IS IMPLEMENTING ERP LIKE POURING CONCRETE INTO A COMPANY? IMPACT OF ENTERPRISE SYSTEMS ON ORGANIZATIONAL AGILITY

Completed Research Paper

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Abstract

Literature is divided on whether enterprise systems promote or hinder organizational agility. To the best of our knowledge, this paradox has never been rigorously theoretically analyzed nor empirically investigated. This paper seeks to address this paradox by leveraging upon innovation assimilation literature and knowledge based and capabilities based views of organizations. We propose a theoretical framework of the effects of ERP assimilation on agility. We also theorize that the dynamic capability of systems agility not only has a direct effect on organizational agility, but also moderates the effect of ERP assimilation levels on agility. We validate the proposed framework by conducting a cross-sectional survey across 215 organizations. The results shed light on one part of the dilemma: higher ERP assimilation levels positively influence organizational agility and validate the proposed model. Moreover, systems agility acts as a critical enabler by amplifying the net positive impact of ERP assimilation on organization agility - in addition to having a strong direct effect.

Keywords: Organizational agility, systems agility, innovation, assimilation, dynamic capabilities, diffusion, routinization, enterprise systems, ERP

Introduction

Over the last two decades, enterprises have faced increasingly turbulent competitive environments. Recent research indicates that in the last decade these competitive dynamics have only accelerated (McAfee & Brynjolfsson 2008). During the same period enterprises have widely invested in enterprise-wide systems like enterprise resource planning (ERP) solutions to better manage their operations. In less than a decade since the early 1990s, 76% of manufacturers, 35% of insurance and health care companies, 24% of Federal Government agencies and 60% of the U.S. Fortune 1000 companies have adopted an ERP system (Stedman 1999; Stein 1999). Currently SAP (the largest ERP vendor in the world by revenues) claims that "70% of the world economy's transactions touch an SAP system in some way, shape or form" (SAP announcement, SAPPHIRE Conference 2009).

The literature is, however, divided whether widespread utilization of ERP systems promotes or hinders organizational agility. One body of literature argues that complex and organization wide IT systems like enterprise systems enable an organization to rapidly sense changing business needs and respond via quick adaptations to business processes (Anderson et al. 2003; Davenport et al. 2005; Sambamurthy et al. 2003). Ergo, these systems promote organizational agility. Another body of literature, in contrast, posits that because enterprise systems assume tight integration and coupling between business processes and different parts of the business, it generates unprecedented complexity and inertia. This leads to rigidity and change avoidance, whereby widespread use of enterprise systems hinders organizational agility (Rettig 2007). This idea is well illustrated in an Economist article titled 'Liquid Concrete' (The Economist, Sep 13 2007),which summarized a practitioner's view of ERP systems by stating that "*implementing SAP [the leading enterprise system] is like pouring concrete into a company*".

To the best of our knowledge, the paradox between enterprise systems both promoting and hindering organizational agility has never been theoretically analyzed nor empirically addressed. This paper addresses this paradox by leveraging upon *innovation assimilation* literature and proposing a theoretical framework of the effects of ERP assimilation - that articulate potentially positive and negative effects - on organizational agility. We also theorize that the dexterity and speed of systems development capabilities, as conveyed by the dynamic capability of *systems agility,* not only has a direct positive effect on organizational agility, but also moderates the potentially positive or negative effects of ERP assimilation on agility. In other words, it acts either as an amplifier on the positive or a brake on the negative aspects of ERP assimilation.

We validate the proposed theoretical model by conducting a cross-sectional survey across 215 organizations that have implemented SAP systems. The validation seeks to detect the impact of ERP assimilation on organizational agility, as well as to find support for the proposed research model. The results demonstrate that higher ERP assimilation levels positively influence organizational agility. Moreover, systems agility forms a powerful and critical enabler, as it has a strong positive direct effect on organizational agility as well as positively moderates the positive impact of ERP assimilation on organization agility. The concepts of ERP assimilation (in contrast to just the presence of ERP) and system agility thus play a key theoretical role in explaining the paradoxical effect of enterprise systems in promoting and hindering organizational agility.

The remainder of the paper is structured as follows. First, we briefly attend to the literature on enterprise systems and organizational agility. Next, we leverage prior research by systematically developing a theoretical framework that organizes ERP assimilation, systems agility and organizational agility into a causal model, to explain either positive or negative effects of ERP assimilation on organizational agility. We also postulate the interaction effects between ERP assimilation and systems agility. We then report our empirical research and review the findings. We finally conclude with a reflection on the implications of the research in this paper for theory and practice of organizational agility.

Literature Review and Hypotheses

Enterprise Systems

ERP (Enterprise Resource Planning) systems typically are large-scale transaction processing software solutions that integrate and automate enterprise-wide organizational processes in the form of

'best practices' (Davenport 1998). *Enterprise systems* are a portfolio of information systems implemented enterprise-wide, which integrate transaction processing *with* data analysis, data reporting, and data flow across enterprise-wide and cross-enterprise units, functions, and processes. Typically, enterprise systems comprise core transactional systems supplemented and potentially tightly integrated with additional applications like business intelligence (BI), customer relationship management (CRM), supply chain management (SCM), etc. Since ERP systems generally form the core foundation of an enterprise-wide application portfolio, the terms 'ERP systems' and 'enterprise systems' will be used interchangeably and synonymously in this paper.

ERP systems are characterized by three attributes, which distinguish them from earlier classes of administrative information systems:

1. ERP systems incorporate very large scale integration of diverse and disparate enterprise processes such as finance, sales, marketing, operations, manufacturing, warehousing, distribution, product development, human resources, etc. in one common database (Markus & Tanis 2000).

2. ERP systems are real-time in nature, such that they enable the real-time propagation of "the same information almost instantaneously through one unified user interface" (Bingi et al. 1999) across almost all functions of the firm.

3. ERP systems are purchased or leased in most cases from a single software vendor. They are not built around the specific business processes of an individual organization (Sharma &Yetton 2003). In contrast, they are designed around generic functional business models, which are considered to reflect 'best industry practices' (Wagner et al. 2006).

ERP systems are often considered transformational in nature, due to these key characteristics.

Organizational Agility

Over the last two decades, organizational agility has been studied across multiple disciplines including strategic management, operations, marketing and information systems. Consequently, the definitions of organizational agility have diversified, leading to a lack of theoretical clarity (Schnackenberg et al. 2011). Three key characteristics distinguish organizational agility in the current discourse from other organizational properties:

First, organizational agility recognizes the *speed* of organizational change as exemplified by the idea of *decision making speed* (Judge & Miller 1991), in 'high-velocity' environments (Eisenhardt 1989). Second, organizational agility recognizes the *ease of organizational change* as exemplified by the constructs of *flexibility* (Bahrami 1992) or *strategic flexibility* (Hayes & Pisano 1994). Although constructs of flexibility and strategic flexibility often implicitly recognize speed as an element therein, their definitions focus more on the *ease of change* than the *speed of change*. Characteristics of both *speed of change* and *ease of change* have been studied in more detail by researchers that seek to identify antecedents to organizational agility, such as modularity (Sanchez & Mahoney 1996), internal organizational structures leveraging upon contingent workforce and loose couplings (Matusik & Hill 1998), external organizational structures supporting strategic alliances (Young-Ybarra & Wiersema 1999), and increased product variety (Worren et al. 2002).[1] The third key characteristic of organizational agility is the presence of *sensing and responding mechanism* which is defined by Sambamurthy et al. (2003 p. 245), as "the ability to detect opportunities for innovation and seize those competitive market opportunities by assembling requisite assets, knowledge, and relationships with speed and surprise".

For this paper, we will use the following definition of organizational agility (Tallon & Pinsonneault 2011):

"(Organizational) agility (is) defined as the ability to detect and respond to opportunities and threats in the environment with ease, speed and dexterity" (Tallon & Pinsonneault 2011, p. 464)

[1] For a contrarian point of view see Raynor & Bower (2001).

This definition not only emphasizes and highlights all three characteristics of *speed of change, ease of change and sensing/responding,* but also adds a dimension of dexterity, implying the need for organizations to achieve an appropriate balance amongst competing requirements.

Enterprise System Assimilation and Organizational Agility

To articulate the impact of enterprise systems on organizational agility, it is not sufficient to simply consider the impact of the *presence* or *absence* of enterprise systems on organizational agility. The main reason is that the system must be *used* in order to have any effects on organizational behaviors qualified as being agile. Just attending to the presence of the system would therefore not incorporate the theorizing of the complex interactions between the three characteristics of enterprise systems as a class of information systems – deep and large-scale process integration, real-time data integration, and "best practices" process design. These *effects* come to bear on an organization's ability to be agile i.e. increasing speed, flexibility and sense and response, only when the systems are *used* over time more extensively.

Our analysis therefore starts with an assumption that ERP systems need to be considered to be a complex technology driven organizational *innovation*. Accordingly, theories of technology innovation are relevant for our analysis, as the key *effect* of technology innovations on organizations is determined by the extent to which the innovation gets *assimilated* within the organization (Armstrong & Sambamurthy 1999; Zmud & Apple 1992). We accordingly ground our analysis of the *effects* of ERP on the concept of *innovation assimilation*. Specifically, we define *ERP assimilation* based on Purvis et al. (2001, p.121) as "*the extent to which the use of technology (ERP) diffuses across the organizational projects or work processes and becomes routinized in the activities of those projects and processes*". We specifically surmise that the extent of assimilation is the key cause of *effects* of enterprise systems on organizational agility.

We will use the construct of *ERP assimilation* along its dimensions of *diffusion* and *routinization* in conjunction with research on *knowledge-based* (Grant 1996; Spender 1996)*, capabilities-based* (Collis 1994; Eisenhardt & Martin 2000; Teece et al. 1997)*, resource-based* (Barney 1991a; Penrose 1959) and *risk-based* (Baird & Hall 1985; Bromiley 1991) views on organization and strategy. Using these theories, we will next build two competing perspectives articulating how ERP assimilation can have either a *positive* effect or a *negative* effect on organizational agility.

ERP Assimilation Promotes Organizational Agility

By definition, increased ERP assimilation will result in increased diffusion and increased routinization of ERP systems within the organization. From a knowledge-based view, increased *diffusion* of ERP systems increases knowledge "*reach*" (Sambamurthy et al. 2003) in an organization, through large scale integration across multiple information sources *within* the organization (e.g. one common integrated database for customers, vendors, products, etc. across business units) as well as integration with databases *outside* the organization (e.g. partner databases, point-of-sale databases, etc). At the same time, increased *routinization* of ERP systems enhances knowledge "*richness"* (Sambamurthy et al. 2003), by encouraging managers to routinely use information that is of higher quality, real-time as well as more customizable (Overby et al. 2006). Increased knowledge "*reach*" and "*richness*" in turn increase the digital options available to a firm, resulting in increased organizational agility (Sambamurthy et al. 2003).

From a capabilities perspective, an increase in both *diffusion* as well as *routinization* of ERP systems enhances *sensing* capability in organizations, through dynamic IT capabilities for "managing by wire" i.e. management with processes enhanced by capabilities to speedily sense and process volumes of environmental information which far exceed the processing capability and capacity of human beings (Haeckel & Nolan 1993). Such increased sensing capabilities result in *increased* agility in more turbulent environments.

From a resource-based view, due to ERP systems being highly customizable, configurable, modular and having an integrated design, an increase in both *diffusion* as well as *routinization* of ERP systems allows business processes within an organization to be extensively and routinely reconfigured for alternative resources (e.g. new material in a component of a bill of material (BOM) of a product) while at the same time lowering the cost and time of switching such resources. This results in enhanced resource *flexibility*, which *increases* organizational agility (Sanchez 1995).

Finally, from a risk-based view, dynamic markets require managerial willingness to redefine organizational strategies, which varies inversely with perceived risk associated with change (Baird & Thomas 1985). Perceived risk in turbulent environments can be reduced when managers can obtain better current information about how customers respond to an organization's products (Eisenhardt 1990). Increased *diffusion* and *routinization* of ERP systems increases wide and routine use of richer and better product and customer information provided by enterprise systems, such as business intelligence (BI) and customer relationship management (CRM) systems. This helps resolve market uncertainties more quickly and accurately, leading to lowered perceived risks in support of *increased* agility (Sanchez 1995).

ERP Assimilation Hinders Organizational Agility

In contrast, literature from knowledge-based views also suggests that knowledge sharing enabled by increased diffusion and routinization of ERP systems may lead to *decreased* organizational agility by reinforcing positions held by executives that come from what has worked in the past. It thus creates a "*competency-trap*" for the future, when dynamic market changes necessitate unanticipated adaptive changes and new knowledge (Christensen 1997, Eisenhardt & Martin 2000).

Similarly from a capabilities perspective, an increase in ERP assimilation may lead to increased diffusion and routinization of "best-practice" processes around which ERP systems are designed. This may lead organizations into a corresponding "*capabilities-trap"* by potentially reducing the ability to develop new capabilities based on new processes and new knowledge (Galliers, 2007), resulting in *decreased* organizational agility.

From a resource-based perspective, based on high implementation and maintenance costs, increased diffusion and routinization of ERP systems may lead to IT executives being more inclined to utilize enterprise systems to extract short-term value, rather than to use such resources to explore new opportunities with longer-term returns (Gupta et al., 2006). Such reluctance to leverage existing resources to alternate usage may result in *lower* organizational agility.

Finally, from a risk-based view, increased diffusion and routinization of ERP systems results in tighter integration and coupling between business processes. Such tight integration creates additional complexity. Increased complexity may lead to increased rigidity and correspondingly higher risk, which may result in *lower* organizational agility (Goodhue et al., 2009; Rettig, 2007).

In summary, the two competing theoretical frameworks synthesized from literature offer two conflicting predictions on the relationship between ERP assimilation and organizational agility.They reflect a paradoxical *tension* inherent in enterprise systems in both promoting *and* hindering agility. Although, independent and exclusive effects of positive and negative influences of ERP assimilation on agility can be predicted based on the theory streams reviewed above, the key in addressing this paradoxical tension is to understand the *net simultaneous effects* of both positive and negative influences of ERP assimilation on organizational agility. Hence we propose the following two competing hypotheses:

Hypothesis H1: ERP assimilation has a net positive impact on organizational agility.

Hypothesis H2:ERP assimilation has a net negative impact on organizational agility.

Effect of Systems Agility on Organizational Agility

To understand the potentially paradoxical impacts of ERP assimilation on organizational agility is to unearth the *conditions* under which the impact can go either way. Literature from dynamic capabilities suggests that in response to environmental changes, organizations may need to often change their business processes and product strategies (Hayes & Pisano 1994; Sanchez & Mahoney 1996). As a result, organizations also need systems development capabilities to render changes to their information systems, to closely match their systems with desired new processes that have emerged in response to market turbulence. Although literature in strategic management argues about the *presence* or *absence* of such systems development capabilities, it generally stops short in delving into the *speed* or range of such systems development capabilities (Sanchez 1995). At the same time, although literature in agile systems development extensively theorizes about the *speed* of system development, it generally does not link it back to the higher level construct of organizational agility (Cockburn 2001;Vidgen& Wang 2009).

We next combine these two insights to posit that the *speed* of systems development capabilities that can effectuate a range of system changes will have a direct effect on organizational agility. We interpret systems agility as a dynamic capability and define it as "*the organizational capability to successfully and swiftly change its information systems*" (Davis 2009, p.16).It is to be noted from the definition of systems agility that it *implicitly* encompasses swift and successful changes to *all* information systems. Hence this dynamic capability of systems agility is *not* limited to only enterprise systems. The higher the systems agility in an organization, the higher would be the *swiftness* and *success* of changes to information systems in the organization. Such higher *swiftness* and *success* of information systems change would then increase the speed at which supported business processes and product strategies could change, resulting in *higher* organizational agility. Hence, we propose:

Hypothesis H3: Systems agility positively impacts organizational agility.

By definition, two of the key *effects* of ERP assimilation are *diffusion* and *routinization* of enterprise systems in the organization, which are hypothesized to influence the levels of organizational agility. *Diffusion levels* can be increased through two mechanisms – by increased *unit scope diffusion* through which *existing functional modules* of the ERP systems are rolled out across *additional business units* in the organization, as well as by increased *functional scope diffusion* through which *additional functional modules* are rolled out in *existing business units*. Since both, *unit scope diffusion* and *functional scope diffusion* require changes to the ERP system, and higher systems agility capability will increase the swiftness and success of such changes to the ERP system, it implies that higher systems agility will increase the levels of ERP *diffusion* and correspondingly influence the levels of organization agility. At the same time, higher *routinization levels* of ERP systems across the processes and projects of an organization require sufficiently stable processes supported by systems, in the time interval *between* successive changes driven by dynamic markets. The stability period of processes can be increased by decreasing the time spent *within* that time interval, in implementing system changes in support of the process changes. This can be achieved with *swifter* and *more successful* changes, corresponding to higher systems agility. Thus, higher systems agility can increase the levels of ERP *routinization* and correspondingly influence the *levels* of organizational agility. Since systems agility can influence both *effects* of ERP assimilation viz. *diffusion* and *routinization* and correspondingly their influence on levels of organizational agility, it implies that systems agility *moderates* the influence of ERP assimilation on organizational agility.

Our earlier analysis of the impact of ERP assimilation on organizational agility provided two competing frameworks along with corresponding hypotheses. Hence, we apply this formulation as a starting point for articulating the moderating effects of systems agility on the influence of ERP diffusion and routinization on organizational agility. If hypothesis H1 is true, then higher systems agility will lead to an *amplifying* effect on the net positive effects of ERP *assimilation* on organization agility. On the other hand, if hypothesis H2 is true, then higher systems agility will lead to a *dampening* effect on the net negative effects of ERP assimilation on organization agility. Both of these scenarios lead us to the following two competing hypotheses on the moderating effects of systems agility, in the impact of ERP assimilation on organizational agility.

Hypothesis H4: Systems agility positively moderates (amplifies) the net positive impact of ERP assimilation on organizational agility.

Hypothesis H5: Systems agility negatively moderates (dampens) the net negative impact of ERP assimilation on organizational agility.

The resultant placement of ERP assimilation, organizational agility and systems agility in a nomological network, produces two competing conceptual models for the research, as shown in Figures 1A and 1B.

Research Design and Methods

To validate our hypotheses we followed a socio-metric *quantitative* approach by conducting a survey on postulated impacts of ERP assimilation and systems agility on organizational agility. The unit of analysis in this study is a strategic business unit. We felt that this was the most appropriate granular level to obtain valid insights of ERP impacts.

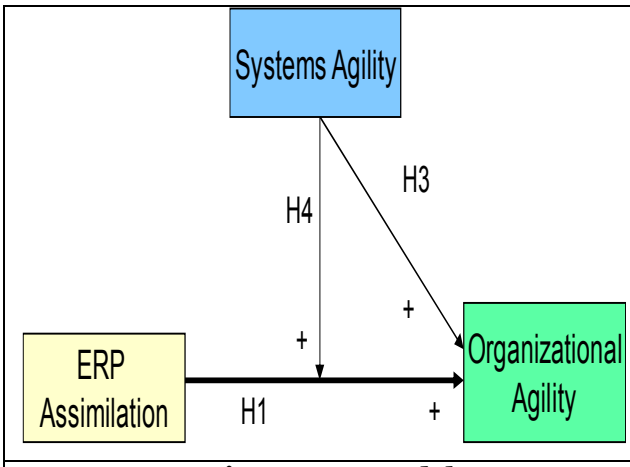

Figure 1A – Model 1

ERP Assimilation Net Positively Impacts Organizational Agility

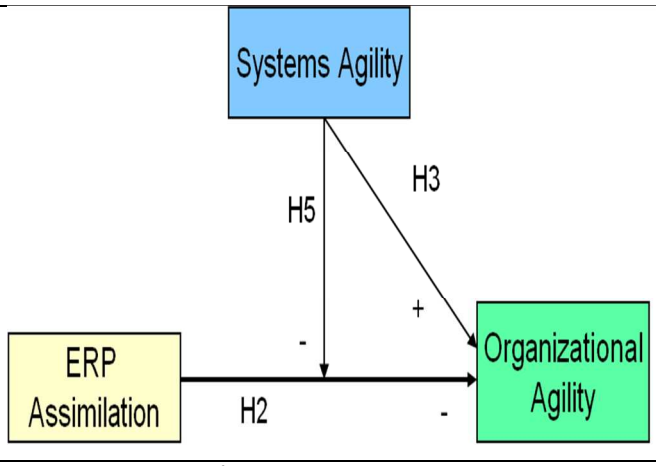

Figure 1B– Model 2

ERP Assimilation Net Negatively Impacts Organizational Agility

Operationalization of Constructs

The scales for most constructs were adapted from existing instruments (Davis 2009; Sambamurthy et al. 2007). Necessary additional revisions were done whenever needed given the context of the study.

Dependent Variable: Organizational agility

We used the 18-item instrument from Sambamurthy et al. (2007) for measuring organizational agility. It is based on the framework of entrepreneurial agility and adaptive agility of Bharadwaj & Sambamurthy (2005) and was adapted to ensure that the unit of analysis was at a business unit level. Entrepreneurial agility was measured along the dimensions of proactiveness (Miller & Friesen 1983; Ramanujam & Venkatraman 1987), preemptiveness (MacMillan 1983; Sethi& King 1994) and radical innovation (Miller & Friesen 1983; Zahra &Covin 1995). Adaptive agility was measured along the dimensions of reactiveness (Hult et al. 2005; Tracey et al. 1999), resilience (Mallak 1998; Sheffi and Rice Jr. 2005) and incremental innovation (Skaggs & Huffman 2003; Subramani &Youndt 2005).

Independent Variable: ERP Assimilation

We leveraged the instrument from Liang et al. (2007) which measured ERP assimilation along dimensions of volume, diversity and depth from Zmud & Massetti (1996). Although these dimensions and their associated items from Liang et al. (2007) address one element in the definition of assimilation viz. *diffusion*, we felt that they do not adequately address the other equally critical component of *routinization* in the definition of assimilation. Hence we consulted with Goodhue (see e.g. Goodhue et al., 2009) to develop an updated scale for measuring ERP assimilation along the three dimensions of *diffusion, diversity of routinization* and *depth of routinization*. *Diffusion* was measured on a 15-point scale by gathering objective input on the number of functional modules of the enterprise system implemented in the business unit. *Diversity of routinization* was measured by gathering input on usage of each of the fifteen functional modules in operational, management, and decision-making routines of the business unit. The final score was computed on a 5-point scale as a weighted average score across all functional modules, with twice the weightage for management and decision-making routines as compared to the baseline operational routines. *Depth of routinization* was measured using a nine item scale, as a measure of the extent to which enterprise systems were '*embedded in the DNA of the business unit*'.

Moderating Variable: Systems Agility

We adapted the instrument from Davis (2009) to measure systems agility with a four item scale, with appropriate changes to ensure that unit of analysis was at business unit level.

Control Variables

We controlled for the following four variables, specific to the business unit, because of their potential impact on organizational agility as suggested by extant literature (Liang et al. 2007; Lu & Ramamurthy 2011; Tallon & Pinsonneault 2011).

Industry type. This was measured in categories of Consumer Products, Industrial Products, Services, Government/Non-profit and Others.

Size: Revenues. This was measured in mutually exclusive intervals of <$300M, <$1B, <$5B, <$10B and >$10B.

Size: Employees. This was measured in mutually exclusive intervals of 1-499; 500-1,999; 2,000-4,999 and 5,000+ employees.

Age. This was defined as the number of years since the founding of the business unit and was measured in mutually exclusive intervals of 0-4; 5-9; 10-19; 20-49 and 50+ years.

Instrument Development

As far as possible, we used existing instruments with good established psychometric properties to ensure measurement reliability and validity. In scale development and contextualization we followed the suggestions from DeVellis (2003). Since the items for at least one key construct in this research were not adapted from existing instruments, a two-step process was followed to ensure validity and reliability of these modified and self-developed items. First, the items were distributed to three well-known management and IS researchers and a PhD student, all of whom had expertise in the specific research area of this paper. The items were updated based on their feedback on face validity and construct validity of the instrument. Second, a pilot survey of the instrument was conducted with 50 respondents in one large publicly traded $3 billion organization in the US. The pilot was a cross-sectional survey with respondents identified across four business units and in positions of executive responsibility, as well as having knowledge of both business and IT components of their business unit. Exploratory factor analysis (EFA) was done on the pilot data and single factor loadings for each construct were found to be acceptable. Reliability analysis based on Cronbach's alpha revealed that all constructs had acceptable values (>0.70), except resilience (0.70) and reactiveness (0.58). Based on subsequent analysis of inter-item correlation matrix, items of resi3 and reac3 were reworded to improve reliability. In addition, based on feedback from pilot respondents on the length of the survey, some constructs that were not core to the research of this paper (project management agility, IT competence in IS, social capital) were dropped. Other than control variables and objective items, the finalized instrument had all scales defined as seven-point Likert scales and is included in Appendix A.

Data Collection

The finalized instrument was sent out as a cross-sectional web-survey to approximately 2000 organizations in the US, who have all implemented SAP ERP solutions. SAP is the largest vendor of ERP solutions in the world. All of the organizations were identified through their membership in a US-based non-profit association of companies in the US, who have implemented SAP ERP. The survey respondents in the organizations were targeted from a pool of both business and IT executives. Respondents were assured of complete confidentiality and did not receive any remuneration for their participation. The link to the web-survey was emailed by the user association to the organizations. A follow-up email was sent two weeks after the initial email, as a reminder. After exclusion of cases with missing data, we had a final sample size of 215 cases. Since the link to the web-survey was emailed by a trade group to the organizations, it was not possible to directly contact the organizations to measure non-response bias. However, emails received by the user association from the non-respondents indicated that the conference

travels as well as organizational policies against participation were the key reasons for not responding. Characteristics of the respondents are provided in Table 1.

Table 1. Respondent Characteristics

Business Unit – Industry		
	Frequency	Percent
Consumer Products	95	44%
Industrial Products	39	18%
Services	45	21%
Govt/Non-profit	10	5%
Other	25	12%
Total	215	100%

Business Unit – Employees		
	Frequency	Percent
1-499	21	10%
500-1999	24	11%
2000-4999	30	14%
5000-9999	68	32%
10,000+	73	34%
Total	215	100%

Business Unit – Revenues		
	Frequency	Percent
< $300 million	29	13%
< $1 billion	30	14%
< $5 billion	94	44%
< $10 billion	22	10%
>= $10 billion	40	19%
Total	215	100%

Business Unit – Age		
	Frequency	Percent
0-4 years	8	4%
5-9 years	19	9%
10-19 years	31	15%
20-49 years	54	25%
50+ years	102	47%
Total	215	100%

Measurement Model

Normality tests based on skewness and kurtosis statistics showed that normality was within normal limits. Additionally, visual inspection for normality, skewness and kurtosis using histogram, Q-Q plot and box-plot for each item confirmed that normality, skewness and kurtosis were within reasonable limits. The data was assessed for multicollinearity, homoscedasticity and outliers, all of which were within limits. Appropriateness for factor analysis was determined by Kaiser-Meyer-Olkin (KMO) measure (excellent at 0.913) and Bartlett's test (significant at the 0.001 level).

An exploratory factor analysis (EFA) using principal axis factoring with Promax rotation resulted in eight factors, with each item loading on its factor (>0.4) and large enough cross-load differences(>0.2). The total variance explained was 68.8%. We however noticed that the sub-construct of preemptiveness (pree) loaded with the sub-construct of proactiveness (proc), within the construct of organizational agility (oa), while items1-3 within the construct of ERP assimilation (erpa) loaded as a separate factor. Hence, preemptiveness could have threats of discriminant validity. No items or sub-constructs were however dropped for subsequent CFA. Confirmatory Factor Analysis (CFA) was carried out with all the eight constructs and associated items using an iterative process where appropriate error covariance relationships were added as well as items deleted (Byrne 2009). Three items (inci3, sar4, resi2) were dropped, leaving a total of 30 items in the final model which had an excellent fit (CMIN/DF = 1.641, CFI = 0.954, SRMR = 0.052 and RMSEA = 0.055 (LO = 0.047, HI = 0.062, PCLOSE = 0.157)) (Byrne 2009:81). For all constructs, both Cronbach's alpha and composite reliability (CR) was greater than the threshold of

0.7. (see Table 2). All constructs showed excellent convergent validity with average variance extracted (AVE)> 0.5 and CR > AVE (Fornell& Larker, 1981). All constructs other than preemptiveness showed acceptable discriminant validity (maximum shared squared variance (MSV) < AVE; average shared squared variance (ASV) < AVE). For pre-emptiveness, ASV was less than AVE but MSV was 0.005 higher than AVE.Hence it was still considered to have acceptable discriminant validity. The inter-factor correlations for the final constructs are included in Appendix B.

Table 2. Reliability and Validity of Constructs

Construct	Sub-Construct	Composite Reliability (CR)	Average Variance Extracted (AVE)	Maximum Shared Squared Variance (MSV)	Average Shared Squared Variance (ASV)	Cronbach's Alpha
Organizational Agility	Proactiveness	0.935	0.828	0.630	0.299	0.899
	Preemptiveness	0.832	0.625	0.630	0.320	0.824
	Radical Innovation	0.888	0.727	0.526	0.307	0.881
	Reactiveness	0.903	0.756	0.531	0.401	0.898
	Resilience	0.715	0.561	0.372	0.224	0.740
	Incremental Innovation	0.935	0.877	0.372	0.251	0.900
ERP Assimilation		0.910	0.513	0.375	0.219	n.a.
Systems Agility		0.924	0.802	0.436	0.250	0.920

Since the data were collected using a single method from a single source, the possibility of a common method bias cannot be eliminated. Harman's single-factor test (Podsakoff et al. 2003) showed that the first factor explained 40% of total variance (< 50%). A common marker analysis was carried out showing the presence of 20% common method variance. This is within acceptable threshold for IS research (Malhotra et al. 2006). A nested model comparison between the final measurement model and the common marker model was not significant (p=0.463), indicating that common method effect was not significant for the measurement model.

Structural Analyses

A structural equation model (SEM) was built in AMOS, as per the causal model in Figure 1. For moderation analysis we used z-scores to minimize the bias in estimating the interaction terms. The final trimmed model was created through reviewing modification indices, adding covariance paths where theoretically justified, and trimming insignificant paths when necessary (Byrne 2009). The final model had a good fit: CMIN/DF = 2.690, CFI = 0.956, SRMR = 0.051, RMSEA = 0.089, (LO = 0.069, HI = 0.110, PCLOSE = 0.001).

Findings

The final structural equation model shows that ERP assimilation (β=0.146) is significant as a determinant of organizational agility at p <0.01 level. Since β is positive, it implies that ERP assimilation has a net positive impact on organizational agility. **Hence Hypothesis 1 is supporte**d whilst **Hypothesis 2 is rejected**. Systems agility (β=0.437) was also found to be significant as a determinant of organizational agility at the p < 0.001 level. With a positive β, **Hypothesis 3 is supported**. The interaction term of systems agility and ERP assimilation (β=0.057) was found to be significant at the p < 0.1 level. This suggests that systems agility positively moderates the effect of ERP assimilation on organizational agility. Combined with the fact that Hypothesis 1 with net positive effects of ERP assimilation was supported, implies that **Hypothesis 4 is supported** while **Hypothesis 5 is not**

supported. Overall, Model 1 with net positive effects of ERP assimilation on organizational agility was supported by the findings and hence Model 2 with net negative effects of ERP assimilation on organizational agility was rejected. Model 1 could explain 49.6% of the variance of organizational agility. Surprisingly, none of the control variables were found to be significant in determining organizational agility. The results are summarized in Table 3.

Table 3. Results of Hypothesized Relationships

	Hypotheses	Supported?	Estimate	p-value
H1	ERP assimilation has a net positive impact on organizational agility.	**Yes**	0.146	0.003
H2	ERP assimilation has a net negative impact on organizational agility.	No	n.a.	n.s.
H3	Systems agility positively impacts organizational agility	**Yes**	0.437	***
H4	Systems agility positively moderates (amplifies) the net positive impact of ERP assimilation on organizational agility.	**Yes**	0.057	0.077
H5	Systems agility negatively moderates (dampens) the net negative impact of ERP assimilation on organizational agility.	No	n.a.	n.s.

Support for Hypothesis H1 implies that a significant linear relationship exists between ERP assimilation and organizational agility (though the effect size is not that large). Support for Hypothesis H3 implies that a significant linear relationship exists between system agility and organizational agility (and effect size is medium). Finally, support for Hypothesis H4 implies that with systems agility moderating the relationship between ERP assimilation and organizational agility, systems agility and ERP assimilation *interact* with each other, thus causing a differential impact on the dependent variable of organizational agility. Hence, we would expect to see a change in the slope and intercept of the linear relationship between ERP assimilation and organizational agility for different values of systems agility. In order to visualize this change, an *interaction plot* was graphed as shown in Figure 2.

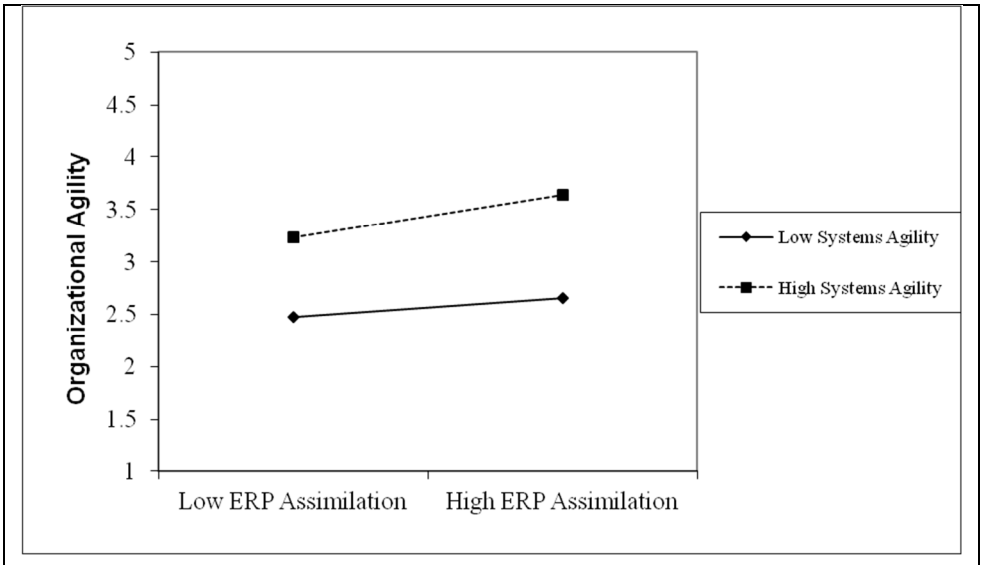

Figure 2. Interaction plot

The results from the interaction plot are illuminating. When an organization has low capability of systems agility, organizational agility is almost flat with increases in ERP assimilation i.e. higher ERP assimilation does not result in significantly higher organizational agility. This can assist in explaining part of the paradox, especially in practitioner literature, of enterprise systems perceptually *not promoting* organizational agility. Another part of the paradox is that prior studies may not have separated or controlled for the level of assimilation of the ERP system. In contrast, for organizations that possess high systems agility, organizational agility increases with an increase in ERP assimilation i.e. systems agility has a true amplifying effect in the impact of ERP assimilation on organizational agility (on top of those achieved by system agility directly). This can again help explain the other part of the paradox, especially in scholarly literature, of enterprise systems *promoting* organizational agility i.e. organizations need complementary resources that are leveraged through system agility. In addition, even for low levels of ERP assimilation, the interaction plot shows that higher levels of systems agility result in higher organizational agility. Systems agility seems to be the key organizational complement, which acts as a catalyst in enabling the positive impact of enterprise system use on organizational agility.

Discussion

Prior research in information systems has shown that enterprise systems improve productivity, efficiency, effectiveness and financial performance in organizations (Goodhue et al. 2009). The primary focus of the research in this paper was to extend this understanding to the impact of enterprise systems on organizational agility - specifically in resolving the paradox of whether enterprise systems *promote* or *hinder* organizational agility. In addition, we also wanted to understand the conditions under which enterprise systems impact organizational agility. In order to achieve these objectives, we leveraged the framework of *innovation assimilation* to embed ERP assimilation, organizational agility and systems agility into a nomological network, with systems agility moderating the impact of ERP assimilation on organizational agility.

Our results show that ERP assimilation overall *promotes* rather than hinders organizational agility, with a net positive relationship between ERP assimilation and organizational agility, independent of the level of systems agility or other controls we used. This supports our original theoretical positioning that *assimilation* of ERP based on the dimensions of *diffusion* and *routinization* is a fruitful framework to understand the impact of enterprise systems on organizational agility. Additionally, the results indicate that *within* an ERP assimilation model, resource-based, capabilities-based, knowledge–based and risk-based views offer an explanation for a net positive connection between enterprise systems assimilation and organizational agility. It also supports prior research (Davenport et al. 2005; Sambamurthy et al. 2003) that information systems, in general, provide capabilities which have a direct effect (though not significantly large) on organizational agility. The results extend prior research to enterprise systems specifically, implying that the theoretical underpinnings justifying this relationship continue to be valid even at the boundary conditions exemplified by enterprise systems, as a class of information systems with high levels of technology integration and complexity in terms of both breadth of process scope and depth of data integration. At the same time, the result forces us to revisit other contrasting claims that enterprise systems always hinder organizational agility (Rettig 2007, Galliers 2007). Specifically, the claim that organizations will find it difficult to achieve dexterity between the efficiency and speed gains from tight and widespread integration in enterprise systems, and the agility declines from their corresponding complexity, needs to be carefully reviewed. One possible explanation for the observed effects in these studies is that they may have examined the connection during early stages of assimilation and in organizations with low levels of system agility.

Our research suggests that the dynamic capability of systems agility has a direct and a medium measured effect on organizational agility. Hence it supports a) the dynamic capabilities view that market turbulence requires changes in business processes and product strategies which necessitates systems development capabilities (Eisenhardt & Martin, 2000), as well as b) supports our extension on dynamic capabilities by validating that the speed of systems development capabilities positively influences organizational agility.

Finally, our research shows that the dynamic capability of systems agility indeed positively and significantly moderates the impact of ERP assimilation on organizational agility. Not only does higher systems agility lead to higher organizational agility when ERP assimilation is higher, but even in

organizations with low ERP assimilation, higher systems agility has an amplifying effect on organizational agility. In a sense, systems agility functions as a catalyst or as a key enabler for unlocking the potential of ERP assimilation to render an organization more agile. This is a significant result, for both theory as well as practice. From a theoretical perspective, our results extend Tallon & Pinsonneault findings (2011) by providing empirical evidence that IT capabilities, like systems agility, provide additional digital options, which can have a *moderating* effect on organizational agility, vis-à-vis the *mediating* or direct effects of digital options on organizational agility in the nomological network from Sambamurthy et al. (2003). From a practitioner's perspective, our result highlights the importance of the development and sustainment of system oriented dynamic capabilities like systems agility in organizations,so as to ensure that they can reap the full value of complex IT innovations like enterprise systems. In contrast to Carr (2003), we argue that IT system capabilities still matter, while all IT in itself may not matter.

Limitations

The paper has several limitations. The data collected was limited to organizations in the United States. Hence the findings may not be generalizable outside USA where the form of system use can be different. The organizations selected for data collection have all implemented one specific ERP solution viz. SAP. Hence the findings may not be generalizable to organization with other ERP solutions, as ERP systems differ in functionality and flexibility. In addition, newer versions of ERP systems offering Web services or cloud based services may change the configurability of ERP systems, such that assimilation effects may accrue earlier or system agility may not be that critical. To participate in data collection, organizations were randomly selected by a non-profit trade group comprising of members who have implemented SAP. It is not known if the request from an association explicitly introduces any selection bias to more successful ones, while identifying the organizations to participate in the survey. Since the link to the web-survey was emailed by a third-party non-profit association to the organizations directly, it is not possible to empirically measure or validate the presence of non-response bias by conducting wave tests (Armstrong & Overton 2003).

Implications for Practice and Future Research

Enterprise systems have remained a key focus for IS practice as executives are concerned by the high sunk cost of implementation and license fees (typically ranging together in the millions of dollars) and high failure rates even well into post-implementation. Such concerns are all the more heightened due to a widely held view that enterprise systems introduce rigidity and hinder an organization in being nimble. Our research addresses these concerns with the primary result that not only do enterprise systems *not* introduce rigidity, on the contrary they have a net positive and direct effect on organizational agility. Organizations can achieve dexterity in both efficiency and agility through their enterprise systems.

In post-implementation or sustainment phase of enterprise systems in an organization, management tends to focus on cost containment strategies, also known as "keep the lights on", in their approach to maintenance. Our results show that IS managers need to change their view and specifically focus on inculcating systems development capabilities, since the speed and range of such systems development capabilities not only have a direct effect on making the organization agile, but in addition it has an *amplifying* effect in enabling the role of enterprise systems to influence organizational agility.

In addition, C-level managers need to be aware that it is not sufficient to simply support *implementation* of enterprise-wide technologies. Such an approach might improve efficiency in the organization; however in order to extract full value from their investments they also need to take an active leadership role in promoting the *assimilation* of such innovations by ensuring that such innovations "*diffuse* across the organizational projects or work processes and become *routinized* in the activities of those projects and processes" (Purvis et al. 2001). In a sense, such enterprise-wide innovation technologies need to be *embedded within the DNA of the organization*.Our results clearly show that higher the *assimilation* of enterprise systems in an organization, higher is the ability of the organization to be agile in the face of dynamic competitive pressures.

Our research invites two areas for further research. First, our research extends on the dynamic capabilities view of organizational agility, with systems agility playing a primary role in the case of enterprise systems. Literature from dynamic capabilities indicates that organizational knowledge and

competencies are foundational in the operationalization of dynamic capabilities, in both moderate and highly dynamic markets (Eisenhardt & Martin, 2000). Hence an important area for further research that we plan to explore is to understand the role of organizational knowledge and competencies within the nomological network outlined in this paper. Second, the research in this paper can be replicated in international organizations with multiple types of enterprise solutions and by controlling for variation in governance structures, in order to make the results more generalizable and accurate. One direction that we plan to additionally pursue is the effect of the configurations of modules that have been implemented within the ERP system on organizational agility, and the moderating effect of the perceived environmental turbulence on these effects.

We started this research with the prime objective of resolving the paradox of enterprise technologies in both promoting and hindering organizational agility, as well as of understanding the conditions under which enterprise systems may impact organizational agility. The motivation for this quest was best summed up by the article on ERP systems in *The Economist* (Sep 13, 2007) which used the metaphor of "*implementing ERP is like pouring concrete into a company*". Along our journey, we have realized that the use of the concrete pouring metaphor is not accurate. Perhaps a revised metaphor might be "*implementing ERP is like pouring high octane fuel into a company, as long as you catalyze that fuel with system agility*".

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Appendix A - Constructs and Items

Construct (label)	Sub-Dimension (label)	Item
Organizational agility (oa)	Proactiveness (PROC)	PROC1. Anticipate new business opportunities PROC2. Seek new business opportunities PROC3. Seek novel approaches to future market needs
	Preemptiveness (PREE)	PREE1. Be the first to market with new business approaches (or models) PREE2. Develop new standards and practices in the industry PREE3. Preempt imitators through marketing actions
	Radical innovation (RADI)	RADI1. Seek high-risk projects with chances of high return RADI2. Support business experimentation despite uncertain returns RADI3. Commit resources to radical changes that can potentially transform markets and competition
	Reactiveness (REAC)	REAC1. Rapidly react to emerging opportunities in customer needs REAC2. Rapidly react to emerging opportunities in markets REAC3. Rapidly react to emerging opportunities in new products and services
	Resilience (RESI)	RESI1. Rapidly respond to natural threats (e.g., natural disaster) RESI2. Rapidly respond to competitive threats (e.g., competitor's price change and new marketing campaign) RESI3. Rapidly respond to operational threats (e.g. production disruption)
	Incremental innovation (INCI)	INCI1. Adapt existing business models INCI2. Adapt existing business processes INCI3. Quickly adopt best practices used by others
Systems Agility (sar)		SAR1. We are successful in rapidly changing our information systems in response to changing business needs SAR2. The information systems in place within our business unit enable our capability to make critical changes quickly in response to changing business needs SAR3. Within our business unit, we can quickly change our information systems in response to changing business needs SAR4. In general, our business unit's IT group can make needed system changes in a timely manner

ERP Assimilation (erpa)	Diffusion (diff)	Which of the following modules of SAP ERP solution have been implemented for your business unit/division? FI-CO (Financial Accounting/Controlling) HR (Human Resource) SD (Sales and Distribution) MM (Materials Management) PP (Production Planning) PM (Plant Maintenance) QM (Quality Management) BW (Business Warehousing) LIS (Logistics Information System) IS (Industry Solutions e.g. Retail, AFS) CRM (Customer Relationship Management) PLM (Product Life Cycle Management) SCM (Supply Chain Management) SRM (Supplier Relationship Management) SEM (Strategic Enterprise Management)
	Diversity of Routinization (r_di)	For those modules implemented, please also identify what they are used for in your business unit/division. Used for Operations Used for Management Used for Decision-making
	Depth of Routinization (r_de)	Item1 We expect the ERP system will provide future opportunities for improving the way we do business. Item2 We see the ERP system as providing additional opportunities for improving the unit's effectiveness. Item3 We see the ERP system not just as a replacement for our old systems but also as a new platform that can provide valuable new capabilities. Item4 We actively look for new ways of using the ERP system to improve our effectiveness. Item5 We encourage our people to further explore and learn the ERP system so that new ways of utilizing it can be found. Item6 We devote resources to exploring the ERP system to find new ways to leverage its power. Item7 We continue to find new ways of taking advantage of the ERP system to improve the way we do business. Item8 We are still discovering new ways of using the ERP system to get business benefits. Item9 The ERP continues to gives us new opportunities to improve our effectiveness.
Controls	Industry	Consumer Products, Industrial Products, Services, Govt/Non-Profit, Others
	Size-# Employ.	1-499; 500-1,999; 2,000-4,999, 5,000+
	Size- Revenue	<$300M, <$1B, <$5B, <$10B, >$10B
	Age – Years	0-4; 5-9; 10-19; 20-49,50+

Appendix B – Inter-factor Correlations

	ERPA	Organizational Agility						SAR
		PROC	PREE	RADI	REAC	RESI	INCI	
ERP Assimilation (ERPA)	0.716							
Proactiveness (PROC)	0.367	0.910						
Preemptiveness (PREE)	0.331	0.794	0.791					
Radical Innovation (RADI)	0.451	0.627	0.725	0.852				
Reactiveness (REAC)	0.518	0.635	0.729	0.695	0.870			
Resilience (RESI)	0.475	0.406	0.401	0.387	0.568	0.749		
Incremental Innovation (INCI)	0.462	0.463	0.378	0.435	0.600	0.610	0.937	
Systems Agility (SAR)	0.612	0.392	0.372	0.455	0.660	0.417	0.517	0.895