994). These researchers have shown us two major sources of a complexity system: the number of elements, and the number of relationships between the elements. This view is perfectly appropriate to ERP because of the large amount of business processes involved, and hence their interactions. Because a system (not just information system) is used by human being, Flood and Carson (1994) point out that complexity is also associated with another important clue: people's *capability in understanding* complex situations as there are so many rules, practices and constitutive meaning around them. Furthermore, each situation may be appreciated in different ways by different people, such a *plurality of understanding* may make a system more complex.

Since a system must reflect the complexity of the environment it models (Ashby 1956), and ERP vendors are trying to make their systems applicable to more and more organizations, we expect organizational IT infrastructure, with ERP in specific, to be more and more complex. This is not only because of the increasingly new components added by the ERP vendors to their packages, but also there are more and more underlying rules and practices embedded in the systems that are too much to understand. Such

[1]Though the technology components of IT infrastructure (i.e., data processing, network architecture, operating systems, etc.) are becoming more and more complex these days, our focus of complexity is not at the technology designing level, but at the users' level. In particular, we are interested in how hard for business people to understand the systems when changes are expected.

complexity certainly hurts organizational sensing agility due to the poor or different understanding of the users when seeing changes. It also impedes firms' response agility if people have difficulty to anticipate the consequence of changing a few parameters of the systems when required.

Organizational Culture

A high level of IT infrastructure capability is necessary to create agility, but it is never a sufficient condition. There exist numerous organizational characteristics that shape firms' agility. One of such important characteristics is organizational culture.

Organizational culture is a broad concept and has been defined in many different ways. In general, organization culture relates to the underlying beliefs, shared values, and practices of participants that influence behavior (Hofstede 1991). Some authors (e.g., Volberda 1998) mention that the shared values and people's tolerance for ambiguity may be more important factors than the basic organizational form to influence organizational reaction process. Haeckel (1999) contends that sense-and-response organizations in this information age have very different ways to think about business and their external environment than the traditional make-and-sell organizations in the industrial age. Though culture research suggests firms differ along many dimensions, here we will focus on just one dimension, a firm's external orientation.

External Orientation

External orientation reflects the beliefs about the relationship of the organization to its environment (Volberda, 1998). Volberda identifies three indicators for this variable. *Focus* describes organizational members' shared idea of the future and the time frame they apply to the future. It can range from short-term to a long-term focus. *Openness* tells about how the members consider their organization as sensitive to external development. This indicator varies from closed to open. Finally, *planning attitude* explains the organizational beliefs about the extent to which the organization can control its environment or is subject to its forces. There are four positions regarding this attitude: reactive, inactive, proactive, and interactive (Ackoff 1971).

In general, as indicated by Volberda, a short-term focus, a closed external orientation, and a reactive planning attitude inhibit the potential for agility, whereas a long-term focus, an open external orientation, and an interactive planning attitude facilitate agility. We may also apply Miles and Snow typology (Miles et al. 1978) to examine organizational external orientation. Miles and Snow propose that businesses should develop enduring strategies to align with the environment and define four categories of firms: reactors, defenders, analyzers, and prospectors (see Miles et al. 1978). According to this typology, prospectors (who perceive an uncertain environment and maintain flexibility) show highest potential for agility.

Control Variables

As described early, there are other organizational characteristics that might have an impact on agility. These variables include organizational size, formal and informal firm structure (Mintzberg 1979), leadership style (Yukl 2001), etc. However, the exact causal effects (i.e., direct or indirect, positive or negative) of these variables revealed from prior research are somewhat unclear and controversial.

For example, some authors claim a matrix form of organizational structure (which is based on dual grouping of activities with a dual hierarchy of authority consisting of few hierarchical levels) is flexible in all ways because of its combination of functional departments and self-sufficient divisions. Others point out that a matrix form creates some major obstacles for developing flexibility due to its complex communication and reporting systems. We can also find similar inconsistent arguments concerning the impact of leadership style on agility elsewhere.

Therefore, though the potential effects of these control variables are acknowledged, we will not develop hypotheses related to these variables in this study and have not displayed them in our conceptual model. However, we will include simple measurements of them for exploratory analysis.

Research Methodology

Our intention is to design a cross-sectional study that could validate the conceptual model described above within the domain of ERP deployment through pen-and-pencil questionnaires. The basic unit of analysis is private-sector organizations. We tend to observe agility in both firms who either have implemented ERP or not, with a purpose to better examine the variance explained by IT infrastructure.

As both ERP and competitive agility are contemporary phenomena, and there has been very little empirical research focusing on issues like ERP benefits and complexity, as well as the measurement of agility, we plan to conduct this study in two steps. Phase 1 involves a series of 8-10 phone interviews with ERP practitioners in various industries to better understand the phenomenon first (Benbasat et al. 1987). Phase 2 is a survey to industrial organizations to test our model. The current model seemingly calls for two respondents from each participating organization: one high level IT leader, and another executive from the business side.

We are currently at the initial stage of Phase 1. The goals of this period are to 1) identify industri(es) that are appropriate for this study; 2) refine the conceptual model and derive a research model with testable hypotheses; and 3) develop instruments for constructs identified in the research model.

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