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ABSTRACT

This paper is the first study of technology assimilation that aggregates across technologies and across the assimilation stages for SMEs. It employs twin lenses of organizational innovation and elements of institutional theory. The research validates some institutional actors and most firm characteristics as important determinants. The relative weaknesses of the institutional actors provide evidence of structural isolation in the SME environment that is inhibiting information flow from intermediaries such as government support agencies and vendors. The study recommends a proactive role on the part of technology and enterprise intermediaries to design SME-appropriate solutions.

***Keywords**: Innovation, adoption, assimilation, institutional theory, intermediaries, small and medium-sized enterprises (SME), value chain, clusters.*

INTRODUCTION

Small and medium-sized enterprises (SMEs) play a very important role in the US economy and should be an important subject of study for IS academic researchers for several reasons. First, the employment scope of SMEs is significant in the US and EU countries (Harindranath et al, 2007); second, the innovation potential of SMEs in many high-tech areas is the primary growth driver of the industry; and finally, this sector drives the renewal process of the economy through birth, death, and restructuring. It is well known that SMEs are different from large firms where information systems are concerned, and organizational theories applicable to large firms may not be applicable to them (Bharati and Chaudhury, 2006). A small firm is “not a little big business,” and there is a need to take off the big organization glasses when studying technology issues in small firms (Thong, 1999). However, few IS researchers in the US focus on the SME sector. This is evidenced by the fact that only a few papers on the subject have been published (Bharati and Chaudhury, 2009) in the last six years in the top IS journals.

This paper focuses on the question, "What institutional actors and what firm-level characteristics affect the full assimilation cycle of technologies spanning the full value chain of small and medium-sized enterprises (SMEs)?" It investigates SMEs in the high-technology manufacturing cluster based in Greater Boston and studies the influences of cluster of competitors, vendors, and others on the direction and pace of innovation. The paper draws on institutional theory (Powell and DiMaggio, 1991) and organization learning theory (Attewell, 1992) to build a model of technology assimilation over the whole technology life cycle. The major contribution of this paper to technology assimilation research is that it seeks to fill the void in research on the determinants of technology adoption and assimilation (i) across the entire value chain of a firm, that is, technologies that support both primary activities such as manufacturing and logistics and secondary activities such as purchase and accounting, and (ii) across the full assimilation life cycle.

IT research on SMEs has mainly been focused on motivators and inhibitors (Caldeira and Ward, 2002; Cragg and King, 1993), acceptance and impact (Iacovou et al., 1995), factors relating to satisfaction and success (Zhang et al., 2008; DeLone, 1988), and implementation issues (Thong et al., 1994; Thong et al., 1996). Thong (1999) provided an integrated model of IS adoption in small businesses where factors relevant to the firm, such as CEO characteristics and organizational characteristics, and a single environmental factor of competition were used. The paper extends Thong’s (1999) model of IT adoption in SMEs by looking into a much wider set of institutional actors that play a role in the full assimilation life cycle and across multiple technologies; it extends the model developed by Liang et al. (2007), which researches a single technology, into technology aggregates that cover the entire value chain; and it adds and relates to the institutional-theory based models in IS research (Chatterjee et al., 2002; Teo et al., 2003) to investigate the full assimilation life cycle.

This research adopts a unique approach with respect to the current state of IS research in technology assimilation. First, it adopts a firm-level approach. Firm-level learning capabilities are becoming increasingly more prevalent as antecedents to technology assimilation (Liang et al., 2007), and this approach has been adopted in the paper. Second, this paper uses an institutional perspective based on firm-level analysis. Concern has been raised about the lack of institutional perspective in IS research (Chiasson and Davidson, 2005), and this paper also attempts to address that lacuna. The technology-organization-environment (TOE) model (Tornatzky and Fleischer, 1990), an institutional-theory-inspired model, has motivated a stream of research investigating the impact of environmental factors such as competitive pressures, trading partners, and environmental uncertainty on IT adoption (Kuan and Chau, 2001). Compared to large firms, SMEs are price-takers in the market, and as a result of their low asset base, are more vulnerable to competitive and business pressures emanating from the institutional environment (Liang et al., 2007). The environment is likely to be an important factor in technology assimilation by SMEs. There is a serious dearth of research that studies the impact of environment on SMEs in the context of IT adoption, with a few exceptions (Thong, 1999). Third, while much of the literature in technology assimilation is based on a single technology, this paper models antecedents to technology assimilation where aggregates of technologies are involved. While this aggregation may hide the differences between the impacts of different technologies, a confirmation also provides evidence of model robustness at the aggregate level and makes policy recommendations more meaningful (Fichman, 2001). This paper focuses on multiple technologies, such as supply chain management (SCM), customer relationship management (CRM), enterprise resource planning (ERP), and similar technologies that make a firm-wide impact, in contrast to studying an individual technology. The paper also addresses some relevant question for SMEs: How much are SMEs impacted by the environment and how much by factors within the organization? Which approach—the institutional approach or the organization learning approach—provides a better understanding of technology assimilation in the case of SMEs? How is the relative contribution of the two theories impacted by firm size? What are the appropriate roles of intermediaries such as government agencies in influencing technology assimilation?

The rest of the paper is organized as follows: The next section sets out the conditions and context in which this research was carried out. This is followed by a description of the model. In the next section, the data analysis and results are discussed. Managerial implications, possible directions of future research, and conclusions are discussed in the last three sections.

RESEARCH BACKGROUND

The research objectives reflect those of our sponsor, the Greater Boston Manufacturing Partnership (GBMP), a government organization, which provided considerable assistance. The common goal was to ascertain the extent of technology usage by Boston SMEs across their entire value chain and research factors that promote and inhibit technology awareness and implementation.

The manufacturing sector in Massachusetts has been under severe competitive pressure. Manufacturers in Massachusetts are trying to cope with these challenges by being innovative and implementing lean manufacturing and continuous improvements. GBMP personnel are observing that firms are investing in technologies across the value chain, in both core areas like manufacturing and support areas like procurement and customer support. In terms of strategic theory, the firms' behavior can be described as value innovation—creating value for the customer and the firm through innovation. Value innovation is a strategic response whereby firms continuously deliver innovative value propositions to customers by using a low-cost business model that also permits agility and flexibility. In value innovation, a firm is able to offer on a continuing basis an exceptional value-price combination that is driven by customers' needs, based on a radically low-cost, exceptional service, and flexible business model. Value-innovation is more than singular past efforts (e.g., one-time major business process engineering) to leapfrog competition: it is an ongoing competitive effort woven throughout the corporate value chain, i.e., supply chain, customer service, product design, and business processes (Little, 1988).

IS Enablers of Value-Chain Innovation

IS researchers have been cognizant of IT playing multiple roles in a company and impacting its performance on many levels. Different firm-level roles played by IT and technology clusters have been identified. Our focus in this research is on technologies that promote value innovation —that is, allow firms to have "low cost, high quality, and fast and flexible response to customer needs" (Venkatraman, 1994). Almost all firm activities and process functionalities across the value chain are involved in delivering value innovation.

We therefore adopt the value-chain framework of Porter (1985) to identify firm-level activities and that of Porter and Millar (1985) to identify all the enabling technologies. According to Porter (1985), a company's value chain "divides a company's activities into the technologically and economically distinct activities it performs to do business." In this framework, a firm's primary activities are divided into five categories: inbound logistics, operations, outbound logistics, marketing, and sales and service. The primary activities require support activities to provide inputs and infrastructure. These support activities are identified by Porter (1985) as firm infrastructure, human resource management, technology development, and procurement.

The value-chain approach has been employed to elucidate the role of technology in value creation and innovation activities (Figure 1). Table 1 lists the value-chain activities and the associated technologies that have been considered in our research.

[Insert Figure 1 and Table 1 here]

RESEARCH MODEL

SMEs individually are often small and weak players in a market economy and are subject to various pressures and influences emanating from their world of peers, customers, and vendors. Institutional theory focuses on institutions and how they influence each other in the context of an institutional field (Scott, 2001). Induction of technologies across the value chain impacts the firm in ways that lead to different business outcomes at various levels. Firm-level analysis is more appropriate to these goals. The innovation diffusion research literature has been concerned with the nature of organizations that are innovative (Rogers, 2003 p. 403), and there is a rich stream of research on organizational innovativeness (Mahler and Rogers, 1999).

Thus we had two sets of characteristics: institutional actors motivated by institutional theory and firm characteristics motivated by organization innovation literature. The two sets comprised the research model.

Assimilation of Aggregate of Technologies

Rogers (2003) described the adoption process as an innovation-decision process having five steps: knowledge, persuasion, decision, implementation, and confirmation. For IT software systems, Fichman (1995) listed six assimilation stages: not aware, aware, interest, evaluation/trial, commitment, limited deployment, and general deployment. After discussion with members of GBMP, a similar scale was adopted for this research, including the following stages: no current activity; aware; interested; evaluated; committed; limited installation; general installation; acquired, evaluated, and rejected; and do not know/other. This technology cluster adoption and assimilation model maps to the theory of Rogers (2003); however, the research model employs a more granular scale by mapping "no current activity" and "aware" to Rogers's knowledge phase, "interest," "evaluation," and "commitment" to the persuasion and decision phase, and "limited deployment" and "general deployment" to the implementation phase.

The assimilation stage of technology is aggregated over multiple technologies covering the entire value chain, including the following: Web sites, electronic data interchange, supply-chain management software, customer relationship software, electronic procurement software, computer-aided design, computer-aided manufacturing, computer numerical control, manufacturing automation, production planning software, human resources software, accounting/financial software, materials management software, supplier management software, and order processing software.

Institutional Actors

The firm-level approach is inspired by institutional theory (DiMaggio and Powell, 1983). The institutional approach in IS research has been used to explain technology adoption (Chatterjee et al., 2002; Liang et al., 2007; Teo et al., 2003). However, to our knowledge, this formalism has not been used to research the assimilation of technologies that span the entire value chain. Powell and DiMaggio (1991) described institutionalism in terms of interest "in properties of supra-individual units of analysis that cannot be reduced to aggregations or direct consequences of individual attributes or motives." According to DiMaggio and Powell's (1983) article, firms are part of an ecology consisting of other firms, vendors, consultants, mass media, government agencies, and customers (Scott, 2001). The survey measures the impact of these actors in the environment. The institutional actors in the environment that are of interest are customers, competitors, vendors, government agencies, and professional associations.

Customers

Customer requirements and legal requirements are usually sources of pressure. According to Pfeffer and Salancik (1978), a firm that controls a scarce resource can force organizations that need the resource to adopt practices that serve the needs of the controlling firm. Institutional arguments for such pressure stem from the resource-dependence theory of Pfeffer and Salancik

(1978) and have received empirical justifications in research literature (Palmer et al., 1983). Knudsen et al. (1994) and Webster (1995) related the effects on industry of pressure from large customers, such as GM and Ford respectively. Teo et al. (2003) researched the role of customers in the adoption of inter-organizational linkages. Therefore, we propose the hypothesis:

Hypothesis 1: Higher levels of influence from customers lead to higher assimilation of aggregate technologies across the value chain.

Competitors

Competitive pressures in an industry cause an organization to evolve over time and become similar to other organizations. Haunschild and Miner (1997) showed that wide use of an innovation serves as a proxy indicator of its worth and induces other firms to adopt the innovation. Such pressures manifest themselves as practices in the industry and the perceived success of the organizations that have adopted these practices. Copying such practices confers status on the organization (DiMaggio and Powell, 1983) and helps minimize experimentation costs in an environment of uncertainty (Lieberman and Montgomery, 1988). These influences are akin to forces of contagion in social capital theory. Thong (1999) found competition to have a positive effect on IS assimilation in small firms. Haveman (1993) and Clemon (1990) pointed to an imitation effect in firm behavior in the airline and banking industry. In the context of ERP systems, Liang et al. (2007) found that competitors have a role; Son and Benbasat (2004) found the same for B2B systems, and Teo et al. (2003) for EDI. While there is nothing specific about technology aggregates for SMEs, based on existing evidence, we therefore hypothesize the following:

Hypothesis 2: Higher levels of influence from competitors lead to higher assimilation of aggregate technologies across the value chain.

Vendors

According to DiMaggio and Powell (1983), pressures are manifested through firm-supplier relationships. Burt (1982) and Markus (1987) pointed to pressures from a dyadic channel as composed by suppliers, vendors, and other intermediaries. Teo et al. (2003) found that suppliers affect a firm's intention to adopt inter-organizational systems. Attewell (1992) claimed that consultants and vendors provide information and training, thereby reducing knowledge acquisition costs and promoting innovativeness. Thong et al. (1994) found that vendors and consultants played an important role in IS implementation, which was extended to the case of small firms by Thong et al. (1996). Therefore, the hypothesis is as follows:

Hypothesis 3: Higher levels of influence from vendors lead to higher assimilation of aggregate technologies across the value chain.

3.2.4 Government Agencies and Professional Networks

Organizational decision-makers are affected by norms and standards that are institutionalized in their environments, such as business and professional circles (DiMaggio and Powell, 1983). Such influences by professional networks are related to prominence in social capital theory (Dubois and Hakansson, 2002). King et al. (1994) and Teo et al. (2003) found evidence that participation in industry and trade associations and with government-sanctioned bodies constitutes pressure on a firm. Rogers (2003 p. 408) discussed the positive role of openness (defined as "the degree to which members of a system are linked to other individuals who are external to the system") as it relates to innovativeness. Openness toward professional networks is likely to lead to innovative behavior. Therefore, we propose the following two hypotheses:

Hypothesis 4: Higher levels of influence from government agencies lead to higher assimilation of aggregate technologies across the value chain.

Hypothesis 5: Higher levels of influence from professional networks lead to higher assimilation of aggregate technologies across the value chain.

Structural Isolation of SMEs

As a result of their size, SMEs are often limited to interacting with firms in a limited geographical area and suffer from structural isolation. The theory of social capital (Burt, 2005) helps shed light on this phenomenon of structural isolation. It has been observed that individuals and institutions tend to cluster together so that entities within a cluster are densely connected to each other, as in a silo, but weakly connected to entities in other clusters. SME firms and their employees tend to belong to a few different communities located in the same region (Burgess, 2002). An over-reliance on social and ethnic ties on the part of SMEs (Mackinnon et al., 2004) leads to the problem of "lock-in" through progressive closure preventing access to other information and cultural sources (Grabher, 1993). Since few information links connect them to external networks, SMEs remain structurally isolated like the proverbial frogs in a well. Hence, we propose another hypothesis:

Hypothesis 6: As firm size decreases, the impact of institutional actors on technology assimilation weakens.

Assimilation of Technologies across the Value Chain

The proponents of value chain innovation (Little, 1988) contend that firms should be investing across the value chain. In contrast, the core competency approach (Hamel and Prahalad, 1990) in strategy literature would suggest that these manufacturing SMEs disproportionately invest more in manufacturing and design than in HR and marketing activities. The question of interest is whether the assimilation level varies based on the strategic importance of the value activity and its associated technology. As per Porter's value chain (1985; 2001), the value activities were categorized into primary and secondary activities. As part of a more in-depth investigation of this phenomenon, the research categorized these activities further into primary core activities, primary non-core activities, and secondary activities. For a manufacturing firm, the primary core activities are operations and technology development; the primary non-core activities are inbound logistics, outbound logistics and marketing, sales, and service; and the secondary activities are procurement, human resource management, and accounting and finance. The technologies associated with these value activities will have to be investigated along the value chain. Hence, we propose another hypothesis:

Hypothesis 7: Assimilation of primary-core, primary-non-core and support technologies are of the similar order across the value chain.

Firm Characteristics

Porter and Millar (1985), defined innovation in for-profit firms as a new way of doing things that is commercialized. Rogers (2003 p. 12) defined innovation more generally in the context of both individuals and organizations as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption."

Scholars have studied innovation under multiple typologies, such as administrative and technical (Daft, 1978) and product and process (Damanpour, 1991). Damanpour (1991) described product innovation as "new product or services introduced to meet an external and market need" and process innovations as "new elements introduced into an organization's production or service operations—input materials, task specifications, work and information flow mechanisms, and equipment used to produce a product or render a service."

Rogers (1995; 2003) provided the popular framework for diffusion that led to several thousand studies of innovation diffusion spread over different domains, from the technology sector to health care to agriculture. Rogers's (2003) diffusion theory is developed around four elements that constitute the process: (1) an innovation, (2) a channel through which the idea of innovation diffuses, (3) time, and (4) a social system in which the diffusion takes place. The focus of researchers has not been uniform over the four elements: they have been primarily concerned with "product perspective" and "people perspective" (Gourville, 2005). The former is concerned with product features that promote rapid diffusion and the latter with features of people who are likely to be early adopters. Since we have a wide variety of technologies involved, we have focused on the "people perspective," that is, the nature of organizations. The following organizational features were considered: top management attitude, firm size, technology specialization, and education.

Top Management Attitude

IS research literature is replete with evidence that top management's support is crucial for technology adoption. Jarvenpaa and Ives (1991) and Chatterjee et al. (2002) have established the role of senior management. More specifically, in the case of small businesses, the importance of the role of top management and the CEO has been verified by Yap et al. (1992) and Thong (1999) in the case of an owner-CEO who is often the top management for a small firm. Thong et al. (1996) showed a positive relationship between top management support and IT adoption. While there is no specific literature support for technology assimilation where large aggregates of technologies are involved, due to implied evidence we propose the following hypothesis:

Hypothesis 8: A more positive top management attitude leads to higher assimilation of aggregate technologies across the value chain.

Firm Size

According to Rogers (2003), size is one of the most critical determinants of innovator profile. It has been well established in innovation diffusion literature that firm size is often a proxy for resource slack and infrastructure that promote innovativeness (Mohr and Morse, 1977; Utterback, 1974). Mytinger (1968) provided evidence that firm size is one of the most important variables explaining innovativeness. Mahler and Rogers (1999) found that organizational size, revenue, and people employed are positively correlated with telecommunications technology adoption. In the case of small businesses, the role of firm size has been established by Alpar and Reeves (1990) and Thong (1999). We therefore propose the hypothesis:

Hypothesis 9: Greater firm size leads to higher assimilation of aggregate technologies across the value chain.

Technology Specialization

Kimberley and Evanisko (1981) ascribed the innovativeness of organizations to specialization in related activities. Rogers (2003) credited organizational innovativeness to a range of occupational specialties. More specialization leads to more sharing of ideas. Having a greater variety of specialists gives a firm an enhanced knowledge base, and Fichman (2001) found specialization to be an important variable affecting assimilation of object-oriented technologies. We therefore hypothesize the following:

Hypothesis 10: Higher technology specialization leads to higher assimilation of aggregate technologies across the value chain.

Education

Zmud (1982) and Fichman (2001) related education to professionalism and thus to the ability to innovate. Rogers (2003) credited organizational innovativeness to degree of professionalism as expressed by formal training. Increased education and professionalism are associated with more boundary-spanning activities and greater willingness to move beyond the status quo (Pierce and Delbecq, 1977). We therefore propose the final hypothesis:

Hypothesis 11: Higher levels of education lead to higher assimilation of aggregate technologies across the value chain.

EMPERICAL STUDY & VALIDITY

Different countries have different definitions of SME. The US Small Business Administration (SBA) provides a numerical definition of "small business" based on number of employees and annual receipts.[1] The Office of Advocacy of the SBA defines a small business for research purposes as an independent business having fewer than 500 employees, and this study has

[1] http://www.sba.gov/size/indextableofsize.htm [last accessed on 07/20/2010]

adopted the same definition.[2]

The survey questionnaire was developed using previously validated constructs and questions as it facilitates the validity of the measures. New questions were developed using relevant literature where this was not possible and these were then later validated. The survey instrument was conceptually validated by consulting faculty in two different universities. Both academics and practitioners working with SMEs reviewed the survey questionnaire to ensure that the indicators captured the appropriate constructs in the research model. This helped rectify several potential problems and ensuring content validity (Campbell and Fiske, 1959; Straub, 1989). This study employs multiple regression analysis.

Working with Greater Boston Manufacturing Partnership, a pilot study was conducted with randomly selected 15 SMEs in order to assess the reliability and validity of the constructs. Since the unit of analysis was the firm, only one survey was conducted per SME. Six items were removed and 3 new items were included.

Since the Greater Boston area includes SMEs in high-technology manufacturing industries, the sample was drawn from industries such as computer and electronic products, fabricated metal products, machinery, electrical equipment, and appliance and miscellaneous manufacturing. Most of the surveyed firms were categorized by North American Industry Classification System (NAICS) codes 332 and 334. NAICS code 332 is Fabricated Metal Product Manufacturing, which includes manufacturing processes such as Forging and Stamping, Architectural and Structural Metals Manufacturing, Hardware Manufacturing, Machine Shops, and Other Fabricated Metal Product Manufacturing. NAICS code 334 is Computer and Electronic Product Manufacturing, which encompasses Computer and Peripheral Equipment Manufacturing, Communications Equipment Manufacturing, and Navigational, Measuring, Electromedical, and Control Instruments Manufacturing. The sample is consistent with the nature of the manufacturing industry in the Greater Boston region.

The research employs the Guttman scale as measures for assimilation across multiple stages. This is in line with past studies employing assimilation stages (Meyer and Goes, 1988). The stages are “no current activity”, “aware”, “interested”, “evaluated”, “committed”, “limited installation”, “general installation” and “acquired, evaluated and rejected” as elaborated in table

[2] http://www.sba.gov/size [last accessed on 07/20/2010]

2. This research used previously tested measures for the different variables. Tables 3 and 7 provide the independent variable description, operationalization and sources. The multi-indicator constructs were viewed as formative rather than reflective. The indicators were viewed as composing the construct as opposed to alternative reflections of the construct (Chin 1998). Reliability in the form of very high internal consistency of indicators is actually undesirable for formative constructs (Petter et al., 2007).

[Insert Tables 2, 3 and 7 here]

From the Massachusetts Manufacturers Register and the contact lists compiled by the GBMP, a dataset of companies with fewer than 500 employees was created. From this dataset, 655 firms from the Greater Boston area were randomly selected to receive surveys. 158 firms responded, resulting in a response rate of 24.1%. Out of this sample, 23 responses were discarded as unusable because of missing data and incomplete information. Response bias is another potential limitation of any survey; the research tested for response bias by comparing the early respondents and late respondents with respect to firm size and industry. Random calls were also made to non-respondents, and unavailability of time was the most common reason for not completing the survey (Armstrong and Overton, 1977).

Table 4 and 6 depicts the descriptive statistics and correlation matrix between the independent variables. The table shows that the independent variables are mostly un-correlated. Very few pairs have a statistically significant correlation of higher than .30. The only statistically significant correlation was between customers and competitors influence variables. This is in line with previous theory that states that customers and competitors both have significant impact on the firm as part of the firm's institutional environment (Teo et al., 2003).

In SMEs, Chief Information Officer (CIO) or Chief Technology Officer (CTO) positions are rare and senior managers often undertake this responsibility, including Chief Executive Officers (CEOs). The survey was administered to senior managers and executives of SMEs who were ultimately responsible for firm-level technology decisions. A significant proportion of the respondents belonged to senior management. Table 6 shows sample demographics.

[Insert Tables 4 and 6]

RESULTS

The research model—in effect, the relationships between the institutional actors and firm characteristics—was tested with multiple regression. Three different models were run to test the different theories: the models are displayed in Figures 2, 3, and 4.

[Insert Table 5 and Figures 2, 3, and 4.here]

Model A (Figure 2) tests the institutional actors of the estimated research model. The hypotheses H 2 and H 5 are strongly supported, as the beta coefficients of competitors and professional networks are significant. The hypotheses H 1, H 3, and H 4 are not supported, as the beta coefficients of customers, vendors, and government agencies are not significant. The model is significant (F-statistics of 2.8; $p< .01$) with an adjusted R^2 value of 0.06 and an R^2 value of 0.10.

Model B (Figure 3) tests the firm characteristics of the estimated research model. The hypotheses H 8, H 9, and H 10 are strongly supported, as the beta coefficients of top management attitude, firm size, and technology specialization are all highly significant. The hypothesis H 11 is not supported, as the beta coefficient of education is not significant. The model is significant (F-statistics of 22.9; $p< .0001$) with an adjusted R^2 value of 0.34 and an R^2 value of 0.36.

The full model, or Model C (Figure 4) tests the firm characteristics and institutional actors of the estimated research model. The hypotheses H 2, H 8, H 9, and H 10 are strongly supported, as the beta coefficients of top management attitude, firm size, technology specialization, and competitors are all significant. The hypotheses H 1, H 3, H 4, H 5, and H 11 are not supported, as the beta coefficients of education, customers, vendors, government agencies, and professional networks are not significant. The model is significant (F-statistics of 12.0; $p< .0001$) with an adjusted R^2 value of 0.37 and an R^2 value of 0.41.

Further data analysis was conducted to ascertain the influence of the firm characteristics and institutional actors based on the size of the SME. The results (Table 5) show that for Model C_1 (firms with less than 50 employees), top management and institutional actors were not significant. However, in the results of Model C_2 (firms with employees between 51 and 500), some firm characteristics and institutional actors were significant. Therefore, when the SME size is below 50 employees, institutional actors do not seem to play the same role in technology assimilation that they do in SMEs with greater than 50 employees.

Data analysis was also conducted for value activities that were categorized into primary core activities, primary non-core activities, and secondary activities. The categorized value activities corresponded to their associated technologies. For the primary core activities, the associated technologies were CAD, CAM, CNC, manufacturing automation, production planning, and materials management. For the primary non-core activities the associated technologies were web sites, EDI, SCM, CRM, supplier management, and order processing. For the secondary activities, the associated technologies were e-procurement, human resource management, and accounting and finance software. The analysis tested whether the assimilation level varied based on the value activity and its associated technology or not. All the paired sample t-tests rejected the hypothesis that the assimilation levels were different with a $p > 0.1$. The data reveals no statistically significant difference, thus supporting the view of value chain innovation proponents. Further, One-way analysis of variance (ANOVA) test was conducted to see difference between the means of these subgroups. The results of the ANOVA show that the F statistic is 0.071 and associated p value is 0.93. Since the p value is much higher than 0.05, then you can reject the hypothesis that the means of at least two of the subgroups differ significantly.

DISCUSSION

In this research, models based on institutional theory and organizational innovation theory were run both separately and jointly to investigate their respective effects on technology assimilation in SMEs. It was found that separately, the institutional actors and firm characteristics models were significant. However, the explanatory power of the institutional perspective was found to be much weaker than that of the organizational innovation perspective. When the models were run jointly, the resulting model was also significant and the explanation power of the joint model increased. This reinforces the claim that multiple perspectives add to the explanatory power of the phenomenon (Van de Ven and Hargrave, 2004).

Contrary to previous institutional theory research in assimilation, which found that all the institutional actors were important (Teo et al., 2003), this study shows that for SMEs, a few institutional actors are predominant, such as competitors and professional networks. Competitors are organizations that are similar to each other and employ people from similar backgrounds, and they were an important actor in determining the assimilation of technology at the SMEs. The study suggests that SMEs are more in tune with their competitors and that once SMEs start assimilating a technology, professional networks ensure dissemination of the knowledge. The SMEs investigated in the study are located in a limited geographical area characterized by their own technology specialization and ownership characteristics. It is expected that relationships of social and cultural nature will provide a social bonding giving rise to a network of actors.

Porter's value chain categorizes activities as primary or secondary. The research categorized the technologies further into primary core activity technologies, primary non-core activity technologies, and secondary activity technologies. There was no difference in the level of assimilation among these three categories of technologies. This supports the value chain innovation perspective (Little, 1988, Porter, 1985; Porter and Millar, 1985) that the firms are stressing on the entire value chain. Additionally this research employed the Guttman scale as measures for assimilation across multiple stages. This is the first SME study to investigate the extent of assimilation of technologies that span the entire value chain; it is novel because the data provided the opportunity to ask which technologies had higher assimilation and how they related to the value chain activities. There was no evidence that assimilation was different for the strategically relevant technology categories.

Consistent with previous research on large firms (Fichman, 2001), firm characteristics such as firm size, technology specialization, and role of top management were found to be significant. Firm size is important and significant in explaining the assimilation of technology, since it acts as a surrogate measure for many other firm characteristics necessary for the assimilation of technology (e.g., overall firm resources, slack resources, and firm structure). The SMEs studied were in the high-technology sector, and not surprisingly, technology specialization was an important characteristic in their assimilation of technology.

Consistent with previous MIS literature on both large firms and SMEs (Thong, 1999), this study found that top management is important for the assimilation of information technologies across the value chain because of the vision and support that it provides toward technology assimilation. The role is even more pronounced in the case of SMEs where the owner is a key driver in the firm.

Claims have been made that small firms differ considerably from large firms in terms of acceptance and assimilation of technology (Cragg and King, 1993; Iacovou et al., 1995; Kuan and Chau, 2001; Thong, 1999). The exact nature of these differences is yet to be widely agreed upon by the IS community. The results of this study confirm some of the conclusions arrived at earlier, although they differ in some important respects. As stated earlier, firm size, role of top management, and technology specialization were found to be significant, which is not surprising because firm size often acts as a surrogate for other variables such as specialization and slack resources (Rogers, 2003). That is, characteristics associated with the firm itself generally play a similar role whether the firm is large or small or the issue is technology adoption or full cycle of assimilation.

This study found that differences were significant between large and small firms when the environment was considered. Previously, many institutional actors such as customers, competitors, vendors, and others were found to significantly affect large firms (Liang et al., 2007; Teo et al., 2003). However, in the case of small firms, the results have been different. For instance, previous SME research has found that the role of institutional actors has either been absent or ambiguous (Kuan and Chau, 2001; Thong, 1999). In this study, competitors and professional networks were significant for the assimilation of aggregate technologies—a first-of-its-kind result in the field of SME research. This result strengthens the previous evidence that small firms are different from larger firms.

This study finds that as a firm becomes smaller, the influence of any institutional actor ceases to be significant (see Table 5). This is an important finding because it explains that institutional actors do not necessarily have the same influence across SMEs of different sizes. This is in line with the observation that organizations assisting firms find it harder to involve smaller firms than larger ones—not surprising, considering the minimal resource slack at smaller SMEs. Taken together with the fact that institutional forces appear weak, this seems to indicate the presence of structural holes in the SME community. The weak connections between entities across clusters have been referred to as holes in a social network (Granovetter, 1973). According to Burt (2005), "holes are like insulators in an electric circuit; people on either side of a hole circulate in different flows of information." As a result of their size, SMEs are often limited to interacting with firms in a limited geographical area and suffer from information insularity. This is the first SME study where evidence of structural isolation has been found, and the structural isolation becomes acute as the SMEs become even smaller.

RESEARCH & MANAGERIAL IMPLICATIONS

This research study investigated the assimilation of aggregated technologies in SMEs. The study found that firm characteristics for SMEs are almost the same for the entire assimilation life cycle as they were for adoption for large firms (Damanpour, 1991). An important similarity of this result is that it is generalizable to all firms irrespective of size and geographical location. This study was limited to the Greater Boston area and thus has the obvious geographical limitation.

The research also provides policymakers with grounded knowledge to formulate effective policies and support systems for high-tech manufacturing areas like Greater Boston. It was found that institutional actors play a role in assimilation and few SME-appropriate solutions exist. This lack of SME-appropriate IT solutions has been identified by others (Wolcott et al., 2007). This is not to minimize the challenges involved in assisting SMEs in secondary activities of the value chain: compared to primary activities that have had the benefit of well-known overarching themes such as lean manufacturing, total quality management, and continuous process improvement, support activities suffer from the absence of such overarching themes. Support activities consist of heterogeneous processes with differing impacts on firm performance, and that they require a potpourri of technologies and varying skill sets to run. Thus, SMEs are in real need of guidance regarding size-appropriate solutions. The current literature and public domain does not provide any size-appropriate technology solutions. The technology intermediary role can be played by vendors such as Oracle, Microsoft, and SAP, who need to develop solutions that are appropriate for SMEs.

The enterprise intermediaries must explore solutions that are not necessarily hardware- or software-based, but rather service-based. SMEs are already employing services for payroll management and benefit management. There is an opportunity to expand the field of services to solutions where the hardware and software is really part of the application service provider while the function is managed as appropriate. There is evidence that SMEs in Europe are increasingly adopting application services in the areas of accounting, taxation, and control (Tholons, 2010). SMEs can also explore solutions such as www.salesforce.com.

SME-appropriate solutions need to be customized and sold to firms. This role belongs to the enterprise intermediary, whose responsibility it is to provide consultancy and application services. Where novel technology solutions exist for secondary activities, they have either been obtained through house trial and error or through peer networks. SMEs, due to their size, suffer from the absence of resource slack, and consequently they are not in a position to experiment with new technologies and solutions. Their small scale of operation ensures that their learning suffers from severe diseconomies of scale. Scale economies in learning can be obtained through intermediaries developing appropriate solutions and implementing them over multiple firms (Attewell, 1992). Currently there are no institutions playing the role of enterprise intermediary. Therefore, there is a need for government agencies and nonprofits to create such intermediaries or take on this important role themselves.

The study clearly demonstrates that the influence of institutional actors is critically dependent on the size of the firm. The study showed that for firms with 50 or more employees, the institutional environment constituted by the peer-to-peer group of competing firms was the only influence. In firms with less than 50 employees, the institutional actors were not found to be significant; this provides evidence that very small firms are subject to acute structural isolation. The institutional theory, which is based on economic actors, is thus found insufficient to capture the influence of the SME environment. This calls for research into the social and community-based institutional actors that the SMEs are embedded in. It is the strong social ties that are at play in the SME environment and not the weak ties of economic actors (Granovetter, 1973). This opens different possibilities of using institutional theory in the IS field. Not only the economic actors have a major role in society but also the social and community actors.

Government agencies and vendors need to play their own roles in order to make this sector competitive. Since small firms and micro-firms are not extensively connected to professional and personal networks, it is incumbent on public-sector agencies to provide the necessary knowledge and support. For instance, they could enhance their outreach programs by offering Web-based knowledge repositories and demonstration laboratories. The Web-based knowledge repositories could consist of technology solutions, relevant SME case studies, and best practices. The demonstration laboratories could also have a significant impact by improving awareness and developing a better understanding of these technologies. Support intermediaries are a life-or-death issue for SMEs, as has been observed in the US Silicon Valley, where vulnerability increased due to lack of support and coordination. These repositories and labs will widen the clusters beyond the confines of local networks to create a virtual network.

The preliminary findings and recommendations were presented at a GBMP-organized roundtable for SMEs. Overall, the SME representatives said that they found the research study very informative and the results reflected their own experiences.

LIMITATIONS

There are several limitations to the study. First, the study's quantitative data is based on perceptions of individuals assessing at an organizational level. Although these persons are knowledgeable and experienced, the results are nonetheless still based on their perceptions and not on measurable organizational output. Second, the study was limited to the Greater Boston area and thus has the obvious geographical limitation. Third, surveys based on respondents' opinion of their organization tend to be biased as the respondents give a positive evaluation of their own organizations. This bias is not characteristic of this research but rather applicable to all similar survey research. Fourth, the quantitative data were collected using a survey instrument. Since this was a correlational study no causal relationships can be drawn among the variables.

FUTURE RESEARCH & CONCLUSION

Firm-level analysis for IT adoption and assimilation has gained acceptance in some recent studies (Fichman, 2001; Liang et al., 2007; Teo et al., 2003). Diffusion studies at the industry level are also becoming popular. Each firm is embedded within the institutional environment of a cluster, and the cluster characteristics have an impact on the firm as well as the institutions. Clusters are critical masses of firms located in a geographically concentrated area that become a source of enduring competitive advantage. It is therefore appropriate to conduct research into the nature and characteristics of these clusters and the extent to which they promote and inhibit the firm-level assimilation of technologies. A question of interest: How are clusters structured, and to what extent do these structural differences explain the organizational-level outcomes?

The institutional lens has been used to examine firm-level adoption issues in recent studies (Liang et al., 2007, Teo et al., 2003). This lens has been limited to economic actors only, but in the case of small firms, sources of institutional influence must be expanded to include the social, cultural, and community environment in which SMEs are embedded. More research is required to study the SME environment in other parts of the US and the world. This has the potential to enrich and expand institutional theory.

Information systems research has focused on inhibitors and promoters of technology adoption, especially where individual technologies are involved. Since SMEs are major contributors to GDP and employment, this study indicates that more empirical studies should be conducted focusing on technologies that are important to the entire value chain. The role of the institutional environment has not been studied for SMEs outside this study. This research highlights multiple intermediary roles that different institutions must play for SMEs to be competitive in the global economy; future research should focus on the role of intermediaries in promoting SME-specific solutions and technologies.

This research model was developed specifically for SMEs, but it might be interesting to investigate its applicability to larger firms. In the case of larger firms, a comparison of firm characteristics with institutional actors might provide important insight. This might also provide a better understanding of where managerial intervention should be directed.

This is the first study of technology assimilation that aggregates across technologies and across the assimilation life cycle. The study employed the twin lenses of institutional theory and organizational innovation in investigating SMEs. A theoretical model was developed and tested to explore the effects of institutional environment and firm characteristics on the assimilation life cycle where multiple technologies are involved. The results showed that the impact of institutional actors diminishes with decreasing firm size and that size is an important determinant of technology assimilation associated with both secondary and many primary activities of the value chain. This also strengthens the claim that a small business is not a "small big business." The relative weaknesses of the institutional actors provide evidence of structural holes in the SME environment that inhibit information flow from economic intermediaries such as vendors, professional networks, and government agencies. For SMEs to stay competitive, the study recommends that technological, enterprise, and community intermediaries develop SME-specific solutions.

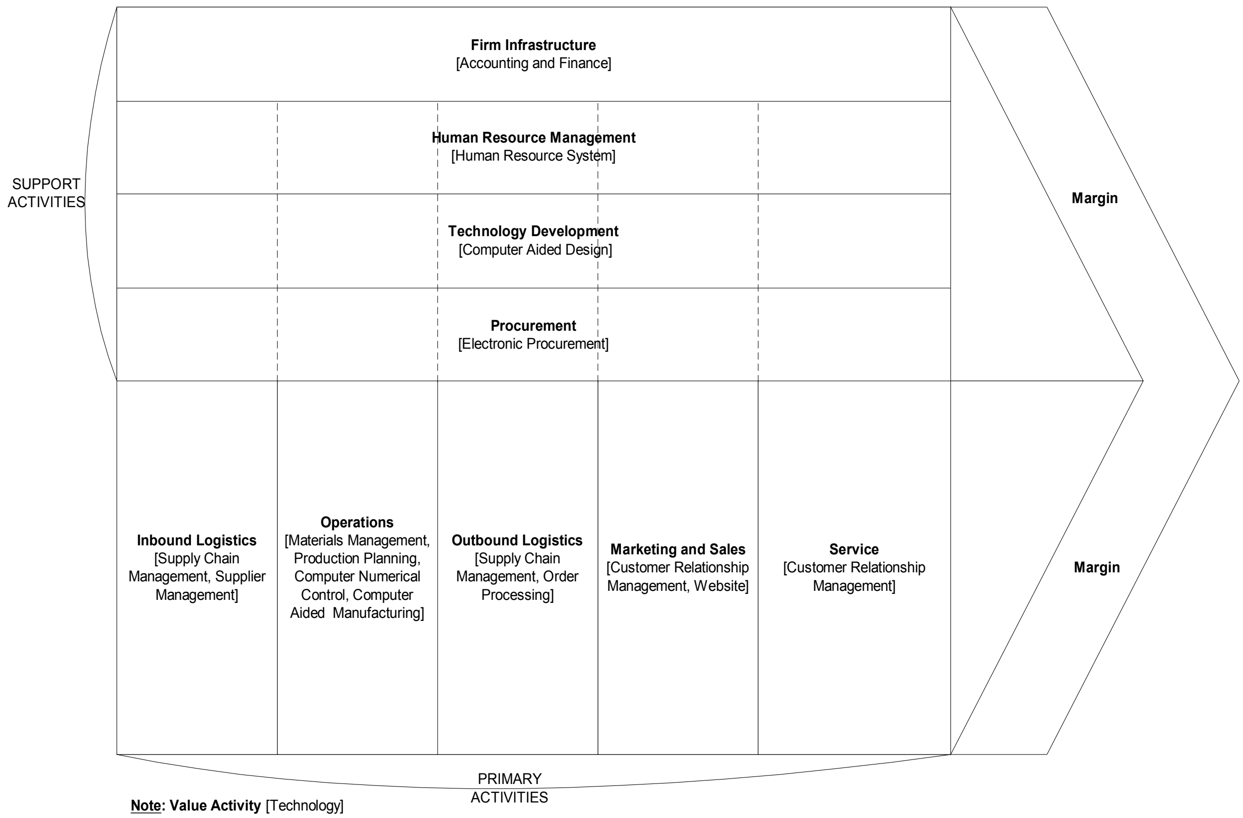
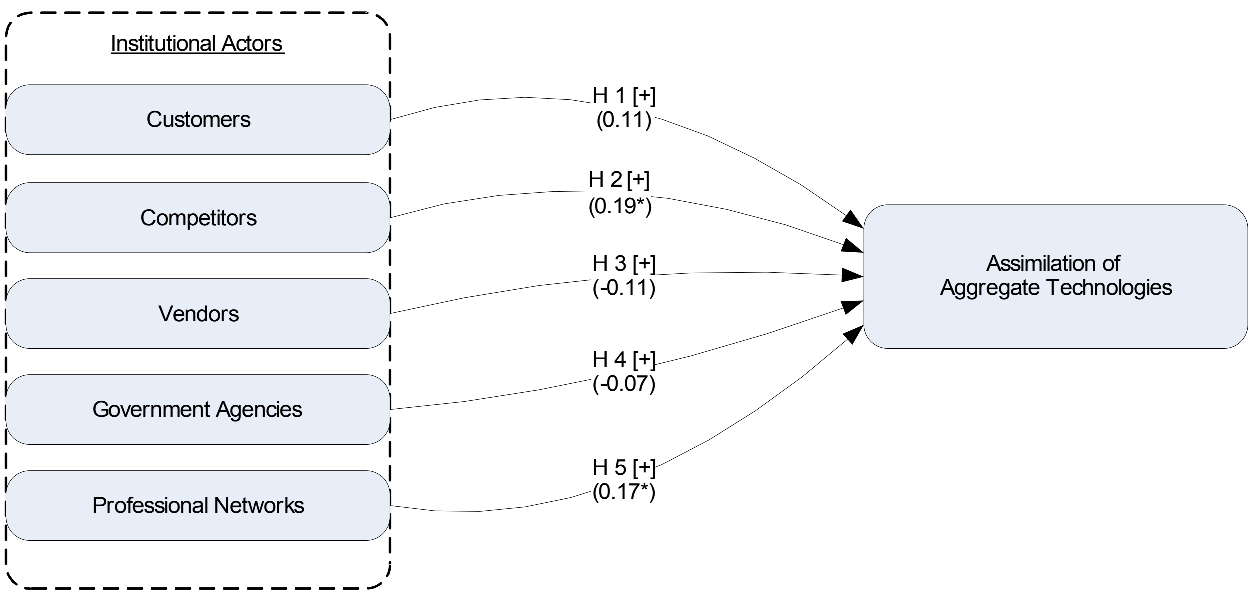


Figure 1: Value and Associated Technologies

Table 1: Value Chain and Associated Technologies

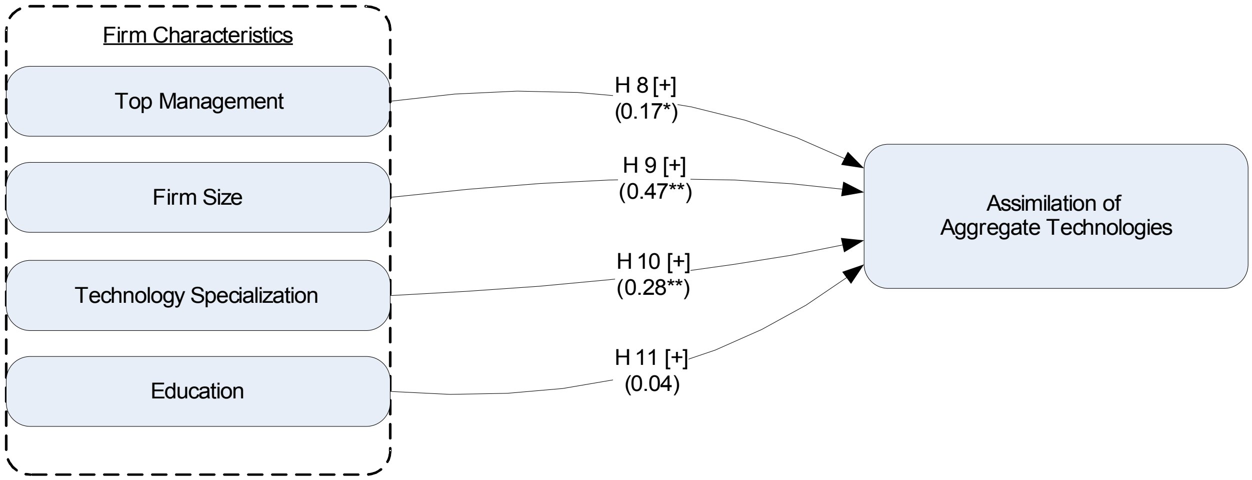
Value Chain Activity	Associated Technologies
Inbound Logistics	Inbound logistics involves actions associated with receiving, storing and supplying of raw materials. Inbound logistics is supported by supplier management and supply chain management technologies. Supplier management is the use of software to store and process supplier-related data. Supply chain management (SCM) is the use of packaged software for planning and monitoring of material flow between the firm and its suppliers and customers.
Operations	Operations involves actions and processes associated with transforming material inputs into a finished product. It is supported by materials management, production planning, computer numerical control (CNC), and computer aided manufacturing (CAM) technologies. Materials management is the use of package software for planning and control of material storage and usage in production environment. For the purpose of this survey, CAM is defined as the use of computers for planning the manufacturing process.
Outbound Logistics	Outbound logistics is the actions associated with the storage and physical distribution of physical goods to buyers. This activity is supported by order-processing and SCM technologies. Order processing is use of package software to store and process customer orders.

Marketing and Sales	Marketing and sales involve actions associated with advertising, promotion, pricing and selling. This activity is supported by firm website and customer relationship management (CRM) technology. CRM is use of software to store customer data for tracking and analysis of customer needs and sales activities.
Service	Service involves actions associated with providing service and assistance to the customer. This activity is also supported by CRM technology.
Firm Infrastructure	Firm infrastructure involves activities associated with general management, planning, finance and accounting. This activity is supported by accounting and finance software technologies.
Human Resource Management	Human resource management activities involve recruiting, hiring, training and compensation for employees. This activity is supported by human resources management software that monitors employee related data.
Technology Development	Technology development involves activities related to development of know-how, procedures and technology. This activity is supported by computer-aided-design (CAD) that assists engineers in their design and drafting activities.
Procurement	Procurement involves activities associated with purchasing raw materials and inputs for the firm.



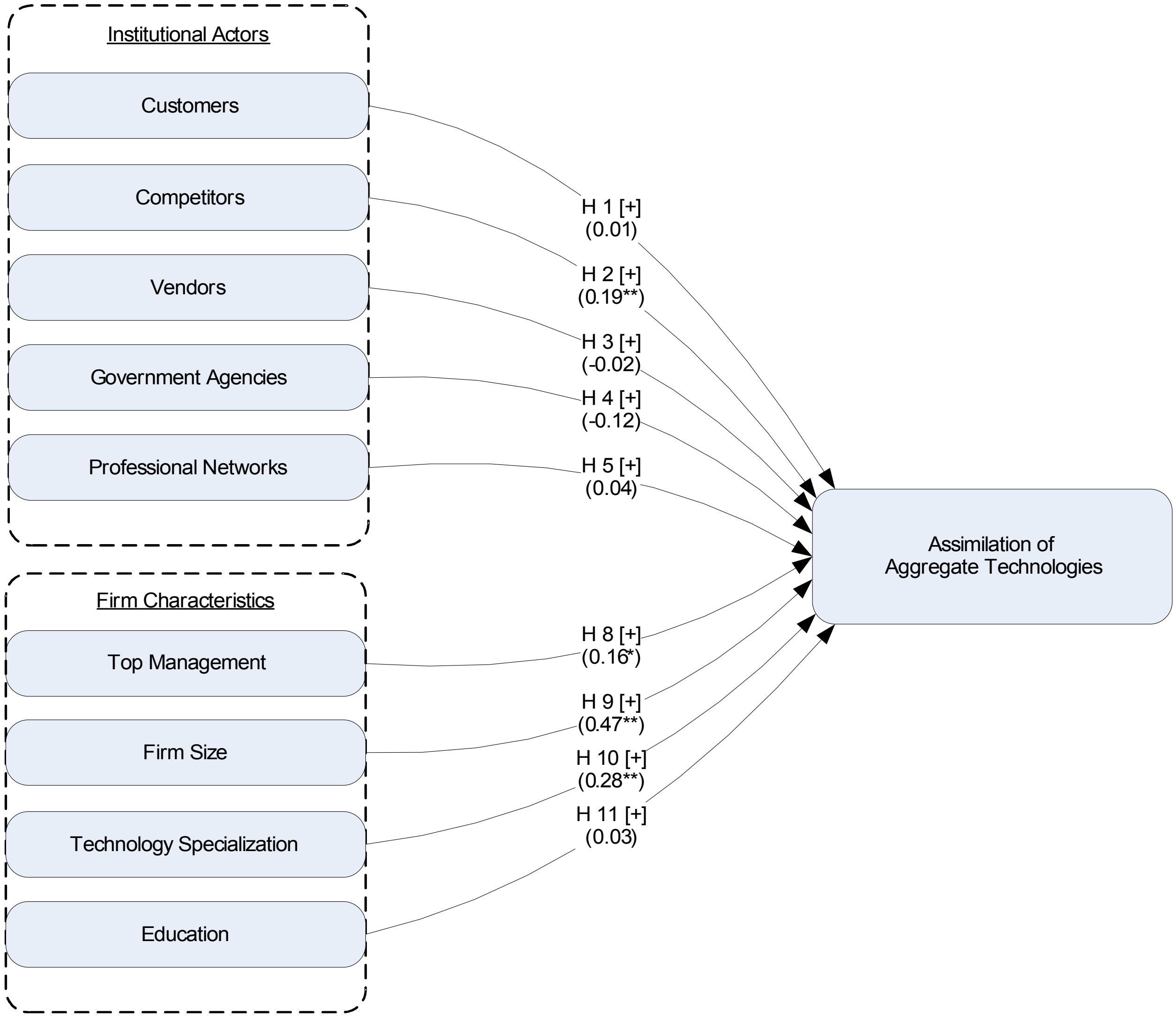
** p<0.01 and * p<0.05

Figure 2: Regression of Institutional actors with Assimilation of Aggregate SME Technologies [Model A]



** p<0.01 and * p<0.05

Figure 3: Regression of Firm Characteristics with Assimilation of Aggregate SME Technologies [Model B]



** p<0.01

Figure 4: Regression of All Characteristics with Assimilation of Aggregate SME Technologies [Model C]

Table 2: Guttman Scale for Technology Assimilation

Stage	Criteria to enter stage
1) No current activity	No present activity related to the technology
2) Aware	Key decision makers are aware of this technology
3) Interested	Organization is committed to learning more about the technology
4) Evaluated	Organization has acquired technology related products and has initiated trial
5) Committed	Organization has committed to use the technology in a significant way
6) Limited Installation	Organization has established a program of regular but limited use of technology
7) General Installation	Organization has reached a stage where the technology is used at least for one large and mission critical system
8) Acquired, Evaluated and Rejected	Organization had acquired and evaluated the technology and later rejected the technology

Table 3: Independent Variables and Sources

Variable Name	Variable Description	References
Customers	Customers significantly influence IT assimilation	Brass, 1985; Knudsen et al., 1994; Palmer et al., 1983; Teo et al., 2003; Webster, 1995.
Competitors	Competitors significantly influence IT assimilation	Brass, 1985, Haveman, 1993; Liang et al., 2007; Son and Benbasat, 2004; Thong, 1999.
Vendors	Vendors significantly influence IT assimilation	Brass, 1985; Markus, 1987; Teo et al., 2003; Thong et al., 1994; Thong et al., 1996.
Government Agencies	Government agencies significantly influence IT assimilation	Brass, 1985; King et al., 1994; Teo et al., 2003.
Professional Networks	Professional networks significantly influence IT assimilation	Brass, 1985; King et al., 1994; Teo et al., 2003.
Top Management	Top management's attitude towards incorporation of IT in the firm	Chatterjee et al. 2002; Jarvenpaa and Ives, 1991; Thong, 1999; Yap et al., 1992.
Firm Size	Actual size of the firm	Alpar and Reeves, 1990; Thong, 1999.
Technology Specialization	Level of IT specialization	Damanpour, 1991; Fichman, 2001; Kimberley and Evanisko, 1981.
Education	Level of higher education in	Damanpour, 1991; Fichman, 2001;

Variable Name	Variable Description	References
	the firm	Pierce and Delbecq, 1977, Zmud, 1982.

Table 4: Descriptive Statistics and Correlation Matrix

Variables	Mean	SD	1	2	3	4	5	6	7	8	9
1. Customers	3.64	1.86	1.00								
2. Competitors	2.60	1.91	0.39*	1.00							
3. Vendors	2.13	1.74	0.07	0.12	1.00						
4. Government Agencies	1.84	1.54	0.20*	0.09	0.09	1.00					
5.Professional Networks	2.57	1.87	-0.01	0.12	0.18*	0.07	1.00				
6. Top Management	4.57	1.16	0.17*	0.08	0.20*	0.02	0.08	1.00			
7. Firm Size (log)	1.65	0.57	0.07	0.00	-0.13	0.03	0.12	-0.11	1.00		
8. Technology Specialization	3.29	0.81	0.17	0.14	0.03	0.21*	0.21*	0.19*	0.13	1.00	
9. Education (log)	1.14	0.41	-0.17	0.05	0.01	0.04	0.05	0.04	-0.12	-0.03	1.00

* p<0.05

Table 5: Results of Model C based on Firm Size

Characteristics	**Model C_1 Assim. Aggregate Technologies (Employees less than 50)**	**Model C_2 Assim. Aggregate Technologies (Employees between 51 and 500)**
Customers	0.07	- 0.13
Competitors	0.13	0.30*
Vendors	- 0.09	0.09
Government Agencies	- 0.11	- 0.18
Professional Networks	0.04	- 0.01
Top Management	0.11	0.26*
Firm Size	0.44***	0.34**
Technology Specialization	0.30**	0.22*
Education	0.09	- 0.04
R^2	0.42	0.36
F Statistics	5.0***	3.8**

*** p<0.001 and ** p<0.01

Table 6: Sample Demographics

Characteristics	Frequency	Percentage
Primary Industry		
Manufacturing – discrete (repetitive and job shop)	60	44
Manufacturing – process (continuous)	51	38
Health care/Medical	2	1
Education	2	1
Business Services and Other Services	6	5
Communication	2	1
Wholesale Trade	3	2
Other	9	8
Number of Employees		
Fewer than 11	25	19
11-100	80	59
101–500	30	22
Current Position		
Chief Executive	26	19
Vice President/Director	50	37
Manager	39	29
Project Leader	1	1
Supervisor	3	2
Other	16	12
Education		
Percentage with bachelor's degree (average)	-	25
Percentage with master's degree (average)	-	8

Table 7: Measures of Variables

Construct	Operationalization	Mean	SD
Assimilation of Aggregate Technologies	Average over multiple technologies across the value chain using the Guttman scale (websites, electronic data interchange, supply-chain management software, customer relationship software, electronic procurement software, computer-aided design, computer-aided manufacturing, computer numerical control, manufacturing automation, production planning software, human resources software, accounting/financial software, materials management software, supplier management software, and order processing software)	4.20	1.49
Customers	An ordinal variable capturing the influence of customers on IT assimilation	3.64	1.86

Competitors	An ordinal variable capturing the influence of competitors on IT assimilation	2.60	1.91
Vendors	An ordinal variable capturing the influence of vendors on IT assimilation	2.13	1.74
Government Agencies	An ordinal variable capturing the influence of government agency on IT assimilation	1.84	1.54
Professional Networks	An ordinal variable capturing the influence of professional networks on IT assimilation	2.57	1.87
Top Management	An ordinal variable capturing the influence of top management attitude on IT assimilation	4.57	1.16
Firm Size	Total number of employees in the firm (Log)	1.65	0.57
Technology Specialization	Count of the number of specialties that the IT department is involved in (technology evaluation, quality assurance, data administration, system testing)	3.29	0.81
Education	Average of percentage of employees that have a bachelor's degree as highest degree and percentage of employees that have a master's degree or higher as highest degree (Log)	1.14	0.41

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