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Innovation diffusion in global contexts: determinants of post-adoption digital transformation of European companies

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Abstract
Grounded in the diffusion of innovation theory and the technology–organization–environment framework, we develop an integrative model to study the determinants of post-adoption stages of innovation diffusion, using enterprise digital transformation as an example of technology-enabled innovations. We specify four innovation characteristics (relative advantage, compatibility, costs and security concern) and four contextual factors (technology competence, organization size, competitive pressure and partner readiness) as determinants of post-adoption usage, and postulate usage as an intermediate link to impact on firm performance. We test the proposed model using a dataset of 1415 companies from six European countries. We find that the innovation needs to be used extensively in value-chain activities before its impact can be realized. Among the innovation characteristics, we find that compatibility is the strongest driver, and security concern outweighs cost as a usage inhibitor. Among the contextual variables, technology competence, partner readiness and competitive pressure significantly drive e-business usage, and the structural inertia of large firms tends to slow down its penetration. Collectively, these results indicate that innovation diffusion can be better understood by including both innovation characteristics and contextual factors, whereas earlier literature has traditionally treated the two separately. Finally, we evaluate an international dimension among European countries and tease out important boundary conditions that would not have been evident in a single-country dataset. Our results show that careful attention must be paid to the economic and regulatory factors that may result in uneven innovation diffusion even among developed European countries.
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Introduction

European companies are increasingly adopting Internet technology to transform value-chain activities. The Internet-based digital or *electronic business* (e-business) is considered as one of the most significant information technology innovations over the last decade (Geoffrion & Krishnan, 2003). As defined in Zhu *et al*. (2006a), e-business refers to conducting transactions along the value chain (including purchasing from upstream suppliers and selling products and services to downstream customers) by using the Internet platform (e.g. TCP/IP, HTTP, XML) in conjunction with the existing IT infrastructure. It is estimated that more

than 50% of European companies have adopted Internet technology in procurement by February 2005 (European Commission, 2005). Yet, e-business exhibits a significant '*post-adoption gap*' – that is, the rate of organizational use lags far behind the rate of adoption. For example, only 27% of European companies used the Internet platform for purchasing more than 5% of their total supplies (European Commission, 2005).

Anecdotal evidence suggests that not all companies have been uniformly successful in achieving deeper usage of the Internet technology; adopters also differ significantly in terms of value creation from e-business (Currie, 2004). On the one hand, exemplars of e-business success demonstrate the potential of the Internet to streamline value-chain activities. For example, companies in the tourism sector in U.K. launched the LondonEye, an e-business initiative with various partners in the area, to provide a wide range of services to tourists, so as to improve customer service and enhance revenue generation. Another example is BASF in the chemical industry, which successfully utilized the Internet platform to automate transactions and enhance coordination along the value chain (European Commission, 2004). On the other hand, companies might confront significant barriers in conducting e-business, such as a lack of technical capabilities and partner support (Chircu & Kauffman, 2000). Accordingly, they have achieved vastly different outcomes from investments in e-business (Melville *et al*., 2004). Observing the mixed evidence, scholars and practitioners call for research to investigate post-adoption variations in e-business diffusion, including the degree of usage and its impact on business performance (Zhu & Kraemer, 2005).

Motivated by these issues, this study seeks to improve our understanding on determinants of post-adoption stages in e-business diffusion. We develop a model based on a synthesis of two theoretical perspectives – the *diffusion of innovation* (DOI) theory (Rogers, 1995) that emphasizes the characteristics of an innovation and the technology–organization–environment (TOE) framework (Tornatzky & Fleischer, 1990) that emphasizes the context of an innovation. We evaluate the combined model using survey data from 1415 companies in six European countries.

The paper is organized as follows. We first present the theoretical development, including the literature, theoretical foundation and hypotheses. We then propose an integrative model for testing the hypotheses, followed by the methodology and results. The paper closes with a discussion of major findings, limitations and implications for both research and management.

DOI theory

Literature review

The classic theory of DOI attributes organizational usage of an innovation to its characteristics. The following major characteristics are proposed by Rogers (1995): (1) *relative advantage*, the degree to which an innovation can bring benefits to an organization; (2) compatibility, the degree to which an innovation is consistent with existing business processes, practices and value systems; (3) complexity, the degree to which an innovation is difficult to use; (4) observability, the degree to which the results of an innovation are visible to others; and (5) trialability, the degree to which an innovation may be experimented with. A meta-analysis by Tornatzky & Klein (1982) identified other characteristics: costs, communicability, divisibility, profitability and social approval. Among them, relative advantage, compatibility and costs were found to be the most frequently identified factors for innovation diffusion among organizations (Tornatzky & Klein, 1982).

The literature shows that the DOI theory has a solid theoretical foundation and consistent empirical support (e.g. Premkumar *et al*., 1994; Beatty *et al*., 2001; Zhu *et al*., 2006a, b). It is a useful theory for studying a variety of information systems (IS) innovations (Moore & Benbasat, 1991). While e-business may have new characteristics compared to previous generations of IT innovations, the impacts of innovation characteristics deserve attention, but have not been fully understood in the e-business context (Zhu *et al*., 2006b). In addition, as reviewed in Zhu & Kraemer (2005, p. 62), 'much of the existing research has focused on the adoption decision and on measures such as 'intent to adopt' and 'adoption versus non-adoption' (Fichman, 2000). Although this is helpful for understanding adoption decisions, we also need a better understanding of the postadoption variations in usage and value'. This motivates the present study to focus on two post-adoption stages – usage and impact.

This study employs definitions for e-business usage and impact that have been used in our previous research. *E-business usage* is defined as 'the extent to which e-business is being used to conduct value chain activities' (Zhu & Kraemer, 2005, p. 67), which include value-chain activities at both the frontend (selling) and the backend (procurement). In the IS literature, researchers used the volume of procurement under Electronic Data Interchange (EDI) to measure EDI usage (Mukhopadhyay *et al*., 1995). Our conceptualization is consistent with the literature and extends to both the frontend and the backend of technology usage, which corresponds to a major characteristic of e-business (Zhu & Kraemer, 2005). *E-business impact* refers to 'the impact of e-business use on firm performance, which is measured by three major activities along the value chain (Zhu *et al*., 2004): downstream sales (i.e., increasing sales and improving customer services), upstream procurement (i.e., reducing inventory and procurement costs and improving coordination with suppliers), and internal operations (i.e., increasing employee productivity and making internal processes more efficient)' (Zhu & Kraemer, 2005, p. 67). Relative to the binary 'adoption *vs* non-adoption' measure of innovation diffusion, a focus on usage and impact allows us to better understand the post-adoption

consequences of digital transformation through the Internet. Drawing upon the DOI theory, we next theorize the role of innovation characteristics in e-business diffusion.

Hypotheses about innovation characteristics

We consider four innovation characteristics in the e-business context: relative advantage, compatibility, costs and security concern. The first three variables are identified based on the literature (Tornatzky & Klein, 1982; Rogers, 1995); the last variable, security concern, represents a unique characteristic of e-business (Zhu *et al*., 2006b).

First, e-business supports a variety of mainstream businesses along the value chain (Straub & Watson, 2001). This is different from previous innovations within the IS department, which were used to improve the efficiency of IS functions such as payroll systems, databases and software development (Moore & Benbasat, 1991). In this regard, e-business is also different from EDI, which supports batch exchange of structured procurement documents (Iacovou *et al*., 1995). In contrast, e-business supports customer personalization, improves after-sale services and enables real-time, two-way information exchange (Barua *et al*., 2004). Compared to EDI that mainly improves operational efficiencies, e-business has the potential to show both strategic benefits (increased sales) and operational benefits (reduced costs). Both should be considered when the relative advantage of e-business is evaluated. Hence, we define relative advantage of e-business as its potential to help increase sales and reduce costs.

Relative advantage has been widely identified as a significant factor driving organizational usage of IT innovations, particularly in the EDI literature (Premkumar *et al*., 1994; Iacovou *et al*., 1995). The global reach and interactive nature of the Internet enables companies to expand their market internationally and reduce transaction and coordination cost (Currie, 2004). The e-business literature documents empirical evidence to support the potential of e-business to improve business performance, including revenue generation (Barua *et al*., 2004) and costs reduction (Garicano & Kaplan, 2001). These potential benefits provide incentives for companies to use e-business (Rogers, 1995). Hence,

H1: *Relative advantage will positively influence e-business usage.*

Second, the innovation literature suggests costs as an inhibitor of technology use (Tornatzky & Klein, 1982). The IS literature also provides such evidence to open systems (Chau & Tam, 1997) and EDI (Premkumar *et al*., 1997). In our research setting, *costs* refer to expenses of implementing necessary technologies for on-line transactions and efforts devoted to organizational restructuring and process re-engineering. This conceptualization draws upon the e-business literature as reviewed next.

E-business requires investments in necessary Internet technologies, as well as other supporting software, hardware and employee training (Chircu & Kauffman, 2000). It also requires companies to accomplish a significant task – connecting technology pieces (including separate modules, packages, databases and systems) to form an integrated technology base (Zhu & Kraemer, 2005). Additionally, efforts on organizational restructuring and business process reengineering, which typically occur with e-business usage (Zhu *et al*., 2006a), will further add to the costs of using e-business. These costs would significantly inhibit e-business usage by organizations. Based on this, we propose costs as a barrier to e-business usage.

H2: *Costs will negatively influence e-business usage.*

Third, in the innovation literature (Cooper & Zmud, 1990), compatibility has been shown to be an important factor to explain innovation usage by organizations. Consistent with Rogers' conceptualization (1995), *compatibility* is defined as the degree to which e-business is compatible with a company's business processes, distribution channel, corporate culture and value system. In e-business diffusion, not all companies deem e-business compatible. The reason has been discussed in our earlier research on e-business diffusion: 'E-business requires firms to transform traditional systems heavily dependent on physical processes to those that rely on digital assets and information flow … making organizational changes on structures and coordination mechanisms … mutually adapting e-business and existing strategy and processes … and acquiring new expertise necessary to use the innovation' (Zhu *et al*., 2006a, p. 1563). Consequently, lack of compatibility may result in organizational resistance, which might retard e-business usage (Premkumar *et al*., 1994). On the other hand, if conducting transactions over the Internet is compatible with existing processes and systems, companies would incur lower efforts to deal with incompatibility and thus are more capable of using e-business (Chatterjee *et al*., 2002). Therefore,

H3: *Compatibility will positively influence e-business usage.*

Lastly, e-business has a unique feature – *security concern*, defined as the degree to which the Internet platform is deemed insecure for exchanging data and conducting on-line transactions. Although few studies have examined it, security concern deserves special attention in the context of e-business. First, Internet technologies are based on open standards. Accordingly, companies conducting Internet-based e-business generally have less control over data standards and access compared to previous legacy systems, such as EDI that is based on private networks (value-added networks) and uses less open data standards (Zhu & Kraemer, 2005). Thus, companies and their

customers would have greater concerns about unauthorized access to data, which would jeopardize information security and privacy (Stewart & Segars, 2002). Second, e-business is integrated in transactions along the value chain, and thus involves fund transfer and exchange of core corporate data (Zhu *et al*., 2006a). This makes security issues particularly significant (Jones *et al*., 2000). Third, e-business is still new, relative to other mature technologies, such as EDI that has been used for two decades. In general, e-business users face a less mature institutional framework regarding contracts, financial transactions and privacy protection (Kraemer *et al*., 2006). Because of the above issues, e-business users would be particularly concerned about security.

Security concern may retard e-business diffusion, because if parties involved in on-line transactions have severe concerns about privacy and fraud on the Internet, they will be reluctant to participate in on-line transactions (Malhotra *et al*., 2004; Zhu *et al*., 2006a). In addition, if the Internet does not serve as a secure platform for exchanging corporate data, potential adopters would perceive a high risk of exposing important corporate information, such as data about product design, key technology, customer accounts, payments and invoices (Stewart & Segars, 2002). The risk would retard e-business usage among organizations (Jones *et al*., 2000).

H4: *Security concern will negatively influence e-business usage.*

The above discussion helps us identify the innovation characteristics that influence e-business usage among organizations. Rogers' (1995) innovation diffusion theory, however, was initially developed to address the diffusion of mass-produced items among individuals in a population. Hence, the DOI theory needs to be enriched if the research focus is on complex technological innovations by organizations. Additional variables representing specific contexts where the new technology is actually used should be incorporated (Swanson, 1994). In diffusion research, 'innovation adoption decisions must be studied within appropriate contexts and with variables tailored to the specificity of the innovation' (Chau & Tam, 1997, p. 3). Along this line, Zhu *et al*. (2006b) investigated how innovation characteristics and contextual variables may interact and differentiate e-business adopters from non-adopters. This research proposes an integrative framework to examine how the two categories together influence post-adoption stages of e-business diffusion. To identify specific contextual variables, we draw upon the TOE framework, which is discussed next.

The TOE framework

Literature review

The specific contexts in which e-business is used are worthy of investigation, because the same technology may be used differently in different environments. The TOE framework serves as an important theoretical perspective for studying contextual factors (Tornatzky & Fleischer, 1990). The TOE framework identifies three aspects that may influence organizational usage of a technological innovation: (1) technological context describes the existing technologies in use and relevant technical skills available in the organization; (2) organizational context refers to internal measures of the organization such as its size; and (3) environmental context is the external arena in which a company conducts its business – its industry, competitors and trading partners (Tornatzky & Fleischer, 1990).

The TOE framework, as described above, has been used in our prior studies on e-business (Zhu *et al*., 2003, 2004, 2006a, b). More broadly, the TOE framework has been tested for a variety of information technologies in the literature (see Zhu *et al*. (2003) for literature review). For example, Iacovou *et al*. (1995) developed a model formulating technological, organizational and environmental variables as major factors affecting EDI usage. Chau & Tam (1997) applied the TOE framework to study open systems. As summarized in Zhu *et al*. (2003), the existing literature demonstrated the usefulness of the TOE framework for understanding the diffusion of a complex IS innovation. Further, the literature suggested that, 'one future line of research is to extend the proposed [TOE] framework to other innovation domains' (Chau & Tam, 1997, p. 17).

We integrate the TOE framework in our theoretical development, because incorporating TOE contexts helps strengthen what has been generally neglected in the DOI theory – specific technological and organizational circumstances of a potential adopter and its industry (Chau & Tam, 1997). There is empirical evidence that 'e-business is enabled by technological development of the Internet, driven by organizational factors such as firm scope and size, and influenced by environmental factors related to customers, business partners, as well as competitors' (Zhu *et al*., 2003, p. 253). Hence, it is important to synthesize the TOE framework with the DOI theory.

Hypotheses based on the TOE framework

Within the technological context, *technology competence* captures an organization's internal technology resources. A meta-analysis (Kwon & Zmud, 1987) asserted the importance of technology competence for IS usage and impact. Mata *et al*. (1995) further suggested that technology competence consists of technology infrastructure and IT skills. Based on this, we conceptualize this factor as including two dimensions – IT infrastructure and Internet skills. This conceptualization also follows our cumulative body of research on technology competence (Zhu *et al*., 2003; Zhu and Kraemer 2005). *IT infrastructure* refers to installed network technologies, which form a technology foundation for developing e-business applications; *Internet skills* refer to employees' skills of using

Internet-related technologies. These two dimensions are complementary to each other, and jointly enable more effective usage of Internet technologies in value-chain activities (Zhu *et al*., 2003). Therefore,

H5: *Technology competence will positively influence e-business usage.*

Organizational factors provide a set of structures that may constrain or facilitate e-business usage (Tornatzky & Fleischer, 1990; Fletcher & Wright, 1997). *Organization size* (or firm size) is one of the most commonly studied organizational factors in the innovation literature (see Damanpour (1992) for a meta-analysis). Since size represents several important aspects of an organization such as slack resources, organizational structure and decision-making flexibility, it is a critical organizational factor to influence IT usage (Rogers, 1995). In the IT literature, several studies found a significant relationship between firm size and IT adoption (Fichman, 2000). Yet, different opinions exist regarding the role that size plays, mainly due to a tension between resource availability and structural inertia (Damanpour, 1992). On the one hand, large organizations generally possess slack resources, which have been argued as an important facilitator in innovation diffusion, especially at the adoption stage (Rogers, 1995). On the other hand, our earlier work has proposed a different perspective regarding the role of size in the post-adoptive diffusion of e-business (Zhu and Kraemer, 2005, p. 69): 'size is often associated with inertia; that is, large firms tend to be less agile and less flexible than small firms. The possible structural inertia associated with large firms may slow down organizational usage [of e-business]'. In contrast, small organizations 'require less communication, less coordination, and less influence to gather support' (Nord & Tucker, 1987, p. 18), in making organizational changes associated with e-business usage. Hence,

H6: *Organization size will negatively influence e-business usage.*

Within the environmental context, major players in the external environment can be classified into two groups: horizontal competitors and vertical trading partners (Teo *et al*., 2003). These are represented by two variables, competitive pressure and partner readiness, respectively. These two variables may play a role, because e-business enables a company to compete in broader market segments and trade with a wider partner base (Porter, 2001). Teo *et al*. (2003) found that a company's intention to use electronic fund transfer increased as the technology diffused among horizontal competitors and vertical trading partners, which provided support to the importance of these two variables.

Competitive pressure refers to peer pressure on using a new technology (Gatignon & Robertson, 1989). In this research, it is defined as the percentage of competitors in the industry that have already used e-business. Competitive pressure has long been recognized as a driving force for new technology usage; it tends to press companies to seek competitive edge by using new innovations (Gatignon & Robertson, 1989). Porter & Millar (1985) analyzed the strategic rationale underlying the relationship between competition and technology innovations. Their analysis has served as the theoretical foundation in IS adoption research (Thong, 1999; Zhu *et al*., 2003). 'By adopting IS, firms might be able to alter the rules of competition, affect the industry structure, and leverage new ways to outperform rivals, thus changing the competitive environment' (Zhu *et al*., 2003, p. 256). In the e-business domain, companies can leverage Internet-based innovations to improve their responsiveness to market changes and enhance customer services. 'As documented in the existing literature, the use of e-business may induce changes of industry structure through disintermediation and reintermediation' (Zhu & Kraemer, 2005, p. 70). Empirical research also suggests that e-business may help increase operational efficiencies and improve coordination with suppliers (Barua *et al*., 2004). All of these effects are critical for companies to maintain their competitive positions (Currie, 2004). Hence,

H7: *Competitive pressure will positively influence e-business usage.*

Based on the literature, we define *partner readiness* as the degree to which trading partners, up and down the value chain, have the systems in place to conduct transactions on the Internet platform (Barua *et al*., 2004). Conducting on-line transactions requires all trading partners to install compatible electronic systems (Premkumar *et al*., 1997); then, they can provide Internet-enabled services for each other. Therefore, a company's use of e-business may be influenced by the readiness of partners in the trading community (Zhu *et al*., 2003). As suggested by empirical evidence, the success of e-business depends on trading partners' readiness to collectively use the internet to digitize value chain activities (Barua *et al*., 2004). In a trading community with greater partner readiness, individual adopters are better positioned to pursue higher levels of e-business usage due to network effects (Shapiro & Varian, 1999). Thus we expect:

H8: *Partner readiness will positively influence e-business usage.*

Within the environmental context of the TOE framework, the national economic environments may shape e-business diffusion. In a more general setting of management science research, Rosenzweig (1994) has challenged the conceptual equivalence across economic environments in theory testing. In the same light, IS researchers argued that testing models of IT usage and impact across national boundaries might result in new insights (Zhu &

Kraemer, 2005; Zhu *et al*., 2006a; Shih *et al*., 2007). This motivates the current research to examine e-business diffusion in national contexts, i.e., across European countries.

European countries differ in the level of economic development and the degree of IT penetration (OECD, 2001). They also seem to be at different stages of e-business transformation (European Commission, 2004). Theoretically, these differences may lead to differential patterns of e-business usage (Zhu & Kraemer, 2005). Empirically, most of the existing research studied e-business in a single-country setting; an increasing number of case studies are seen in the literature while relatively few large-sample cross-country studies are presented. This calls for statistically rigorous evidence about the differences of e-business usage among European companies.

'At the general level, technology diffusion studies have found that diffusion occurs unevenly across countries with different environments. Moreover, the extent of diffusion depends on a variety of economic, social, and political factors' (Zhu & Kraemer, 2005, p. 71). Looking specifically at IT usage, national wealth has been identified as an important factor accounting for differences across countries (Pohjola, 2001). At the organization level, inadequacy of the basic IT infrastructure and scarcity of technical and financial resources may significantly impede new technology usage (Dasgupta *et al*., 1999). Factors regarding culture and politics may also influence IT diffusion, such as the rule of law, political openness and property rights protection (Kraemer *et al*., 2006). Therefore, the same determinants of e-business usage may show differential effects across countries with different economic environments.

H9: *The strength of the determinants of e-business usage will differ across national environments.*

Linkage from usage to impact

Having hypothesized the role of innovation characteristics and contextual factors, we now proceed to investigate the relationship between post-adoption stages in e-business diffusion: usage and impact. The diffusion theory contends that the impact of a new technology depends on the extent to which the technology is used in key value-chain activities. It is through the ingrained use that the new technology can improve business performance (Cooper & Zmud, 1990). Soh & Markus (1995) conceptually proposed the process-oriented view to examine the use and value of information technologies, which was extended and implemented by Zhu *et al*. (2006b). According to this view, merely examining the initial adoption might not reveal variations in IT value, because IT creates business value in sequential stages (Zhu & Kraemer, 2005). This perspective also emphasizes the need to investigate the key post-adoption activity – value creation through usage, rather than simply adoption and penetration (Soh & Markus, 1995). Despite its theoretical importance, usage has been understudied in empirical research as pointed out by Zhu & Kraemer (2005). This motivates us to analyze the linkage from usage to impact.

In the e-business context, 'although the Internet is a generic platform for e-business, firms create specific resources by integrating their systems and databases internally in the backend and with their trading partners and customers…. The greater the flexibility and adaptability of the platform created, the greater the asset specificity and the greater the value. Thus, higher degrees of e-business usage will be associated with improved firm performance' (Zhu & Kraemer, 2005, p. 70). Before e-business is widely used in value-chain activities, it would be unlikely to attain significant performance improvements in upstream, internal and downstream operations. This argument is consistent with empirical findings of the importance of usage in different contexts such as EDI (Mukhopadhyay *et al*., 1995) and decision support systems (Devaraj & Kohli, 2003). This study extends the linkage from usage to impact to e-business.

H10: *Greater e-business usage will lead to greater impact on business performance.*

An integrative model

We synthesize the above discussion and propose an integrative model as shown in Figure 1. We specify two sets of factors – e-business innovation characteristics (H1–H4: relative advantage, compatibility, costs and security concern) and TOE contextual factors (H5–H8: technology competence, organization size, competitive pressure and partner readiness) – as determinants of e-business usage. We will evaluate the effects of these factors across countries (H9). As discussed above, we also posit a linkage from e-business usage to e-business impact (H10). In addition to these theoretical variables, control variables need to be incorporated to better explain cross-sectional variations in e-business diffusion. Our data set includes a number of industries and countries. Hence, we need to control for industry and country effects. Following the literature (Chatterjee *et al*., 2002, Zhu *et al*., 2003), we incorporate industry dummies and country dummies as control variables.

Research methodology

Data

To evaluate the theoretical relationships proposed above, we used survey data from the SIBIS database created by Empirica, a research institution based in Bonn, Germany. The questionnaire was designed by an expert panel comprising senior researchers of Empirica, and was further refined through several rounds of pretests, revisions and pilot-tests. The survey was executed via computer-aided telephone interviews in March–May

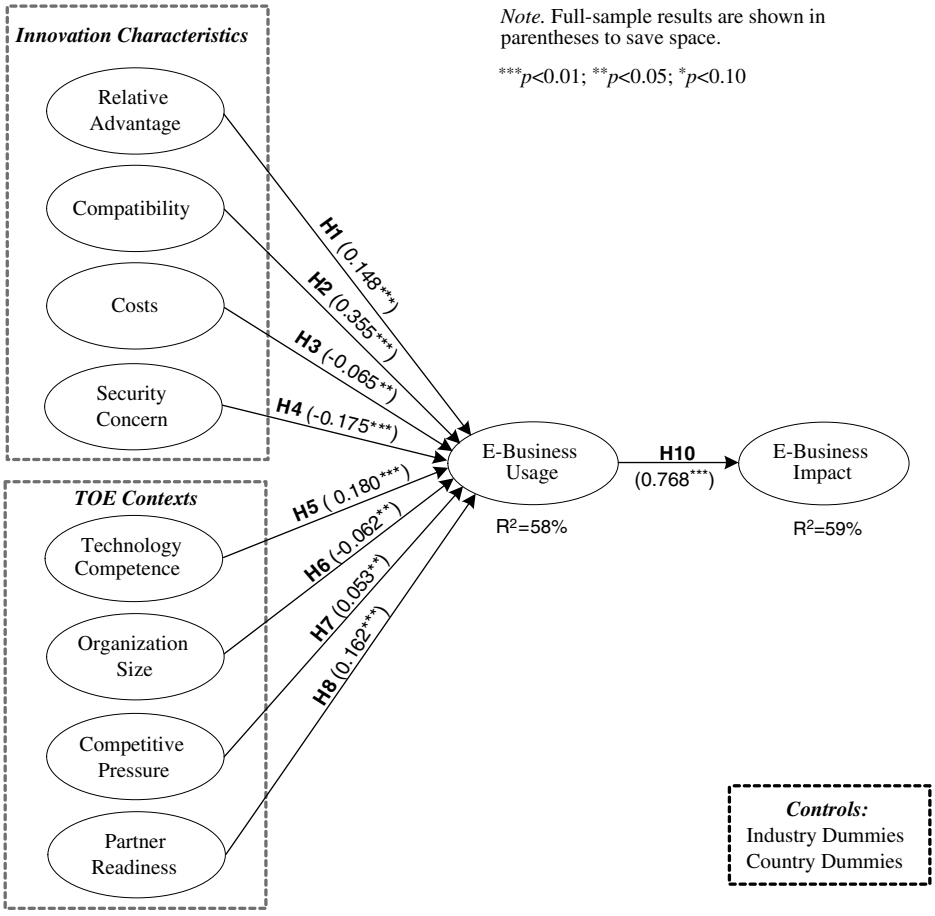

Figure 1 An integrative model. *Note*: Full-sample results are shown in parentheses to save space ***$P<0.01$; **$P<0.05$; *$P<0.10$.

Table 1 Sample characteristics ($N=1415$)

	Obs.	*%*		*Obs.*	*%*
Country			*Industry*		
Finland	185	13.1	Manufacturing	350	24.7
France	164	11.6	Construction	76	5.4
Germany	350	24.7	Retail/wholesale distribution	181	12.8
Italy	195	13.8	Hotels, restaurants	83	5.9
Spain	217	15.3	Transport, communication	110	7.8
UK	304	21.5	Banking, insurance	69	4.9
Respondent's position			Business services	205	14.5
CIO/Head of IS department	574	40.6	Public administration and social work	241	17.0
Other senior IS managers	446	31.5	Other personal or social services	100	7.1
Owner/Director/Board member	285	20.2			
Other senior business managers	110	7.8			

2002. The survey was conducted in six European countries (Finland, France, Germany, Italy, Spain and U.K.) and in industry sectors covering manufacturing, retail/wholesale distribution and service sectors. In each country, the sampling was stratified by industry and firm size, with sites selected randomly within each size – industry cell to minimize bias. Respondents were managers at each site responsible for or significantly involved in decisions regarding IT, mainly including the CIO, Head of the IS department or senior IS managers.

The final data set contains 1415 valid data points. Table 1 shows the sample characteristics. We examined non-response bias and found no statistically significant differences in terms of revenue and organization size, and we found no apparent bias across the countries. We also examined the so-called 'common method bias' as

potentially occurring in survey data. The result of Harman's single-factor test (Podsakoff *et al*., 2003) suggested that there was no significant common method bias in our data set.

Measures

We developed the measurement items based on a comprehensive review of the literature as well as expert opinion. In order to reinforce construct validity and facilitate cumulative research, we employed operationalizations that had been tested in previous studies to the extent possible (such as technology competence, size, and competitive pressure). The definitions for all measurement items are listed in the Appendix.

To assess constructs with multiple items, we conducted confirmatory factor analysis using partial least squares (PLS). For *formative constructs*, the weights of all measurement items are significant ($P<0.01$) and above the suggested cutoff value of 0.30 (Chin, 1998). For reflective constructs, we examined construct reliability, convergent validity and discriminant validity. According to standard textbook definitions, *construct reliability* measures the degree to which items are free from random error and therefore yield consistent results. As shown in Table 2, all constructs have a composite reliability above the cutoff value of 0.70 (Chin, 1998). *Convergent validity* assesses the consistency across multiple operationalizations. Table 2 shows that all standardized path loadings are significant ($P<0.01$) and have acceptable magnitude, suggesting good convergent validity (Chin, 1998). *Discriminant validity* evaluates the extent to which different constructs diverge from one another. We used Fornell and Larcker's (1981) criteria: the square root of AVE should be greater than the inter-construct correlations. Our measurement model meets this criterion.

We modeled *e-business impact* as a second-order construct, capturing three related dimensions – impact on upstream coordination, internal operations and downstream sales, as first proposed in Zhu *et al*. (2004) and used in Zhu and Kraemer (2005). Representing a theoretically strong basis for capturing complex measures, this second-order approach views the three dimensions in a collective and mutually reinforcing manner (Zhu and Kraemer, 2005). Accordingly, e-business impact is operationalized to be an integrative measure of Internet-enhanced business performance. As shown in Figure 2, the paths from e-business impact to the first-order dimensions are significant and greater than the suggested cutoff of 0.7 (Chin, 1998). Thus, the conceptualization of e-business impact as a higher-order, multi-dimensional construct seems justified.

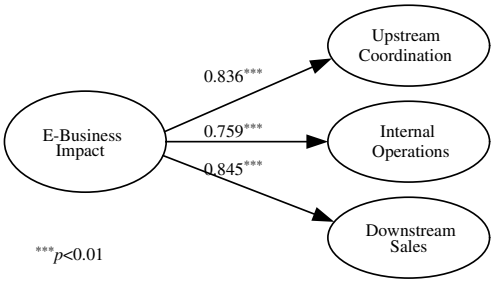

Figure 2 E-business impact: second-order construct (adapted from Zhu & Kraemer, 2005).

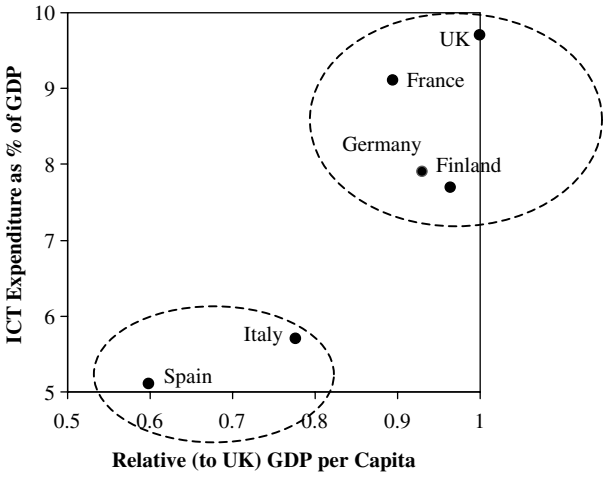

Figure 3 Scatter plot between ICT expenditure and GDP per capita. Data sources: Worldbank (2001) and OECD (2001).

Table 2 Construct reliability and convergent validity

	Range of standardized path loadings	*Convergent validity (P-value)*	*Composite reliability*	*Average variance extracted*
Relative advantage	0.712–0.855	All < 0.01	0.763	0.619
Compatibility	0.678–0.820	All < 0.01	0.844	0.574
Costs	0.878–0.893	All < 0.01	0.879	0.784
Security concern	0.684–0.862	All < 0.01	0.752	0.605
Competitive pressure	0.690–0.879	All < 0.01	0.801	0.576
e-Business usage	0.673–0.841	All < 0.01	0.855	0.598
Upstream coordination	0.789–0.907	All < 0.01	0.893	0.737
Internal operations	0.766–0.884	All < 0.01	0.812	0.684
Downstream sales	0.707–0.911	All < 0.01	0.886	0.664

Table 3 Summary statistics

	Full sample		*High ICT-intensity*		*Low ICT-intensity*		*ANOVA*
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*t-stat*
Relative advantage	3.65	0.66	3.85	0.63	3.16	0.74	3.05***
Compatibility	3.40	0.87	3.48	0.85	3.21	0.92	1.43
Costs	3.15	0.90	3.04	0.88	3.43	0.95	−2.39**
Security concern	3.53	0.71	3.41	0.69	3.82	0.76	−2.52**
Technology competence	3.10	0.79	3.26	0.75	2.71	0.87	2.63***
Organization size	236	497	249	514	204	453	0.85
Competitive pressure	28.6	13.2	28.8	12.9	28.1	13.8	0.12
Partner readiness	3.69	0.78	3.77	0.77	3.48	0.82	1.47
E-Business usage	5.58	7.76	6.13	8.19	4.25	7.41	2.33**
Upstream coordination	3.68	0.75	3.87	0.72	3.18	0.83	1.91*
Internal operations	3.72	0.63	3.91	0.61	3.23	0.69	2.03**
Downstream sales	3.63	0.55	3.77	0.53	3.26	0.58	1.72*

***$P<0.01$; **$P<0.05$; *$P<0.10$.

Summary statistics across countries

We used two indices to assess the economic environment across countries: (1) national expenditure on information and communication technologies (ICT), as a percentage of GDP and (2) GDP per capita (Figure 3). This approach has been used in previous studies (Zhu & Kraemer, 2005). These two indices capture country-level intensity of ICT investment and national wealth, which may influence new technology diffusion among organizations (Caselli & Coleman, 2001; Shih *et al*., 2007). We find that the two indices are highly correlated ($r=0.88$, $P<0.01$). A non-hierarchical cluster analysis classified the six countries into two groups. France, Finland, Germany and U.K. are in the first group; Italy and Spain are in the second group (Figure 3). One-way analysis of variance (ANOVA) shows that the first group has significantly higher ICT expenditure and GDP per capita ($P<0.05$) than the second group. Thus, we label the first group as 'high ICT-intensity subsample' ($N=1003$) and the second group as 'low ICT-intensity subsample' ($N=412$).

Summary statistics across countries are provided in Table 3. The high ICT-intensity subsample reports significantly greater e-business usage and impact, as well as higher levels of technology competence and relative advantage; while the low ICT-intensity subsample reports higher levels of concerns on costs and security.

Results

Analysis of the full sample

We first estimated the structural model on the full sample using PLS. The results are inserted in Figure 1 to save space. The R^2 of e-business usage is 58%, suggesting substantive data variation explained by the independent variables. Among e-business innovation characteristics, relative advantage ($P<0.01$) and compatibility ($P<0.01$) have a significant and positive path to e-business usage; costs ($P<0.05$) and security concern ($P<0.01$) have a significant but negative path to e-business usage. Among the TOE factors, technology competence ($P<0.01$), competitive pressure ($P<0.05$) and partner readiness ($P<0.01$) have a significant and positive path to e-business usage with technology competence being the strongest; organization size ($P<0.05$) has a significant and negative path to e-business usage. In addition, e-business usage has a positive and significant path to impact ($P<0.01$), which has a high R^2 of 59%.

These results suggest that relative advantage and compatibility significantly drive e-business usage while costs and security concerns significantly inhibit e-business usage. Within the TOE factors, technology competence, partner readiness and competitive pressure significantly drive e-business usage while large size retards e-business usage. As suggested by the path magnitude, *compatibility* turns out to be a stronger driver than relative advantage. In fact, it is the strongest factor among all innovation characteristics and contextual factors in our model. Security concern is a more significant inhibitor than costs. Finally, the significant linkage from usage to impact indicates the critical role of usage in the path leading to performance improvements through e-business.

Cross-country comparison

We then estimated the structural model on the high ICT and low ICT subsamples, respectively. The results are shown in Figure 4. On both subsamples, all e-business innovation characteristics and TOE factors have significant paths to e-business usage, which is significantly linked to its impact on business performance. These relationships are robust and consistent with the full sample results in Figure 1.

We tested their differences by comparing each path across the two subsamples. We used *t*-test to examine the statistical significance of the differences (Keil *et al*., 2000). Relative advantage, costs, security concern and competitive pressure have significantly different paths

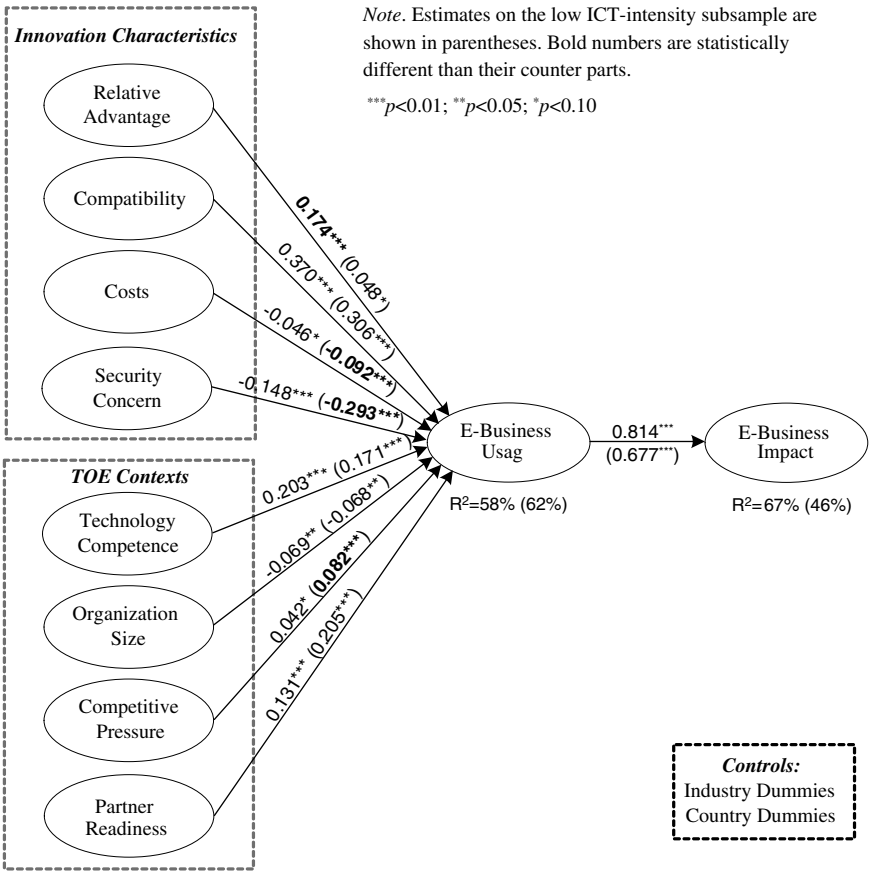

Figure 4 Empirical results of the cross-country comparison. *Notes*: Estimates on the low ICT-intensity subsample are shown in parentheses. Bold numbers are statistically different than their counterparts. ***$P<0.01$; **$P<0.05$; *$P<0.10$.

($P<0.01$). Relative advantage has a significantly greater effect on e-business usage in the high ICT-intensity countries, while costs, security concern and competitive pressure have a significantly greater effect in the low ICT-intensity countries. These results indicate *differential effects* of innovation characteristics and TOE factors on e-business usage, contingent on different economic environments. This supports our theoretical proposition that economic environments shape e-business diffusion and usage.

Discussion

An integrative perspective

This research integrates two theoretical perspectives to build an integrative framework. It draws upon the DOI theory and the TOE framework. This is different from most of the studies in the literature that focused on either innovation characteristics or contextual factors, but not on both. Using e-business as an example of more general technology innovations, our study fills a theoretical gap by developing this integrative model and evaluating it via a large international data set. Showing significant effects of both innovation characteristics and contextual factors, the integrative model represents a theoretical advancement to synthesize different perspectives in the innovation diffusion literature.

Our results also reveal several new insights regarding specific factors influencing e-business diffusion. First, *compatibility* turns out to be the strongest factor driving e-business usage. Prior to e-business, inter-firm value chain activities mainly relied on the integration of physical processes, and business-to-business transactions were conducted based on paper/phone/fax-based communications. Leveraging the Internet platform, e-business transforms the traditional approaches to those that rely on digital assets and information flow. Hence, compatibility between e-business and existing selling/procurement processes and distribution channels is critical for driving e-business usage. Our results indicate that, among characteristics identified by the DOI theory, compatibility outweighs other factors. This sheds new light on the transformational nature of e-business.

Second, *security concern* appears to be a more significant inhibitor of e-business usage than costs. This is new to the innovation literature, as few studies in the literature examined security concerns while most studies showed a significant negative role of costs in IT adoption (e.g. Chau

& Tam, 1997; Premkumar *et al*., 1997). This finding complements country-level observations that the lack of security and legal framework retarded e-business diffusion (Kraemer *et al*., 2006). Further, this finding offers an implication for innovation research: one needs to investigate innovation characteristics tailored to the specificity of an innovation. This can help build cumulative knowledge upon the classical innovation theory.

Third, the negative effect of *organization size* on e-business usage is an extension to the innovation literature. While it has been commonly believed that large organizations have more slack resources for committing investments for new technology adoption (Rogers, 1995), our result seems to suggest that large organizations might be burdened by structural inertia in *using* the technology. In general, large organizations have more fragmented legacy IS built over years. This may result in the phenomenon of 'islands of automation'. When using the newer Internet technologies to reconfigure existing systems and applications, large organizations may confront difficulties due to inconsistencies of legacy systems. As a result, the corporate-wide digitization may be more difficult for large organizations. This could explain our empirical result. That is, the *structural inertia* tends to retard the digital transformation associated with e-business usage.

Post-adoption linkage: from usage to impact

With a focus on the *post-adoption linkage* from usage to impact, this work moves beyond the 'adoption *vs* non-adoption' dichotomous measure, which has been frequently used in the diffusion literature. Our work highlights usage as a critical stage leading to performance impact of e-business. This significant linkage seems to suggest economies of scope and scale in e-business diffusion. When e-business is used across a wider scope of value-chain activities and in a substantial proportion for each of them, the fixed investments in e-business can be spread over more business activities, thus increasing cost-effectiveness. Further, as diversified business activities are migrated over the Internet-enabled, open-standard platform, companies are more likely to connect various systems to support a variety of value-chain activities. This increases the degree of process automation and reduces coordination costs along the value chain. In addition, with a greater proportion of each business activity conducted on the Internet platform, the economies of specialization may lead to improved skills for managing e-business. By showing the significant role of usage, which seems to be a 'missing link' in the literature, our analysis joins Zhu & Kraemer (2005) to call for further investigation into the post-adoption stages in innovation diffusion.

An international dimension

Finally, this work evaluates an *international dimension* among European countries. Using data collected in six countries, this work has teased out important boundary conditions that would not have been evident in a single-country data set. As evident in the results, careful attention must be paid to the economic and regulatory factors that may result in uneven innovation diffusion across countries. A recent cross-country study showed differential importance of TOE factors in driving e-business usage by organizations in developed *vs* developing countries (Zhu & Kraemer, 2005). The results here show that differential effects exist even among developed countries in Europe.

In general, the leading countries in the use of ICT have a more supportive national environment for the diffusion of new technologies. Accordingly, companies in these countries are more likely to derive payoff from using new technologies. Further, companies in these countries generally have more experience of using IT, and therefore, they would be more aware of and pay more attention to the benefits of using e-business. These effects together make companies in countries with high ICT-intensity more informed in learning, implementing and exploring IT and e-business to achieve greater returns of investment. Hence, the relative advantage of e-business plays a more significant role in driving e-business usage in these countries. In contrast, companies in countries with low ICT-intensity generally possess fewer complementary assets, such as the necessary infrastructure and knowledge base to support effective use of e-business. Consequently, they are lagging behind in realizing the relative advantage of e-business. Their use of e-business is more likely to be driven by competitive pressure, with an incentive to avoid falling behind in the technology curve. Therefore, competitive pressure is more significant for firms operating in these countries. Further, in using e-business, companies in these countries would have greater concerns on related costs, mainly because of lower levels of technical and financial resource endowment. Moreover, the low ICT-intensity countries, in general, have a relatively less mature institutional framework to protect on-line transactions and facilitate e-business usage. As a result, companies in these countries may be more concerned about security issues.

Limitations and future research

The key limitations of this study are as follows. First, the measures for impact on business performance are based on survey responses from managers. Such measures may be subject to potential biases. It would be desirable to use alternative measures of performance impact to cross-validate our findings. For example, accounting indices such as operational cost, inventory turnover and profit margin could be used to measure financial performance. Market share and stock market performance could be used to examine competitive performance. A second limitation is that our study adopts a cross-sectional design. As a result, we can only test associations between constructs and not their causal relationships. Third, other than the innovation characteristics and contextual factors included in this study, there could still be other

factors influencing e-business diffusion. Lastly, our use of industry dummy variables may not fully control for industry effects. Specific industry characteristics could also influence e-business usage and impact.

These limitations suggest avenues for further research. Future studies could use alternative measures of impact on business performance, such as accounting indices and stock market performance to validate our findings from survey measures. Also, managers need to adapt e-business applications as the enabling technologies advance and the business environments change. A longitudinal study may provide further insights into the dynamics of e-business usage and impact. In addition, future studies could examine other factors affecting e-business diffusion such as specific industry characteristics.

This study offers implications for IS researchers. First, we have shown the usefulness of the DOI theory in conjunction with the TOE framework for identifying factors that affect e-business usage. This framework could be used to study other technological innovations. More importantly, future research can extend what we have shown in this work by analyzing the interaction between innovation characteristics and contextual variables. For instance, the same innovation characteristics like relative advantage and costs may show differential effects, contingent on the contexts of diffusion. Such contingency effects would be an interesting area to focus on in further research. Second, we have found that usage is an important link to e-business value. At a more fundamental level, this result has an important implication for the renewed debate on 'IT value paradox' (Carr, 2003). Information technology must be extensively used in value-chain activities before it can produce any significant impact. Therefore, failure to achieve deeper usage beyond initial adoption might be one of the reasons for insignificant performance impacts of IT. Technology usage stands out to be an intermediary stage that companies need to undergo before they can succeed in the next stage where IT business value is realized. Systematic tests of this proposition may help explain the mixed evidence on IT impacts. Third, grounded in theory and data, we have categorized innovation characteristics and contextual factors, and analyzed their relative significance for e-business usage and impact. The result could serve as a theoretical base for studying further sources of value creation from technology innovations.

Managerial implications

Our study has implications for managers as well. To start with, managers can draw upon our integrative framework to assess conditions for e-business usage and value creation. This framework includes a series of important characteristics describing the nature of e-business innovation, which may be useful for managers to evaluate e-business initiatives in terms of relative advantage, compatibility, costs and security concerns. This framework also covers technological, organizational and environmental conditions. Managers of e-business need to take these contextual factors into consideration.

Among the innovation characteristics, our results highlight the critical role of compatibility with existing processes, channels and corporate culture. To better leverage technology advances – global connectivity and real-time information exchange – companies must also have a compatible organizational system. This is particularly critical when managers face institutional resistance to changes, which, for example, may occur in the case of channel conflict. This also reminds e-business vendors to put more effort into assisting companies to adjust their processes and structures for using e-business technologies. Toward this end, vendors need to offer tailored services and training programs for companies with unique managerial resources and corporate culture. In addition, costs and security issues suggest that e-business managers need to allocate resources to build electronic connections with their trading partners in a more economic and secure way. Then companies can leverage the open Internet standards and the connectivity of the network platform to increase sales and reduce costs.

Within the contextual factors, we have found that e-business usage is influenced by the readiness of trading partners. This highlights the networking nature of e-business. It is more of a value-chain phenomenon involving a cluster of value chain partners, rather than an individual company's effort to digitize its own stage in the value chain. Our results also suggest that companies pay attention to their existing technology competence, and keep in mind that this competence includes both physical infrastructure and intangible skills. As Internet technologies diffuse and the access to them becomes easier in markets, technical and managerial skills will act as more significant determinants of e-business success. This urges top managers to foster managerial skills and human resources that possess knowledge of e-business.

Managers also need to keep in mind the importance of promoting e-business usage in a wider scope of value-chain activities and to a greater degree for each activity. By using the Internet to support customer-facing activities, companies can obtain richer information about markets, increase responsiveness to demand changes, reach new customers and improve customer relationships. By using the Internet to support supplier-facing activities, companies can improve information flow and strengthen on-line integration with business partners. These effects help enhance revenue generation and reduce coordination costs.

Finally, our results point to an important role for public policy to promote e-business usage. Security is a major concern affecting e-business usage. Issues related to security include both privacy protection for corporate and individual data and financial protection for on-line transactions. Without strong privacy legislation and security protection against credit card fraud, on-line transactions will diffuse slowly (Kraemer *et al.*, 2006). Governments can encourage e-business usage by provid-

ing such protection in legislation and public policies. This will increase consumers' willingness to engage in online purchasing, which in turn will increase organizational willingness to use e-business. There is also an opportunity for both e-business vendors and industry associations to promote e-business usage by working with governments to establish the institutional framework appropriate for each country.

Conclusions

This work investigates the Internet-enabled enterprise digital transformation. Using Internet technology as an example of more general technological innovations, we develop an integrative model to study determinants of innovation diffusion at the post-adoption stages. More broadly, this study falls into our cumulative stream of research on innovation diffusion. The results in this paper provide new insights and contribute to the innovation diffusion literature in three ways.

First, this research demonstrates the usefulness of combining the DOI theory and the TOE framework for understanding innovation diffusion. To the best of our knowledge, most of the research in the extant literature focused on either the DOI theory or the TOE framework, but not on both. Our earlier research showed the usefulness of the TOE framework (e.g. Zhu *et al*., 2003, 2004; Zhu & Kraemer, 2005). This current work demonstrates the combined explanatory power of the two perspectives.

Second, focusing on the post-adoption stages, this study is different than the literature that mainly analyzed diffusion using the 'adoption *vs* non-adoption' measure. Although useful for understanding adoption decisions (Zhu *et al*., 2003; 2006a), the dichotomous measure cannot inform post-adoptive variability. This calls for research on the stage of performance impacts (Zhu *et al*., 2004) and the linkage from usage to impacts (as first proposed by Zhu & Kraemer, 2005). Seeking to further our understanding on the post-adoption stages, this work proposes a more comprehensive framework that features innovation characteristics and contextual variables as determinants in the two post-adoption stages. This research shows its usefulness, and thus suggests that it can be applied to study other technological innovations.

Third, this paper builds on our earlier work and extends the international dimension of innovation diffusion. Unlike the literature that mainly focused on single countries, we seek to analyze innovation diffusion in an international setting (Zhu *et al*., 2006a, b). Toward that end, our studies in this stream are based on data collected in different countries and at different periods of time (e.g. Zhu *et al*., 2003, 2004; Zhu & Kraemer, 2005). In particular, European countries that lag behind in ICT diffusion were left out in Zhu & Kraemer (2005) and Zhu *et al*. (2004). This current paper fills in this gap and demonstrates the differential effects in European countries with high and low ICT-intensity, which provide new insights beyond the literature as well as our earlier studies. Some of our ongoing work continues to explore these issues more deeply (2006b). We hope more researchers will join the efforts to investigate this area so as to collectively build a cumulative body of knowledge.

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Appendix
Measurement items

Constructs		*Measures*
Relative advantage	RA1	The degree to which your company expected e-business to help increase sales
	RA2	The degree to which your company expected e-business to help reduce costs
Compatibility	CO1	Selling over the Internet is compatible with your company's current selling process
	CO2	Buying over the Internet is compatible with your company's current procurement process
	CO3	Conducting transactions over the Internet is compatible with existing distribution channels
	CO4	Doing e-business is compatible with your company's corporate culture and value system
Costs	CT1	Costs of implementing Internet-based online sales (including hardware, software, training, organizational restructuring, business process reengineering)
	CT2	Costs of implementing Internet-based online procurement (including hardware, software, training, organizational restructuring, business process reengineering)
Security concern	SC1	The degree to which your company is concerned about the security of data and transactions over the Internet
	SC2	The degree to which your customers are concerned about the security of data and privacy over the Internet
Technology competence	TC1	IT infrastructure: the strength of existing IT infrastructure, as measured by related technologies that your company has in place, including electronic data interchange (EDI), intranet, extranet, local area network (LAN), wide area network (WAN)
	TC2	Internet skills: The extent to which the majority of your employees are capable of using the following applications: Web browser, intranet, online order processing

Appendix (Continued)

Constructs		*Measures*
	TC3	Skill development – Has your company done the following to help employees develop e-business skills: (a) in-house training? (b) participating in IT training such as courses and seminars by third parties? (c) legitimizing certain work time for IT learning/training? (d) establishing self-learning or e-learning programs? (e) recruiting staff with special IT skills?
Organization size	FS	Number of employees (log transformed)
Competitive Pressure	CP1	Percentage of competitors in your industry that have conducted Internet-based selling
	CP2	Percentage of competitors in your industry that have conducted Internet-based procurement and coordination
	CP3	Percentage of competitors in your industry that have conducted Internet-based services
Partner readiness	PR1	The extent to which downstream customers have e-business systems ready to support Internet-based selling
	PR2	The extent to which upstream partners have e-business systems ready to support Internet-based procurement
	PR3	The extent to which e-business systems owned by trading partners are interoperable with yours
E-Business usage	EU1	Percentage of sales to businesses conducted online
	EU2	Percentage of sales to consumers conducted online
	EU3	Percentage of customer services conducted online
	EU4	Percentage of procurement conducted online
Impact on upstream coordination	UO1	Coordination with suppliers improved
	UO2	Procurement costs decreased
	UO3	Inventory costs decreased
Impact on internal operations	IO1	Internal processes more efficient
	IO2	Employee productivity increased
	IO3	Operational costs decreased
Impact on down-stream sales	DO1	Sales increased
	DO2	Sales area widened
	DO3	Customer service improved

Note: All items are based on 5-point Likert scale except those noted otherwise.