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An Empirical Study of IT-enabled Enterprise Risk Management and Organizational Resilience

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20. AN EMPIRICAL STUDY OF IT-ENABLED ENTERPRISE RISK MANAGEMENT AND ORGANIZATIONAL RESILIENCE

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Abstract

Contemporary organizations are increasingly challenged by the expanding variety of risks and threats posed by turbulent and complex business environments. This paper addresses the importance of organizations having the ability to cope with risks and uncertainties by exploring IT-enabled enterprise risk management (ERM) capability as a means of achieving organizational resilience. Based on the synthesis of prior risk management theoretical frameworks, we posit that information technology is a key enabler of enterprise risk management capability that integrate risk management into enterprise-wide business processes, with organizational commitment as a complementary enabler. By examining the relationship of IT-enabled ERM capability and organizational resilience under the moderating effect of business network structure strength, this study provides insights on how to ensure continued survival of organizations in today's volatile operating climate where risks extend beyond the organizational boundaries. Empirical findings from a survey of 185 organizations in Singapore show that IT assets and organizational commitment play significant roles in building up IT-enabled ERM capabilities. Organizational resilience is also found to be strongly impacted by the organization's IT-enabled ERM capabilities, while the firm's business network structure strength negatively moderates this relationship to a small extent. Managerial implications stemming from the empirical findings are discussed and directions for future research on enterprise risk management as a burgeoning research area for IS researchers are also offered.

Keywords

IT-enabled enterprise risk management, organizational commitment, business network structure strength, organizational resilience

1. Introduction

Organizations today face an increasingly complex business environment in which survival is highly dependent on the capability to cope with uncertainties and disruptions of varying magnitudes. Firms must grapple with the challenges of technological obsolescence, geopolitical shocks, regulatory changes, and the emergence of new business models. More importantly, the necessity to develop strong organizational capabilities for anticipating and mitigating risks under increasingly unpredictable and volatile business conditions has heightened. Governments have responded by developing and introducing tougher laws to ensure that companies continue to be financially stable. Stricter financial regulations, such as the Sarbanes-Oxley Act of 2002 (SOX) are imposed on businesses to enforce greater levels of compliance and transparency. Consequently, there is a pressing need for firms to adopt sound risk management practices that would enhance their organizational resilience to cope with the myriad of threats and risks.

However, firms cannot afford to be dependent on external intervention from governments and institutional forces to maintain an ideally stable, predictable business environment with reduced risks. It is imperative for them to proactively develop the capability to anticipate and overcome potential threats. The growing sophistication in risk management techniques and methodologies undoubtedly plays a central role in providing organizations with the means to assess and control risks and threats. In recent years, there has also been a shift in focus for organizational risk management from specialized, silo-ed approaches of addressing the risks of different business units to a more integrated and holistic approach that can improve risk reporting and cross-functional coordination.

The increasing interdependence between different business functions and their associated risks makes it crucial for top management to address all these risks collectively. This integrated approach, commonly known as enterprise risk management (ERM) has emerged as an important means of managing risks in organizations. ERM shows much promise where development of organizational resilience is concerned, providing firms in industries ranging from logistics and supply chain management to financial institutions and insurance firms with an increased awareness of potential disturbances and a variety of responses (Coutu 2002; Starr, Newfrock, and Delurey 2003). Developing resilience in the face of business disruptions is critical to survival. However, it will require organizations to be able to sense likely disturbances ahead of time and to respond to external environmental changes quickly and effectively.

Although the managerial guidelines and methodologies for ERM are well established, there is a lack of understanding as to what organizational elements or conditions could lead to the development of ERM capability. In spite of the growing importance of information technology (IT) in today's information-intensive organizations, it is surprisingly to note that the application of IT as an organizational-spanning resource that can enable enterprise-wide risk management has not been adequately examined in most risk management studies.

Therefore, the overriding objective of this paper is to develop and empirically test a theoretically-grounded model for the development of organizational resilience through IT-enabled ERM capability. It is hoped that the exploratory efforts of this study would set the foundation for starting a stream of research into the realm of IT-enabled enterprise risk management.

2. Definitions of Enterprise Risk Management

With the growing interest in ERM since the 1990s, various risk management, insurance and accounting associations have offered several formal definitions of enterprise risk management.

The definition given by CAS (Casualty Actuarial Society) is:

Enterprise risk management is the discipline by which an organization in any industry assesses, controls, exploits, finances and monitors risks from all sources for the purpose of increasing the organization's short and long term value to its stakeholders.

By incorporating the emphasis on management involvement, the Committee of Sponsoring Organizations of the Treadway Commission (COSO) provided another alternative definition of ERM as:

A process, effected by an entity's board of directors, management and other personnel, applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and manage risk to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objectives.

The COSO (2004) framework further defines ERM to comprise of the following components: i) internal environment, ii) objective setting, iii) event identification, iv) risk assessment, v) risk response, vi) control activities, vii) information and communication and viii) monitoring. The COSO ERM framework is observed to be a refined extension of earlier risk management frameworks (e.g. Bandyopadhyay et al. 1999; Mehr and Hedges 1963) that places substantial responsibilities on the organizations' top management for effecting risk management initiatives.

3. Conceptual Developments

3.1 Conceptualization of IT-enabled ERM Capabilities

For the purpose of this study that explores how a firm may minimize the effects of external shocks and adverse events, our working definition of risk is the probable negative impact of an event which the firm is exposed to. To develop a new conceptualization of IT-enabled ERM capability, we synthesized the practitioner-based COSO framework and the IT and project risk management academic literature.

In today's information-intensive organizations, IT plays a critical role to enable all operational processes that span across the entire extended enterprise. We identified the key ERM capabilities as risk measurement, risk control and risk monitoring capabilities. As these three capabilities are reflections of an overall ERM capability, we conceptualized IT-enabled ERM capabilities as a second-order construct comprising of these three first-order capabilities. First, *risk measurement* involved event identification and assessment of their likelihoods and impacts based on historical data and present state. Risk analytics supported by technology and mathematical methods are required to perform accurate risk assessments. Second, *risk control* involved the selection and execution of the appropriate response to risk. Third, *risk monitoring* involved the on-going evaluation and tracking of risk management effectiveness and communicating feedback to management. Accordingly, we define IT-enabled ERM capability as follows:

IT-enabled enterprise risk management capability is the ability of an organization to assess, control, and monitor risk from all sources, facilitated by an organizational IT architecture in order to provide reasonable assurance of realizing increased firm value.

3.2 Conceptualization of Organizational Resilience

The importance of organizational resilience cannot be understated especially in the age of globalization where business environments are increasingly dynamic and linked to factors such as political upheavals, diplomatic tensions and social issues. Being able to respond appropriately to changes and risks is one of the keys to ensuring a sustainable competitive advantage and the long-term survival of an organization.

Resilience is a concept that has its roots in the field of ecology. Different interpretations of the meaning of resilience have been offered by various researchers over the past decades since it was first defined by Holling (1973) as:

Resilience is a measure of the ability of systems to absorb changes of state variables, driving variables, and parameters and still persist.

Further work on the concept of resilience has enriched the definition of resilience in two main ways (Gunderson 2000). The first type of definition is termed as engineering resilience (Holling 1996), which refers to the time required for a system to return to an equilibrium or steady-state following a perturbation (Pimm 1991). The second type of definition, termed as ecological resilience, refers to the magnitude of disturbance that can be absorbed before the system redefines its structure by changing the variables and processes that control its behaviors (Holling 1973).

A closer examination of the definition of ecological resilience suggested that the persistence or survival of a system depends on its variety of its functional groups (Gunderson 2000). In accordance with ecological perspective and complex adaptive systems theory, it would be necessary for a system to continually evolve and maintain enough diversity and complexity in the form of an array of available responses in order to ensure its persistence when faced with unexpected changes in the environment (Berkes, Colding, and Folke 2003; Dervitsiotis 2004).

An organization is typically structured very much like an ecosystem consisting of different organisms; it comprises of different subsystems in the form of business units and people that interact with one another. Drawing parallel with its ecological counterpart, variety is equally valuable to an organization operating in dynamic business environments as it is to an ecosystem subject to changing conditions. Hence, the capacity to generate variety in an organization is important in boosting its resilience, as variety influences the capacity of the organization to accommodate disturbances and also determines the options available for its response to changes. If the range of strategic alternatives available to an organization is significantly narrower than the breadth of changes facing it, the organization will be a victim of turbulence (Hamel and Valikangas 2003).

Underlying the importance of variety in an organization is the Ashby's Law of Requisite Variety, which states that the only way a system may survive when there is a change in its environment is to have enough complexity and a variety of responses whose variety matches the variety of challenges presented by the environment (Ashby 1960). Adhering to the law, it would therefore be vital for a system to possess capabilities to build up sufficient variety in order to anticipate and survive disturbances (Gunderson 2000). In addition, it is also very important for a system to be able to recover quickly and return to equilibrium. Recovery would be facilitated by methods that involve buffering mechanisms and nurturing sources of renewal (Berkes and Folke 1998; Gunderson 2000). Such methods would mitigate the effects of adverse changes in the system and shorten the time to return to normal state, as well as learning mechanisms to lead the system out of crisis through reformation (Gunderson, Holling and Light 1995).

Fusing these insights from ecological perspectives and systems theory and applying them to a changing business environment that could often be subjected to frequent cyclical upturns and downturns, we conceptualized organizational resilience as a second-order construct with two first-order constructs: *anticipatory competence* contributing to the provision of requisite variety necessary to absorb disturbances prior to a perturbation, and *recovery competence* contributing to speed of return to optimal operations after a perturbation.

Drawing upon the notion of competence proposed by Sanchez, Heene and Thomas (1996), organizational resilience can be viewed as an organizational competence that sustains the coordinated deployment of tangible resources, and intangible assets in form of capabilities that help the organization anticipate disruptions and recover from them. Therefore, we define organizational resilience as follows:

Organizational resilience is the competence of an organization to anticipate external shocks and disruptions, and to recover swiftly with a sufficiently rich variety of safeguards and responses.

4. Research Model and Hypotheses

Figure 1 depicts the proposed research model.

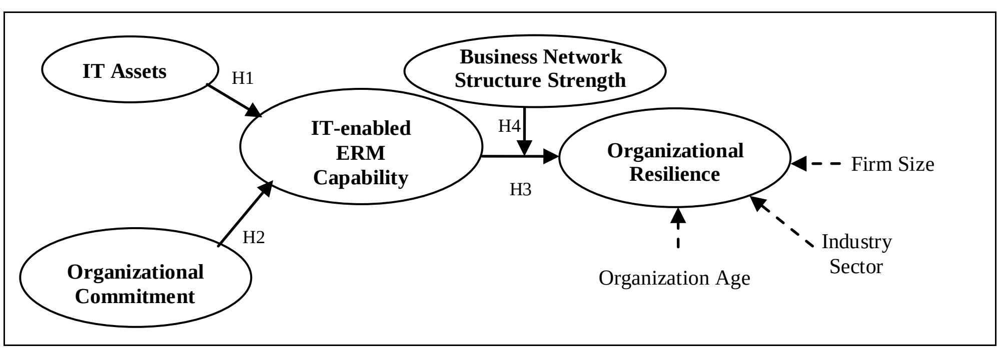

Figure 1: Research Model

4.1 Antecedents of IT-enabled ERM Capabilities

An organization's IT assets can be described as a base of IT resources within an organization comprising of the IT infrastructure and the IT business applications that utilize the infrastructure (Broadbent and Weill 1997). We therefore conceptualized IT assets as a second-order construct comprising of these two first-order components.

IT infrastructure is pivotal to ensure that personnel are provided with the information necessary for them to manage risk (Duncan 1995). It allows the sharing of databases and information across the enterprise. It also provides a common platform for applications, with high-performance and robust hardware central to supporting complex risk analysis, valuation and measurement technology crucial to the risk management function (Strobel and Krishna 2006).

IT business applications are important in the embedding of ERM practices into business processes. In our research context, key examples of risk management applications include: the use of business intelligence tools to provide concise risk reporting for senior managemenent (Lam 2003), the application of mathematical modeling and simulation software in the measurement and analysis of the likelihood and impact of possible risks (Marphatia and Tiwari 2000), the use of decision support tools to select the appropriate response to risk (Lange 1998), and automation of verification, controls and stop-loss limits to ensure compliance (Ramamoorti and Weidenmier 2006).

The seamless dissemination and proper management of risk information is crucial to ensure that concise risk reporting is provided to senior management and that a repository of historical data and present data is available for risk analysis (Lange 1998). Furthermore, IT makes necessary risk information easily accessible to personnel of all levels and this empowers them to make day-to-day risk management decisions at the operational level. This would give rise to a greatly enhanced ERM capability. Hence, it is hypothesized that:

Hypothesis 1 (H1): The quality of information technology assets positively influences IT-enabled ERM capability.

A critical complementary resource identified in the risk management literature is the level of organizational commitment to promoting and ensuring effective risk management practices and raising awareness of risk across the enterprise (Lam 2003). Porter et al. (1974) defines commitment as a belief and acceptance of organizational goals and values, a willingness to exert effort to organizational goal accomplishment, and a strong desire to maintain organizational ownership. When an organization is viewed as a coalition of various constituencies, organizational commitment can be regarded as a collection of multiple commitments to various groups that comprise the organization (Reichers 1985).

In this study, organizational commitment comprises of commitment from top management, line management as well as the employees. Leadership is important in ERM for setting the tone of the organization, through top-down communication, formulation of risk policies, risk-adjusted allocation of resources and initiation of training programs. Line management and employees would need to be involved actively in managing day-to-day risks faced at the front-end and executing business transactions and decisions in line with the overall organizational risk profile

(Lam 2003). We therefore conceptualized organizational commitment as a second-order construct comprising of the two first-order components, top management commitment, and employee commitment.

In the context of an enterprise-wide risk management initiative within the organization, the management plays a vital role in leading by example and setting the tone of the organization. This in turn would bring about acceptance of IT-enabled changes and commitment towards achieving organizational goals from the employees (Lam 2003). We expect that strong organizational commitment would lead to: i) heightened sensitivity at all levels of the organization in identifying risks and threats, ii) top management, line managers and employees taking on more responsibilities in managing risks within their functions, and iii) a proactive involvement in the continual monitoring and improving of risk management activities. Hence, it is hypothesized that:

Hypothesis 2 (H2): Organizational commitment positively influences IT-enabled ERM capability.

4.2 Impact of IT-enabled ERM Capabilities on Organizational Resilience

Increasing rates of environmental turbulence require firms to be able to transform themselves into highly responsive "living entities" capable of adapting to drastic environmental changes (Pascale, Milleman and Gioja 2001). In a volatile business environment, the possession of IT-enabled ERM capabilities provides a firm with the necessary means to anticipate unexpected or adverse changes, and to recover quickly and resume normalcy.

IT-enabled ERM provides top management and personnel with timely and accurate assessments of the likelihood and impact of possible risks and threats facing the firm, which allows them to take the necessary steps to prepare and build up the economic capital and variety required to absorb disturbances (Lam 2003). The firm's ability to measure risk well also puts in place both formal and informal structures of high quality conversation and communication that will give rise to the necessary generation of ideas and solutions for tackling impending threats (Dervitsiotis 2001).

IT-enabled ERM capabilities also ensure that the optimal response to risk is taken and executed properly, so that the effects of perturbations are placed under control or negated as much as possible. Comprehensive policies and action plans provide a variety of options at the disposal of the firm for controlling and reducing risks. The active involvement of all employees at the operational level ensures that risk responses are carried out based on formal procedures dictated by top management. Automation of checks and controls with the use of IT streamlines execution, aiding compliance staff responsible for handling exceptions (Ramamoorti and Weidenmier 2006).

Monitoring and feedback mechanisms in ERM could also provide management and personnel with on-going updates on the actual impact of the disturbance and the effectiveness of risk responses that would help in the reorganization and renewal efforts to resume business operations as quickly as possible. This would also facilitate continual learning that aids in the reformative process of developing more effective mechanisms to combat threats and risks.

IT-enabled ERM capabilities could help the organization build up and maintain a repertoire of strategic alternatives and responses which is sufficiently complex and varied, in order to match the potential disturbances in its operating environment in line with the requisite variety principle (Ashby 1960). Hence, it is hypothesized that:

Hypothesis 3 (H3): IT-enabled ERM capability positively influences organizational resilience.

4.3 Moderating Effect of Business Network Structure Strength

Based on the strategic network theory (Gulati 1999), firms accumulate network resources over time from their inter-firm business networks. These resources which resided outside of the firm's boundaries in the form of embedded ties with business partners and clients could be sources of valuable information (Powell 1990). Network structure of a firm can be viewed as a resource in the form of the structural pattern of its network of relationships that enables information sharing, which can boost the firm's sensitivity and responsiveness to external events and competition (Gulati, Nohria and Zaheer 2000). This is because strong network structures enable firms to extend its reach in gathering information, sharing information, and allowing them to tap into partners, suppliers and even customers for advanced knowledge of threats.

Hence, we argued that if a firm is able to identify threats ahead of time and minimize their potential impact by relying on the extrinsic network resource of business relationships, the reliance on internal capabilities for dealing with environmental volatilities would be reduced. This is so because it is likely that strong network structures could compensate adequately for the lack of robust risk management capabilities within the firm. Consequently, the beneficial effects of minimized threats derived from the use of internal capabilities might be diminished to some extent. Firms with strong network structures would therefore likely to experience comparatively less impact on their organizational resilience accrued through internal IT-enabled ERM capabilities. Strong network structures seemed unlikely to augment IT-enabled ERM capabilities significantly due to the enterprise-centric focus of internally developed ERM capabilities differing from the outward focus of network structures. Hence, it is hypothesized that:

Hypothesis 4 (H4): The strength of the organization's business network structure negatively moderates the relationship between IT-enabled ERM capabilities and organizational resilience.

4.4 Control Variables

Based on prior business value of IT research, we expected organizational resilience to be influenced by firm size and organization age due to large, well established firms having the advantages of having more resources and cumulative business experience over smaller firms. In addition, firms in different industry sectors are exposed to different levels of threats and risks, resulting in different levels of required risk management. These three variables firm size, organization age and industry sector were therefore used as control variables for organizational resilience.

5. Research Methods

5.1 Constructs Operationalization

The quality of an organization's IT infrastructure was assessed in terms of communication network connectivity, flexibility and performance, using a six-item scale adapted from Byrd and Turner (2000). The quality of the IT business applications used in the organization was measured in terms of their risk management functionalities. Since no suitable existing instrument was found for this, a six-item scale was self-developed based on past literature (e.g. Lam 2003; Lange 1998; Ramamoorti and Weidenmier 2006). Employee commitment was measured by three items adopted from the Organizational Commitment Questionnaire (OCQ) developed by Porter et al. (1974), while top management commitment was measured by adapting four items from the scale for top management support developed by Chatterjee, Griwal and Sambamurthy (2002).

IT-enabled ERM capability was operationalized as a second-order construct comprising of three first-order constructs of risk measurement capability, risk control capability and risk monitoring capability. Since there was no previous instruments suitable for measuring these constructs, the items were developed from a conceptual synthesis based on Lam (2003), the COSO framework and IT project risk management literature (e.g. Bandyopadhyay et al. 1999). Organizational resilience was operationalized as a second-order construct comprising of two first-order constructs of anticipatory competence and recovery competence. Due to the novelty of this construct and unavailability of suitable scales for the study context, the items were self-developed based on the conceptual definitions in the extant literature (Ashby 1960; Gunderson 2000; Holling 1973; Pimm 1991). We self-developed the four items scale to measure business network structure strength by reviewing past studies conducted on business relationships in supply chain management literature (Kleindorfer and Saad 2005; Tan, Kannan, Handfield and Ghosh 1999). All constructs were measured on seven-point Likert-type scales.

5.2 Survey Data Collection

We collected the empirical data through a large scale survey in Singapore. The survey organizations were drawn from the Singapore 1000 company directory, a listing of the largest companies by revenue. The final sampling frame comprised of 868 companies after screening firms that are holding companies with no commercial activities. The survey employed a three-wave mailing procedure advocated by Dillman (1999). A survey package with a postage-paid return envelope was mailed to the top executive of each company. Two weeks after the initial mailing, a reminder postcard was sent to the companies. After another two weeks, a complete survey package was remailed to the non-respondents. We obtained a usable sample of 185. The response rate of 21.3 percent was considered satisfactory because the survey is unsolicited and involved the participation of senior management. We motivated the respondents to provide valid data by offering a summary of the research results and an invitation to a free workshop on the research findings. This incentive helped to ensure that the respondents take on a professional interest and become committed to provide accurate data. We tested for common method bias as well as non-response bias and found no evidence of such biases in the dataset. Table 1 presents the characteristics of the survey sample.

	Category	Number	%
Respondent Position	CEO, CFO, CIO, Managing Director	111	60.0
	Department Managers, Middle Managers	52	28.1
	Executives	12	6.5
	Others	10	5.4
Industry Sector	Services (e.g., IT, Healthcare, Hospitality etc)	32	17.3
	Shipping and Transport	25	13.5
	Retail	13	7.0
	Property and Construction	18	9.7
	Utilities	6	3.2
	Finance	15	8.1
	Wholesale – Equipment and Machinery, Electrical and Electronics	18	9.7
	Wholesale – Petroleum, Chemical Products and Raw Materials	18	9.7
	Manufacturing – Equipment and Machinery, Electrical and Electronics	25	13.5
	Manufacturing – Petroleum, Chemical Products and Raw Materials	15	8.1
Number of Employees	100 and below	56	30.3
	101-400	57	30.8
	401-1000	34	18.4
	1001-5000	21	11.4
	5001 and above	17	9.2
Company Age (Years)	10 and below	37	20.0
	11-25	63	34.1
	26-40	54	29.2
	41 and above	31	16.8

Table 1: Characteristics of Survey Sample

6. Data Analysis and Results

6.1 Analysis Technique

Partial Least Squares (PLS) technique as implemented in Smart-PLS version 2.0M3 was used for the data analysis (Ringle et al. 2005). PLS was found to be appropriate for the following reasons. First, PLS is able to handle errors of measurement in exogenous variables better than other methods such as multiple regression technique, which aids the study of moderating effects (Chin 1998; Chin, Marcolin and Newsted 2003). Second, given that there was little prior research or well tested theories in the area of study, the flexibility of PLS to accommodate both exploratory and confirmatory analysis made it a suitable method for the research context (Gefen, Straub and Boudreau 2000). Finally, PLS is able to accommodate smaller data sample models and latent constructs under conditions of non-normality in small to medium sample sizes (Chin 1998).

6.2 Measurement Model Validation

6.2.1 Discriminant Validity

Discriminant validity, which refers to the degree to which items differentiate between constructs was examined by checking the correlations between the measurement items of distinct constructs against the average variance extracted (AVE) by construct (Fornell and Larcker 1981). Table 2 reports the results of the discriminant validity test for the constructs. The diagonal elements are the AVE for each construct, and they are all shown to be higher than the squared inter-construct correlations depicted in the off-diagonal elements.

Construct	ITA	OC	ERM	RES	NSS
IT Assets (ITA)	**0.792**				
Organizational Commitment (OC)	0.156	**0.761**			
IT-enabled ERM (ERM)	0.341	0.253	**0.878**		
Organizational Resilience (RES)	0.279	0.305	0.598	**0.902**	
Business Network Structure Strength (NSS)	0.046	0.225	0.125	0.185	**0.656**

Table 2: Results of Discriminant Validity Tests

6.2.2 Reliability and Convergent Validity

Table 3 below shows the descriptive statistics and first-order item loadings for the constructs. All constructs had Cronbach's alpha value of 0.707 or larger indicating adequate internal consistency (Nunnally and Bernstein 1994). Convergent validity refers to the degree to which the items measuring the same construct agree (Cook and Campbell 1979). We used three tests to determine the convergent validity of the constructs: item loading, composite reliability of construct and the AVE extracted by construct. All item loadings for these first-order components were greater than 0.7.

Table 4 presents the loadings, composite reliability and the average variance extracted (AVE) of all second-order constructs. All composite reliability scores are greater than 0.7, the criterion recommended by Nunnally and Bernstein (1994), thus demonstrating sufficient reliability for all constructs. Average variances extracted are also all above the recommended threshold of 0.5, proving further convergent validity. These tests therefore provided evidence for adequate convergent validity of the constructs in the study.

6.3 Testing of the Structural Model

With sufficient evidence of good psychometric properties from the reliability and validity tests, we assessed the structural model with the use of PLS technique to evaluate its explanatory power and the significance of the hypothesized paths. Figure 2 shows the path analysis results of the structural model.

Since Smart-PLS does not directly permit the modeling of second-order constructs with first-order constructs, we followed the approach employed by Yi and Davis (2003). We first computed the first-order factor scores and then used them as manifest indicators of the second-order constructs. For the assessment of the moderating effect of business network structure strength, we adopted the interaction term method recommended by Chin et al. (2003). We first standardized the scores to minimize collinearity before multiplying each of three first-order factor scores for IT-enabled ERM capabilities with each of the four indicators for business network structure strength (NSS) to obtain product indicators for the interaction construct (ERM × NSS). The interaction construct comprised of 12 product indicators.

Constructs (Measurement Items)	Item Loading
IT Infrastructure (*Cronbach's Alpha* = 0.925; Mean = 5.052, Std. Dev. = 1.143)	
Information is shared seamlessly through electronic means across our organization.	0.826
We deploy robust and high-performance IT hardware to support business applications.	0.882
IT systems used in our organization support our operational objectives well.	0.897
Our inter-departmental IT systems are tightly-linked to each other.	0.877
Our IT systems allow us to interface with external entities.	0.813
Our existing IT systems are flexible enough to support changing business processes.	0.827
IT Applications (*Cronbach's Alpha* = 0.906; Mean = 4.076; Std. Dev. = 1.311)	
Our IT applications support concise risk reporting for management adequately.	0.835
Our IT applications support risk measurement and analytics adequately.	0.848
Our IT applications provide automation for risk controls and checks in the organization.	0.819
Our IT applications provide decision support for management in making decisions on risk.	0.829
Our IT applications provide ongoing monitoring of risk and performance.	0.811
Our IT applications are able to capture and archive historical risk information continuously.	0.810
Top Management Commitment (*Cronbach's Alpha* = 0.918; Mean = 5.658; Std. Dev.= 0.856)	
The top management demonstrates strong beliefs in organizational change initiatives.	0.866
The top management is able to articulate a vision for the organization effectively.	0.883
The top management is highly engaged in the formulation of strategies for the organization.	0.936
The top management participates actively in the setting of goals and standards for the organization.	0.900
Employee Commitment (*Cronbach's Alpha* = 0.803; Mean = 5.128; Std. Dev. = 0.803)	
Staff of all levels are willing to put in effort beyond that normally expected in order for this organization to succeed.	0.873
Staff of all levels are flexible to accept almost any new tasks or roles that would help the organization to achieve its goals.	0.866
Staff of all levels are actively involved in solving the organization's problems.	0.816
Risk Measurement Capability (*Cronbach's Alpha* = 0.928; Mean = 4.544; Std. Dev. = 1.124)	
Our organization has effective and systematic processes in place to identify and assess risks across the enterprise.	0.867
Our organization has the required expertise in quantifying risks.	0.911
Our organization effectively consolidates and aggregates risk reporting based on historical and present data.	0.923
We are able to assess and analyze the likelihoods and impacts of different risks accurately.	0.928
Risk Control Capability (*Cronbach's Alpha* = 0.929; Mean = 4.620; Std. Dev. = 1.025)	
We are able to select effective responses for managing risks.	0.883
The organization has a wide variety of options to mitigate risks.	0.909
We ensure that our people understand very well what is required of them when it comes to implementing risk control measures.	0.921
We execute our responses to risk effectively.	0.919
Risk Monitoring Capability (*Cronbach's Alpha* = 0.945; Mean = 4.558; Std. Dev. = 1.169)	
The management is informed regularly of current progress and effectiveness of risk responses undertaken.	0.932
Personnel at all levels are actively engaged in the risk monitoring activities.	0.907
We evaluate current risk management practices for areas of improvement on a regular basis.	0.944
We make adjustments to current risk management measures that address changing circumstances effectively.	0.923
Anticipatory Competence (*Cronbach's Alpha* = 0.917; Mean = 4.718; Std. Dev. = 0.916)	
The organization is able to assess the likelihood of an adverse event occurring.	0.870
The organization is able to gauge the magnitude of potential business disruptions accurately.	0.895
The organization is well prepared for potential risks and threats.	0.915
The organization has a wide range of responses available to cushion against the effects of adverse events.	0.900
Recovery Competence (*Cronbach's Alpha* = 0.930; Mean = 4.930; Std. Dev. = 1.028)	
The organization has effective processes in place to aid recovery from disruptions to its business.	0.933
The organization has contingency resources to continue functioning after a disruptive event.	0.925
We reorganize and resume normal operations quickly after business disruptions.	0.912
We assess the causes and effects of disruptive events and learn from them.	0.868
Business Network Structure Strength (NSS) (*Cronbach's Alpha* = 0.830; Mean = 5.027; Std. Dev. = 0.864)	
We have built an extensive network with our external business partners.	0.880
We have established reliable relationships with our external business partners.	0.896
We share a great deal of information with our business partners.	0.722
We often receive timely feedback about our organization from our external partners.	0.723

Table 3: Descriptive Statistics of Constructs and Item Loadings for First-Order Components

Constructs	Loading	Composite Reliability	AVE
IT Assets (ITA)		0.884	0.792
IT Infrastructure	0.876		
IT Applications	0.904		
Organizational Commitment (OC)		0.864	0.761
Top Management Commitment	0.853		
Employee Commitment	0.891		
IT-Enabled ERM Capability (ERM)		0.956	0.878
Risk Measurement Capability	0.937		
Risk Control Capability	0.939		
Risk Monitoring Capability	0.935		
Organizational Resilience (RES)		0.949	0.902
Anticipatory Competence	0.951		
Recovery Competence	0.949		

Table 4: Psychometric Properties of Second-Order Measurement Model

The R^2 value of the endogenous constructs represents the amount of variance explained of a construct and is an indication of the explanatory power of the structural model. On the other hand, path coefficients represent the strength and direction of the relationships between the dependent and independent constructs, and thus serve as verifications of the hypotheses in the model. The standard errors and the significance of the path coefficients were determined by performing a boot-strap resampling procedure.

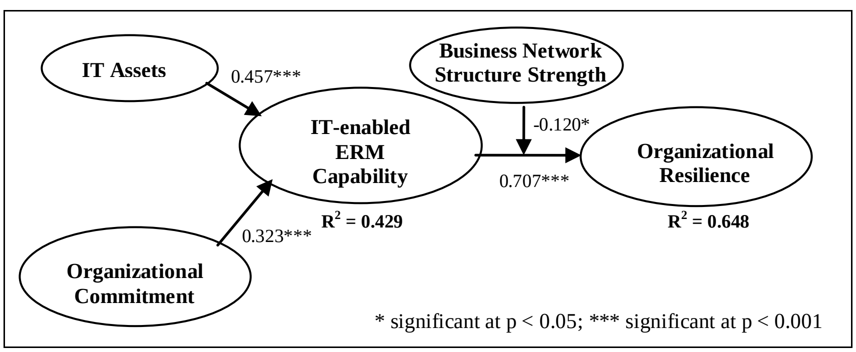

Figure 2: Results of PLS Analysis

From Figure 2, we observed that 42.9% of the variance in IT-enabled ERM capabilities and 64.8% of the variance in organizational resilience can be explained by the variables in the research model. All the hypotheses were supported. The antecedents IT assets and organizational commitment both significantly affect IT-enabled ERM capabilities. We noted that the path coefficient for the hypothesis (H1) between IT assets and ERM capability (b = 0.457, $p < 0.001$) was larger than the hypothesis (H2) on organizational commitment and ERM capability (b = 0.323, $p < 0.001$).

Before the introduction of the moderating variable, a base model with ERM capabilities directly impacting organizational resilience with no moderating effect was tested. The relationships were found to be significant at $p < 0.001$ and the variance explained for organizational resilience was 60.9 percent. With the introduction of NS as a moderating variable in the full model, the variance explained in organizational resilience increased by 3.9 percent. We proceeded to statistically assess the effect of adding the moderating variable NSS to the change in the R^2 of organizational resilience, by calculating the effect size, f^2 as $((R_{moderated}{}^2 - R_{original}{}^2)/((1 - R_{moderated}{}^2))$. The effect size f^2 of 0.111 for the full moderated model is between a small and medium effect (Cohen 1988). This effect size is larger than those found for the majority of IS research studies in the past (Chin et al. 2003). Next, a pseudo F-test was then conducted to determine the significance of the moderating effect by deriving a pseudo F-statistic by multiplying the effect size with $(n - k - 1)$, where n is the sample and k is the number of independent constructs. The pseudo-F(1,181) statistic of 19.980 was found to be significant at $p < 0.001$. As observed in the full model, IT-enabled ERM capabilities have a significant direct impact on organizational resilience ($b = 0.707$, $p < 0.001$), and this relationship is weakly moderated by business network structure strength ($b = -0.120$, $p < 0.05$). All control variables were insignificant at $p < 0.05$.

7. Discussion

7.1 Key Findings

Results suggest that both IT assets and organizational commitment had significant impacts on the development of IT-enabled ERM capabilities. IT assets can be viewed as an enterprise-wide backbone of technological infrastructure and applications that enable information flow and embed risk management practices into business processes. A firm possessing strong IT assets would therefore be able to maintain an accurate and timely flow of critical risk information to its employees, enabling them to make effective decisions on enterprise-wide risks.

However, the business value of IT can be fully realized with the complementary presence of other organizational resources, one of which being organizational commitment. Organizational commitment ensures a heightened awareness of risk and greater responsibility for risk management across all levels of the firm, and augments the integration of IT with business processes. Effective ERM demands active engagement from the top management level right down to the operational level in risk management activities. This demonstrates that the “soft”, human aspects of risk management are just as important as the “hard” aspects, which are the enabling tools and measures in place.

Findings also show that a firm’s IT-enabled ERM capabilities significantly impact its organizational resilience. Organizations with strong IT-enabled ERM capabilities are able to detect threats in advance and assess their impacts quickly. The ensuing advantage of capturing and interpreting critical information in a timely and accurate fashion allows them to anticipate potential disruptions in their business environment. IT-enabled ERM capabilities also provide them with a variety of options to undertake in response to threats and these measures can be calibrated and fine-tuned as needed. As such, organizations are able to minimize the adverse effects of disruptions when they strike and resume normalcy in a short time.

In addition, the results also revealed that the impact of IT-enabled ERM capabilities on organizational resilience is slightly weakened for firms with access to strong network structure. This is because such firms can rely more on the information advantages and other resources derived from its extensive networks to anticipate threats and cushion against external shocks. Their network partners can facilitate reliable and speedy sharing of information. Conversely, the impact of IT-enabled ERM capabilities on organizational resilience is stronger for a firm with a weak network structure because the firm can only rely on its internal capabilities as opposed to weak, unreliable business relationships in order to handle crises and disruptions. The moderating effect of business network structure strength is found to be weak indicating that the direct effects of IT-enabled ERM capabilities remain very important in enhancing organizational resilience. This is also possibly due to the inherent risks and unpredictability of partners in network relationships.

7.2 Limitations

The current study has several limitations which must be acknowledged. First, the term "risk" can be subject to different interpretations by different individuals. For example, someone may consider risk as the likelihood of loss, while another perceives risk as uncertainty, which can lead to either favorable or unfavorable outcomes. The perception of risk thus can vary from being negative to neutral, and even positive in some instances. As such, it is possible to conceptualize risk as an opportunity for gain in addition to the potential negative impact, which is the focus of the present study. Second, the interpretation of the findings should take into consideration that data was collected in Singapore, a small technologically-advanced country with a unique economic environment. While the dataset comprises of local as well as foreign companies from diverse industry sectors with a good mix of organizational characteristics, future research should attempt to replicate the study in other countries, and preferably with multiple respondents. For instance, data pertaining to different constructs could be gathered from CEO, CIO, and COO. Third, although rigorous statistical tests have been carried out to address potential respondent bias, it should be noted that the possible biases inherent in single informant responses could still be present.

7.3 Managerial and Theoretical Implications

We have found evidence that IT assets alongside organizational commitment comprising of top management support and employee involvement are key drivers of IT-enabled ERM capabilities. It is hence imperative for managers to understand that these organizational resources have to be managed in tandem, rather than in isolation, so as to leverage on the synergistic effects between them, in addition to the value they bring to the firm individually from a risk management perspective. The finding that IT had a greater impact on ERM capabilities compared to organizational commitment suggest that firms should substantially increase their investments in IT infrastructure and risk management applications.

The operationalization of ERM as a second-order capability enriches our understanding of the multi-faceted dimensions of ERM in terms of risk measurement, control and monitoring. The availability, reliability and conciseness of risk information greatly impact decision making at all levels of the firm. Managers have to understand the importance of ensuring that risk information are being captured, organized and reported effectively. Risk controls in the form of action plans, buffers and policies form integral parts of risk mitigation. Managers will do well to boost the range and effectiveness of options available for risk control. It is also important to establish the internal discipline of continually monitoring the effectiveness of these risk controls, making adjustments as needed.

The finding that a firm's business network structure strength has a weak, negative moderating effect on the impact of IT-enabled ERM capabilities on organizational resilience is interesting. While network structures may be a substitute to a small extent for the lack of internal risk management capabilities, managers should still focus on developing IT-enabled ERM capabilities as the main means of attaining organizational resilience. A chief reason for focusing on building internal capabilities to manage risk is that capabilities which reside within the firm can be better controlled and managed compared to business networks whereby the actions of external partners are not within the control of the firm. On the other hand, managers can also look into the possibility of making ERM within the organization more outward looking in line with the extrinsic network structure of the firm, as current findings seem to show that the firm's network of relationships share little synergy with inward looking ERM capabilities (Sutton 2006).

The conceptualizations of IT-enabled ERM capabilities and organizational resilience as second-order constructs are very significant theoretical contributions of this study. The conceptual integration of the fragmented literature of risk management into a coherent framework of IT-enabled enterprise risk management has laid useful foundation for IS researchers. Next, we synthesized and extended the works by socio-ecological researchers on resilience and developed a conceptualization of organizational resilience applicable to firms operating under complex business environments. The findings also indicate a strongly positive link between IT-enabled ERM capabilities and the building of organizational resilience. More importantly, the finding that business network structure strength has a moderating role dovetails with the emerging research interest in the extended enterprise model.

Ample future research opportunities abound from this exploratory work. First, while the present study has considered the emergence of the extended enterprise and its implications on risk assessment and management, the operationalization of ERM capability is nevertheless pre-dominantly enterprise-centric. More research is needed to develop improved measurements that address risks outside the organizational boundary. This will help in the building of models that can explain risk management better in the extended enterprise context. Next, the nurturing of organizational resilience is discussed from the perspective of managing risks, with ERM as the main factor in building resilience. Future work should attempt to examine other possible ways or processes in which an organization can create and maintain diversity and complexity in order to build up its organizational resilience. Lastly, the link between organizational resilience and firm performance can be investigated as a possible extension of the current research model.

The exploratory efforts to develop a model for managing enterprise risks address the lack of a theoretically-grounded research that can contribute to the domain of IT-enabled enterprise risk management. This study will be useful as a bridge to establish the link between information systems and risk management research. More significantly, we hope that it will stimulate research interests that can further uncover a greater role for information systems in organizations faced with a dynamic business environment increasingly fraught with risks and uncertainties.

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References

Ashby, W. R. *Design for a Brain,* 2nd edition, Wiley, New York, 1960.

Bandyopadhyay, K., Mykytyn, P. P., and Mykytyn, K. "A Framework for Integrated Risk Management in Information Technology," *Management Decision* (37:5), 1999, pp. 437-444.

Berkes, F., and Folke, C. "Linking Social and Ecological Systems Management Practices and Social Mechanisms for Building Resilience," Cambridge University Press, New York, 1998.

Berkes, F., Colding, J., and Folke, C. *Navigating Social-Ecological Systems*, Cambridge University Press, 2003.

Broadbent, M. and Weill, P. "Management by Maxim: How Business and IT Managers Can Create IT Infrastructures," *Sloan Management Review* (38:3), 1997, pp. 77-92.

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

Casualty Actuarial Society Enterprise Risk Management Website. "ERM Education Resources," http://www.casact.org/research/erm/frame.pdf

Chatterjee, D., Griwal, R. and Sambamurthy, V. "Shaping Up for E-Commerce: Institutional Enablers of the Organizational Assimilation of Web Technologies," *MIS Quarterly* (26:2), June 2002, pp. 65-89.

Chin, W. W. "The Partial Least Squares Approach for Structural Equation Modelling. Modern Methods for Business Research," 1998, pp. 295-336.

Chin, W. W., Marcolin, B. L. and Newsted, P. R. "A Partial Least Squares Latent Variable Modeling Approach for Measuring Interaction Effects: Results from a Monte Carlo Simulation Study and an Electronic-mail Emotion/Adoption Study," *Information Systems Research* (14:2), June 2003, pp. 189-217.

Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd edition. Erlbaum, Hillsdale, New Jersey, 1988

Cook, T. and Campbell, D. *Quasi-experimentation: Design and Analysis Issues for Field Settings*, Houghton Mifflin, Boston, 1979.

COSO. "Enterprise Risk Management: Integrated Framework," The Committee of Sponsoring Organizations of the Treadway Commission and PricewaterhouseCoopers LLP, 2004.

Coutu, D. L. "How Resilience Works," *Harvard Business Review* (80:5), 2002, pp. 46-51.

Dervitsiotis, K.N. "Looking at the Whole Picture in Performance Improvement Programmes," *Total Quality Management* (10:3), 2001, pp. 687-700.

Dervitsiotis, K. N. "Navigating in Turbulent Environmental Conditions for Sustainable Business Excellence," *Total Quality Management* (15:5-6), 2004, pp. 807-827.

Dillman, D. *Mail and Internet Surveys: The Tailored Design Method,* Second Edition. John Wiley, New York, 1999.

Duncan, N. B. "Capturing the Flexibility of Information Technology Infrastructure: A Study of Resource Characteristics and their Measure," *Journal of Management Information Systems* (12:2), 1995, pp. 37-57.

Fornell, C. and Larcker, D.F. "Structural Equation Models with Unobservable Variables and Measurement Errors," *Journal of Marketing Research* (18:1), 1981, pp. 39-50

Gefen, D., Straub, D.W. and Boudreau, M.C. "Structural Equation Modeling and Regression: Guidelines for Research Practice," *Communications of the AIS,* 4, 2000, pp. 1-77.

Gorsuch, R. L. *Factor Analysis*, Lawrence Erlbaum Associates, New Jersey, 1983.

Gulati, R. “Network Location and Learning: The Influence of Network Resources and Firm Capabilities on Alliance Formation,” *Strategic Management Journal* (20:5), 1999, pp. 397-420.
Gulati, R., Nohria, N. and Zaheer, A. “Strategic Networks,” *Strategic Management Journal* (21:3), 2000, pp. 203-215.
Gunderson, L. H., Holling, and C. S., Light, S. *Barriers and Bridges for the Renewal of Ecosystems and Institutions*, Columbia University Press, New York, 1995.
Gunderson, L. H. “Ecological Resilience - In Theory and Application,” *Annual Review of Ecology and Systematics*, 31, 2000, pp. 425-439.
Hamel, G. and Valikangas, L.“The Quest for Resilience,” *Harvard Business Review,* (81:9), 2003, pp. 52-63.
Holling, C. S. “Resilience and Stability of Ecological Systems,” *Annual Review of Ecology and Systematics*, 4, 1973, pp. 1-23.
Holling, C. S. “Engineering Resilience vs. Ecological Resilience,” in *Engineering Within Ecological Constraints*, Schulze, P.C. (Ed.), National Academy, Washington, DC, 1996, pp. 31-43.
Johnson, R. A. and D. W. Wichern. *Applied Multivariate Statistical Analysis,* Prentice Hall, Englewood Cliffs, New Jersey, 1998.
Kim, J. and C. W. Mueller. Factor Analysis: Statistical Methods and Practical Issues. Sage, CA, 1981.
Kleindorfer, P. R. and Saad, G. H. “Managing Disruption Risks in Supply Chains,” *Production and Operations Management* (14:1), 2005, pp. 53-68.
Lam, J. *Enterprise Risk Management: From Incentives to Controls*, John Wiley & Sons, Inc, 2003.
Lange, S. “Building the Next Generation RMIS,” *Risk Management* (45:4), 1998, pp. 23-33.
Lyytinen, K., Mathiassen, L., and Ropponen, J. “A Framework for Software Risk Management,” *Scandinavian Journal of Information Systems* (8:1), 1996, pp. 53–68.
Marphatia, A. C. and Tiwari, N. *Risk Management In the Financial Services Industry*. Tata Consultancy Services White Papers, 2000.
Mehr, R. I., and Hedges, B. A. *Risk Management in the Business Enterprise*, Richard D. Irwin, Inc. Homewood, IL, 1963.
Nunnally, J.C. and Bernstein, I. *Psychometric Theory*, 3rd edition. McGraw-Hill, New York, 1994.
Pascale, R., Milleman, M. and Gioja, L. *Surfing the Edge of Chaos*, Crown Business, New York, 2001.
Pimm, S.L. *The Balance of Nature?* University of Chicago Press, Chicago, 1991.
Porter, L. W., Steers, R. M., Mowday, and R. T., Boulian, P. “Organizational Commitment, Job Satisfaction, and Turnover among Psychiatric Technicians,” *Journal of Applied Psychology*, 59, 1974, pp. 603-609.
Powell, W. W. “Neither Market nor Hierarchy: Network Forms of Organization.,” in *Research in Organizational Behavior*, 12, Staw B. M. and Cummings L. L. (Eds.), JAI Press, Greenwich, CT, 1990, pp. 295–336.
Ramamoorti, S. ,and Weidenmier, M. L.“Is IT next for ERM?,” *Internal Auditor*, April Issue, 2006, pp. 45-50.
Rasmussen, M. and Stamp, P. *IT’s Role in Enterprise Risk Management*. Forrester Research, 2005, http://www.csoonline.com/analyst/report3614.html
Reichers, A. E. “A Review and Reconceptualization of Organizational Commitment,” *The Academy of Management Review*, (10:3), 1985, pp. 465-476

Ringle, C.M., Wende, S., and Will, A. "SmartPLS," University of Hamburg, Hamburg, Germany, 2005.

Sambamurthy, V., Bharadwaj, A. S., and Grover, V. "Shaping Agility through Digital Options: Reconceptualizing the Role of Information Technology in Contemporary Firms," *MIS Quarterly*, (27:2), 2003, pp. 237-263.

Sanchez, R., Heene, A. and Thomas, H. "Towards the Theory and Practice of Competence-Based Competition," in *Dynamics of Competence-Based Competition: Theory and Practice in the New Strategic Management*, Sanchez, R., Heene, A. and Thomas, H. (Eds.), Elsevier Science, Oxford, 1996, pp. 1-36.

Starr, R., Newfrock, J. and Delurey, M. "Enterprise Resilience: Managing Risk in the Network Economy," *Strategy and Business*, 30, 2003.

Strobel, D. and Krishna, D. "The Makeup of ERM," *Best's Review*, 2006, http://www.teradata.com/t/page/154972/index.html

Sutton, S. G. "Extended Enterprise Systems' Impact on Enterprise Risk Management," *Journal of Enterprise Information Management* (19:1), 2006, pp. 97-114.

Tan, K. C., Kannan, V. R., Handfield, R. B., and Ghosh, S. " Supply Chain Management: An Empirical Study of its Impact on Performance," *International Journal of Production and Operations Management* (19:10), 1999, pp. 1034-1052.

Yi, M.Y., and Davis, F.D. "Developing and Validating an Observational Learning Model of Computer Software Training and Skill Acquisition," Information Systems Research (14:2), 2003, pp. 146-169.