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Wei Jie

City University of Hong Kong, lovelyinhuli@hotmail.com

Choon Ling Sia

City University of Hong Kong, iscl@cityu.edu.hk

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The process of RFID assimilation by supply chain participants in China: A technology diffusion perspective on RFID technology

Jie, WEI
lovelyinhuli@hotmail.com

Choon Ling, SIA
iscl@cityu.edu.hk

Department of Information Systems
City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong

ABSTRACT

RFID technology is recently an emerging technology that is being used in many echelons of supply chain participants. Most recent IS research on this technology focus on factors which will impact its organizational adoption. However, adoption is just one part of assimilation process which cannot make sure that RFID can be full-scale deployed in an organization. Assimilation theories also suggested that most information technologies exhibit an “an assimilation gap” which means widespread usage tends to lag behind their adoption. Therefore, a stage-based model is necessary for us to understand the assimilation process of RFID technology.

In this paper, we will draw on innovation diffusion theory, institutional theory and stage-based model to investigate which innovation factors play significant roles during three assimilation stages: initiation-adoption-routinization. Factors under each category of TOE (technological, organizational, and environmental) framework will be potential antecedents of the stage-based assimilation process and their impacts on each stage will be investigated.

Keywords

Innovation diffusion, RFID technology, TOE framework, stage-based model

INTRODUCTION

RFID is recently an emerging technology that has been used in warehouse management, inventory monitoring by many echelons of supply chain participants including suppliers, manufacturers, retailers to improve their operations efficiency. Giant companies such as Wal-Mart and Tesco, mandate that their 100 key suppliers attach RFID tags on pallets and cases by certain date. This was closely followed by the DOD (Department of defense) RFID mandate in October 2003. However, the benefits resulting from this promising innovation will be curtailed if it cannot be widely adopted (Zhu et al. 2006a). Adoption is just one part of an innovation assimilation process which cannot make sure wide-scale assimilation. As indicated by Chatterjee et al. (2002), many firms failed to achieve deep usage beyond initial adoption. However, most recent IS research on RFID focus on a single stage such as one-shot adoption decisions, and we know very little about the various stages of RFID assimilation. According to the literature review of Fichman (2000) and Zhu et al. (2006b), the post adoption stages of assimilation are especially worthy of a focused study.

This research will fill the research gaps and investigate various factors' differential impacts on each stage of assimilation processes. As indicated by Fichman (2000), it is necessary since the same factors may have “differential effects,” depending on the stages of assimilation. Tornatzky (1980) also suggested that factors affecting adoption may actually have the opposite effect upon infusion although adoption is necessary for infusion to occur. Similar to the definition of e-business assimilation by Zhu et al. (2006), RFID assimilation in our paper is defined as a series of stages from a firm's initial evaluation of this technology at the pre-adoption stage (initiation), to its formal adoption, and finally to its full-scale deployment at the postadoption stage in which RFID becomes an integral part of the value chain activities (routinization).

Further, it is also important to identify antecedents that influence RFID assimilation. According to Roger's innovation diffusion theory, technology characteristics which will influence innovation diffusion include: relative advantage, complexity, compatibility, observability, triability. Moreover, influences from the environment could also affect RFID assimilation. As indicated by Teo et al. (2003), three institutional pressures-mimetic pressures, coercive pressures, and normative pressures have significant influence on organizational intention to adopt an innovation. However, there is a lack of literature which

integrates these different factors into a research framework. Thus we are encouraged to develop an integrated model to investigate different contextual factors' effect.

Motivated by the above theoretical gaps, we intend to develop an integrative model to address these questions: (1) which factors (including technological, organizational, and environmental factors) would impact RFID assimilation? (2) How do these different factors impact each assimilation stage? An integrative theoretical model combining the innovation diffusion theory, institutional theory and stage-based model will be built to investigate these problems. Research model will be tested through data collected from supply chain participants in China which are at different phases of assimilation.

THEORY AND HYPOTHESIS

The phases of innovation diffusion

As described by Bolloju and Turban (2007), assimilation used in IS literature is to represent a comprehensive and complete process of implementation of IS and other IT innovations in organizations. From the stage-based perspective, Cooper and Zmud (1990) identified that assimilation can be viewed as a six-stage process from initiation to a complete infusion. Meyer and Goes (1988) categorized assimilation into three primary stages: knowledge-awareness stage, evaluation-choice stage, and adoption-implementation stage with each of these primary stages having three sub-stages. To describe the phenomenon of a system implementing organizational innovation, Lewin (1952) proposed a three-stage change model including unfreezing, moving and refreezing. In our paper, we focus on three stages of Cooper and Zmud's six-stages based model: initiation, adoption and assimilation. Initiation is the first stage of RFID assimilation which involves active or passive scanning of organizational problems and opportunities. Two kinds of pressures to changes evolves from either organizational need (pull), and technological innovation (push) or both. At this stage, the organizations are aware of this innovation and evaluate whether it can solve the organization's problems.

Following initiation is the stage of adoption. At this stage, an organization makes decisions on whether allocate resources to the innovation and physically acquire the technology. Most innovation related IS research focus on adoption stage and investigate antecedents of innovation adoption from both technology and organizations perspective.

However, adoption does not always result in wide-scale deployment of the innovation by a firm. According to innovation assimilation theory, assimilation gap exist between adoption and large-scale deployment (Fichman and Kemerer 1999). A new technology may enjoy widespread initial acquisition, but still fails to be thoroughly deployed among many acquiring firms. It is because once a new technology is adopted, members of the organization usually confront knowledge barriers which may inhibit its routinization.

Antecedents of RFID assimilation

Through reviewing literature, we think that technology-organization-environment (TOE) framework is appropriate to study antecedents of RFID assimilation (Tornatzky and Fleischer 1990). Based on this framework, there are three aspects of a firm's context that influence its assimilation of a technological innovation: (1) Technological context which refers to the existing technology in use and new technologies relevant to the firm (2) Organizational context refers to the characteristics of organizations such as size, scope and managerial structure (3) Environmental context is the arena in which a firm conducts its business-its industry, competitors, and dealings with government (Tornatzky and Fleischer 1990). This framework is useful to analyze innovation assimilation from the perspective of technology characteristic, organizations characteristic as well as the external environment surrounding the organizations.

To identify specific factors within the TOE framework, we first investigate the factors which have been found to be significant in other IS innovations. In the technological context, according to Roger's innovation diffusion theory, there are five innovation characteristics perceived by adopters which will determine the ultimate rate and pattern of adoption: relative advantage, complexity, compatibility, observability, triability. Among these five innovation characteristics, the former three are considered important factors to predict innovation diffusion.

Besides technology characteristic, organizational context which refers to the organization size, managerial structure are other components of TOE framework. These factors could help explain why some organizations are more innovative while others are less prone to innovate. Organizational size and structure (including formalization and centralization) are usually important factors that differentiate organizations' innovation adoption and implementation. Since innovation diffusion requires organizational adaptation such as business processes reengineering and organizational restructuring, which demands firms to possess relevant managerial skills. Therefore, we include managerial obstacles within the organizational context.

According to Tornatzky and Fleischer (1990), environmental context is the arena in which a firm conducts its business—its industry, competitors, and dealings with government. DiMaggio and Powell's institutional theory which include coercive, mimetic and normative pressures will be employed to illustrate enterprise's environment. Institutional theory proposes that institutional environment provides rule-like social expectations and norms for appropriate organizational structures, operations, behaviors and practices (DiMaggio and Powell, 1983; Meyer and Rowan, 1977; Scot, 1995; Zucker, 1987). The factors of institutional pressures represent the external environment which will influence an organization's innovation assimilation process.

THEORETICAL DEVELOPMENT AND HYPOTHESES

RFID initiation stage

Initiation is the first stage of RFID assimilation which involves active or passive scanning of organizational problems and opportunities. Two kinds of pressures to change evolve either from organizational need (pull), and technological innovation (push) or both. At this stage, organizations are aware of this innovation and evaluate whether it can solve the organization's problems.

According to Roger's innovation diffusion theory, there are five innovation characteristics including relative advantage, complexity, compatibility, trialability, observability which will influence an organization's innovation adoption and assimilation. O'Callaghan et al. (1992) examined the role of compatibility, relative advantage, and external influences on EDI adoption decision of insurance agents. Their field study of 1242 insurance agents suggested that relative advantage was the only variable influencing adoption decision.

Since at initiation stage of RFID technology, firms are aware of the innovation and evaluate whether it can solve the organization's problems. Relative advantage and the function of RFID technology will be assessed to check its usability. Compared with traditional bar code, RFID can identify tagged product without line of sight and track the status of products when they are received or shipped away from the warehouse in real time. Therefore, product inventory status can be monitored in real time with less labor force which will increase the inventory management efficiency. Complexity and compatibility may not draw special attention at this stage since organizations need not decide whether to adopt RFID or not.

Therefore we have the following hypotheses:

Hypothesis 1a: Relative advantage has positive influence on RFID initiation stage.

Hypothesis 1b: Relative advantage's effect on RFID initiation stage is stronger than that of complexity and compatibility.

With reference to the organization context, we intend to use Gilbert's organizational inertial theory to illustrate the organizational factors. According to Gilbert (2005), there are two distinct categories of inertia: resource and routine rigidities. They indicate a firm's inability or failure to change resource investment patterns and organizational process respectively in response to external threats or opportunities. Resource rigidity can significantly inhibit initiation stage since at this stage organizations begin to consider whether they have enough financial resources and technical expertise to implement RFID technology. It will be easier to overcome as long as the organization has enough financial and human capital, technological capability and readiness (Cartwright et al. 2005). Rogers (1995) indicated that firm size is probably a surrogate measure of several dimensions that lead to innovation: total resources, slack resources, technical expertise of employees. Therefore, larger firms who usually have resource advantage are more prone to be aware of RFID technology and the benefits of it.

Hypothesis 2a:

Firm size has strong positive influence on RFID initiation stage.

According to the classification of innovation, RFID belongs to radicalness innovation and Fichman (2004) suggested technologies that enable more radical improvements require substantial complementary changes to organizational structures, routine, and policies. Thus RFID may involve some unique changes with regard to organizational adaptations (Chatterjee et al. 2002). Roberts (2003) indicated that not all firms can effectively manage organizational adaptation because of lack of managerial skills and know-how for change management. Therefore, the effect of managerial obstacles which refer to the lack of managerial skills for managing organizational adaptations to accommodate RFID assimilation is worth investigating. Organizational adaptations in RFID assimilation include making organizational changes on structures and coordination mechanisms (Chatterjee et al. 2002, Orlikowski and Hofman 1997), and acquiring new expertise necessary to use the innovation (Fichman and Kemerer 1999). Most literatures owe IT failure to management issues such as lack of synergy between business and IT skills, how to integrate the technology with the business strategy, skilled technical people and experienced, trained users. These literatures suggested that managerial obstacles can impede RFID initiation, adoption and

routinization when organizations cannot make organizational changes, redesign business processes, and acquire new expertise. Therefore, we have hypothesis 2b as follows:

H2b: Managerial obstacles are negatively related to RFID initiation, adoption and routinization.

According to DiMaggio and Powell (1983), institutional pressures emanate from the institutional environment and push firms to adopt shared notions and routines. The firm's perception of these pressures affects its interpretation of the environment in general and innovation adoption intentions in particular (DiMaggio and Powell, 1983; John et al., 2001; Ketokivi and Schroeder, 2004; Zsidisin et al., 2005). Therefore, we think institutional pressures constitute the external environment which will impact organization's innovation adoption and diffusion and their effect will vary as assimilation progress to a deeper stage. Institutional pressure are categorized into normative, coercive and mimetic pressures which come from constituents in the field, such as professional associations, customers, suppliers, and competitors (Oliver, 1997). Mimetic pressures make an organization imitate others when the organizational technologies are poorly understood, goals are ambiguous, or the environment is uncertain. According to Burt (1987), the imitation usually happen among organizations which are structurally equivalent because these organizations occupy a similar economic network position in the same industry and may share similar goals, produce similar commodities, share similar customers and suppliers. Thus when an organization begins to adopt RFID technology, competitors in the same industry with similar economic position may become aware of its adoption and also consider adopting it. Therefore, the influence of mimetic pressure is significant on the initiation stage. We have hypothesis 3a as follows:

Hypothesis 3a:

Mimetic pressure has strong positive influence on the initiation of RFID technology.

Also indicated by DiMaggio and Powell (1983), coercive pressures are defined as formal or informal pressures exerted on organizations by other organizations upon which they are dependent. Usually, coercive pressures are requirements raised by constituents including suppliers and customers. One common characteristic of the constituents is that they hold resources organizations need, such as new business contracts or funding (Choi and Wasti 1995; Grewal and Dharwadkar 2002). Therefore, a powerful firm can exert pressures on these partners by raising requirements. (John et al., 2001; Zsidisin et al., 2005). The firm's dependent partners may become aware of RFID technology due to these requirements and tend to comply with the demand to secure their market status and continued access to scarce resources provided by the powerful firm. Therefore, coercive pressure has significant positive influence on the initiation stage of RFID assimilation.

Hypothesis 3b:

Coercive pressure has strong positive influence on initiation of RFID technology.

Normative pressures evolve either from dyadic inter-organizational channels of firm-supplier and firm-customer or through professional, trade, business, and other key organizations (Powell and DiMaggio 1991). Thus, in the context of RFID adoption, the frequency of use among an organization's suppliers and customers may positively ignite the organization's initiation of the technology. Moreover, key institutions such as government sanctioned bodies, standard bodies, and professional and industry associations could also influence organizational behavior. If an organization participates in these institutions, decision makers are more likely to be positively inclined toward the innovation. Therefore, participation in associations that promote and disseminate information on RFID will wake up decision makers' awareness of this technology and increase their adoption intention. Based on the above analysis, we have hypothesis 3c as follows:

Hypothesis 3c:

Normative pressure has strong positive influence on the initiation of RFID technology.

RFID adoption stage

The outcome of initiation process leads to the adoption decision. At this stage, an organization makes decisions on whether allocate resources to the innovation and physically acquire the technology. As indicated by Bajwa et al. (2004), key activities in adoption process include: definition of project objectives, collection of vendor consultant information, need analysis, evaluation of vendor and consultant alternatives, and evaluation of IT infrastructure, feasibility study, and finalizing of contracts. Most innovation related IS research focus on adoption stage and investigate antecedents of innovation adoption from both technology and organizations perspective.

At this stage, firms make decisions whether or not to invest capital to acquire RFID. The adoption stage of RFID is somewhat risky since it involves large investment cost and whether the investment cost can be paid off by the benefits should be carefully considered. Therefore, cost/benefit analysis should be conducted to make sure organizations can achieve benefits

compared with its initial cost and during this process relative advantage may play significant roles. Moreover, as indicated by Wang et al. (2010), the immaturity of the RFID technology, lack of common standards, and the difficulty of integrating RFID with the existing enterprise information systems and business processes make the adoption process more complicated. Therefore, complexity of innovation should also be analyzed to make sure that organization has enough financial and human capital to overcome the difficulties during implementation process. Compatibility will be another important concern since deployment of RFID may have some conflict with existing enterprise applications. If RFID cannot integrate with other applications well, there will be a risk of investment failure. Moreover, whether RFID can be compatible with existing work procedures of the organization is still a major concern when making adoption decisions. Thus compatibility has a significant positive effect on the adoption stage. Therefore, we have hypothesis 4a as follows:

Hypothesis 4a: Relative advantage, compatibility have strong positive influence on adoption of RFID technology.

Hypothesis 4b: Complexity has strong negative influence on adoption of RFID technology.

At adoption stage, organizations need to evaluate their ability to overcome resource rigidity on RFID investment. As referred in the initiation stage, organization size is a surrogate measure of its ability to provide total resources, slack resources, and technical expertise of employees. Therefore, larger firms which usually have a lot of slack resources can overcome resource rigidity much easier than smaller firms. However, adoption stage does not require firms to redesign business structure (Zhu et al. 2004) and adjust organizational structure. Thus structure inertia of large firms may not impede the adoption stage. We can conclude that organization size has a significant positive influence on the adoption stage and have hypothesis 5 as follows:

Hypothesis 5:

Organization size has strong positive influence on adoption of RFID technology.

Mimetic pressures also play significant roles on the adoption stage. Since mimetic pressures happen between competitors, when an organization begins to adopt RFID technology, competitors in the same industry with similar economic position may become aware of its adoption and also consider adopting it. Therefore, mimetic pressures also play significant positive role on the adoption stage.

Hypothesis 6a:

Mimetic pressure has strong positive influence on the adoption of RFID technology.

As in the initiation stage, coercive pressures play significant roles on the adoption stage. Just as in the case of Wal-Mart and US's department of defense which are in large bargaining powers, when they mandate their suppliers adopt RFID, suppliers would first perceive coercive pressure which call attention to the asymmetry of power and then better understand the consequences of adopting or not adopting. Usually, the dependent firm tends to comply with the powerful partners' request and be inclined to adopt RFID technology. Therefore, coercive pressure has significant positive influence on the adoption stage of RFID technology.

Hypothesis 6b:

Coercive pressure has strong positive influence on the adoption stage of RFID technology.

As illustrated in the initiation stage, normative pressure evolves either from dyadic inter-organizational channels or firm-supplier and firm-customer (Burt 1982) or through professional, trade, business, and other key organizations (Powell and DiMaggio 1991). Thus one organization's suppliers and customers' adoption of RFID will motivate the organization's adoption intention. Moreover, key institutions such as government sanctioned bodies, standard bodies, and professional and industry association could also influence organization's adoption behavior. Thus, we hypothesize that normative pressure has significant positive influence on RFID adoption stage.

Hypothesis 6c:

Normative pressure has strong positive influence on adoption of RFID technology.

RFID routinization stage

At routinization stage, RFID has already been used in the company's value chain activities. Relative advantage needs not be evaluated and therefore does not have significant influence on this stage. And through adaptation and acceptance stage during which employees are trained to use RFID, they become more skilled in using it. Thus, complexity may not influence RFID's routinization process significantly. Nevertheless, compatibility may still play significant role in this stage since this stage requires RFID be integrated to organization's daily operation and therefore it should be compatible with other IS applications

of the organization to make sure it can be integrated into the organization's daily operations. Therefore, we have following hypothesis:

Hypothesis 7:

Compatibility has stronger influence on routinization stage of RFID technology than relative advantage and complexity.

Routinization stage requires adopting firms to adapt existing IS (Barua et al. 2004), redesign business structure (Zhu et al. 2004), and adjust organizational structure (Chatterjee et al., 2002). Since at routinization stage, organizations need to integrate RFID into their other information applications as well as their working procedures, it is critical for them to overcome routine rigidity. Usually, larger organizations may embed structure inertia or have complex business processes, entrenched organizational structure, and hierarchical decision making which make it more difficult to reengineer the structure and processes. Therefore, organization size negatively influences routinization stage of RFID technology. We have hypothesis 8 as follows:

Hypothesis 8:

Organization size has strong negative influence on RFID routinization since it is difficult for larger firms to overcome routine rigidity.

After adoption of RFID technology, the uncertainty of environment and technology will be alleviated to a certain level, companies will not have to imitate other organization's routinization activities to reduce risks related with uncertainty. Moreover, different organizations possess different organization structures and information systems applications, they may encounter various problems when routinize RFID technology. Therefore, in the routinization stage of RFID, mimetic pressure may not play a stronger role compared with that on initiation and adoption stage.

According to Fichman and Kemerer (1999), to routinize complex technologies, firms need deep technical and managerial skills beyond simple awareness and adoption of the innovation. And these skills can be acquired mainly through a learning-by-using process. Therefore, normative pressure which comes from other trading partners or industry associations may not have strong influence on RFID's routinization.

As in the situation of adoption stage, powerful firms may require their dependent firms to routinize RFID technology into their daily operations process in order to make the transaction processes more efficient. In order to maintain relationships with these powerful partners, dependent firms may have to routinize RFID into their daily operations processes across various departments within the organization. Therefore, we hypothesize that coercive pressure has stronger positive influence on the routinization of RFID technology than that of mimetic and normative pressure.

Hypothesis 9:

Coercive pressure has stronger positive influence on RFID routinization than mimetic and normative pressure.

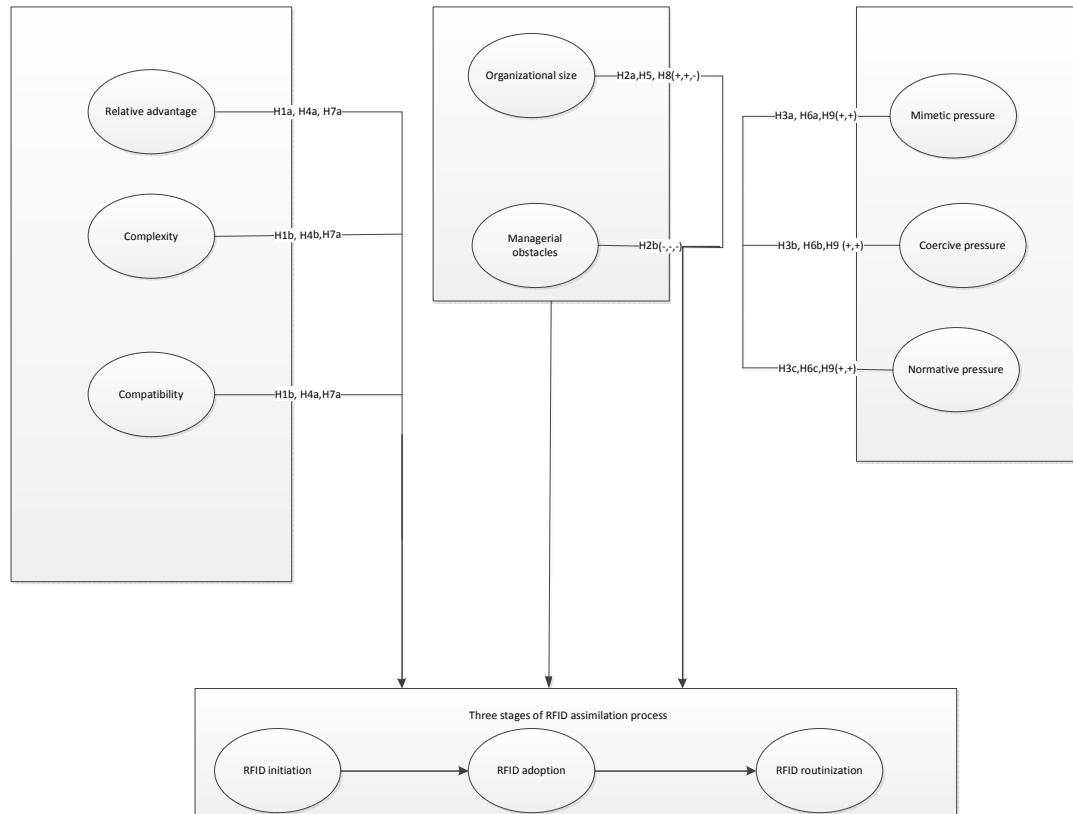


Fig.1 Different factors' impact on three assimilation stages of RFID technology

RESEARCH DESIGN

Sample design

A large-scale survey of Chinese companies which have diffused RFID technology in different stages will be conducted. The sample frame will be obtained from Chinese supply chain participants which have assimilated RFID in different phases or intend to adopt this technology. Top managers and IS-managers who are familiar with the diffusion process of RFID technology will be contacted for investigation and this can avoid response bias from a single informant. It was also suggested by previous research that senior executives are an appropriate source of information concerning IT investments and benefits. However, IS and non-IS managers tend to have different perceptions about RFID usage and benefits (Zhu and Kraemer 2005). Thus it is worthwhile to conduct a formal test to examine whether responses provided by IS managers differ from that provided by non-IS managers. Samples will be split into two subgroups: IS managers (CIO, CTO, VP of IS, and IS manager) and non-IS managers (CEO, president, COO, CFO, and other business managers) and then the Kolmogorov-Smirnov (K-S) test will be used to compare the sample distributions of the two groups (Ryans 1974). If the K-S test is non-significant, it means that the sample distribution of the two independent groups do not differ statistically (Ryans 1974).

Measures

Measurement items were developed based on a comprehensive review of the literature as well as expert opinions. To facilitate cumulative research, operationalizations tested by previous research were used as much as possible, such as those for relative advantage, complexity, compatibility, firm size, institutional pressures, etc. Other constructs were designed specifically for this study, including managerial obstacles.

Independent variables

The measuring items for relative advantage and complexity were adapted from the instrument developed by Moore and Benbasat (1991), each containing three items. Compatibility was examined from two perspectives: technical compatibility of

RFID with the existing hardware/software, and organizational compatibility with respect to the work procedures and value systems of the actual users. They were measured by one and two items respectively. Organizational size was measured by the number of employees in the organization, log-transformed to reduce data variation (Meyer and Goes 1988). According to Zhu et al. (2006), managerial obstacles were operationalized by three items: the difficulty of making organizational changes, integrating RFID into the overall strategy and business process, and acquiring expertise for RFID. Institutional pressures which include coercive pressure, mimetic pressure and normative pressures are adapted from DiMaggio and Powell's work and revised to fit our research context.

Dependent variables

- (1) **Initiation.** According to Thompson (1965) and Rogers (1995), at initiation stage, a potential adopter's major task is to gather relevant information about an innovation and evaluate its potential benefits. Therefore, RFID initiation was measured by how to evaluate the potential benefits before the firm began to adopt RFID. Similar to Zhu et al. (2006)'s measure of e-business initiation, we measure RFID's initiation using four items: cost reduction, market expansion, entering new businesses, and supply chain coordination.
- (2) **Adoption** is defined as the decision for investing RFID and physically acquiring this technology as well as preparing for redesigning operations processes;
- (3) **Routinization.** Routinization is characterized by using RFID technology in a comprehensive and integrated manner to support higher-level aspects of organizational work and widespread transfer of the technology to other system applications. It can be measured by the extent of organizational usage of RFID to support value chain activities (Chatterjee et al. 2002). Based on the work of Zhu et al. (2006) which investigated e-business routinization, RFID routinization is measured by the extent to which RFID has been incorporated into the value chain activities and information generated from it can be used in other system applications. Therefore, we self-develop this measurement based on the measure of previous literature.

CONCLUSION AND SUMMARY

More and more organizations are adopting RFID technology in their supply chain operations. Drawing on innovation diffusion theory, TOE (task-organization-environment) framework and stage-based IT diffusion model, this research empirically investigates different factors' impact on different diffusion stages. This research is innovative since most IOS research focus on one stage-adopts or non-adopts which neglect the dynamic nature of RFID assimilation. However, our research captures this nature of RFID diffusion in an organization and provides some important implications for scholars and practitioners.

For researchers, most previous innovation research discussed the technology implementation issue from a single decision view of adoption or acceptance which has often caused inconsistent findings. This study used a multi-stage diffusion approach and proposed a novel theoretical framework to explain RFID's diffusion processes within an organization. Subsequent research could be based on this foundation and investigate RFID's diffusion processes across various trading partners since it's an inter-organizational technology and only through collaborating with trading partners can its benefits be greatly achieved.

For practitioners, the relationships between different external antecedents and different diffusion stages will guide organizations to diffuse RFID technology more efficiently and effectively. They should consider different factors' impact on their assimilation process of RFID technology including the characteristics of RFID technology, their own organizational characteristics (size and managerial obstacles), and their institutional environment. Through this, they can more efficiently implement the technology and transfer successfully from one stage to another.

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