Migration to Open-Standard Interorganizational Systems: Network Effects, Switching Costs, and Path Dependency

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Abstract

The phenomenon of interest in this study is organizational migration across interorganizational systems (IOS) that are built on standards with relatively different degrees of openness. As firms increasingly seek to improve inter-firm coordination through the use of network technologies, open standards are becoming increasingly important. To better understand the process of standards diffusion, this study investigates the migration to open-standard IOS (i.e., the Internet) from relatively less open IOS (i.e., electronic data interchange or EDI). Viewing the decision to adopt open-standard IOS in terms of its benefits and costs, we develop a model of open-standard IOS adoption that features network effects, expected benefits, and adoption costs as prominent antecedents. We test this model and associated hypotheses using structural equation modeling on a large international dataset of 1,394 firms. The empirical results demonstrate that network effects are a significant driver of migration to open-standard IOS. We also find a differential effect of adoption costs between those firms that were migrating from EDI (significantly negative) and those firms that were not (no effect). While this finding may sound counter-intuitive, it illustrates the subtle role of *path dependency* in standards migration. Experience with older standards may keep the firm "trapped" and make it difficult to shift to open and potentially better standards. Our work also teases out finer-grained relationships such as the positive impact of trading community influence on the strength of network effects, and the importance of managerial complexity as a key determinant of adoption costs. Relative to the literature, this work focuses on an open-standard network with broader impacts on a firm's value chain activities (compared to EDI networks), and examines a wider scope of partner efforts involved in establishing network effects (compared to automated teller machine networks). Overall we believe that this study, based on a rigorous empirical analysis of a large international dataset, provides valuable insights into how network effects influence standards diffusion.

Keywords

Open Standards, Standards Adoption, Network Effects, Path Dependency, Interorganizational Systems, Internet, Electronic Data Interchange, Economics of Standards

1. Introduction

An increasing number of firms are looking to collaborate with their partners by deploying interorganizational systems (IOS) to exchange information and conduct transactions (Shapiro and Varian 1999a; Hacki and Lighton 2001). With the dramatic reduction of costs in communications and the associated development of open standards, firms are migrating toward networked organizational forms such as value networks that hold the promise of substantial productivity gains (Greenspan 2002). While standards have consistently played an important role in the adoption and diffusion of information technology (IT), the current scale of IT use and the widespread availability of network access has increased the potential payoffs to companies from these networked partnerships, focusing renewed attention on the importance of open standards.

It has been widely noted that technological innovations, especially standards innovations, are a primary driver of industrial productivity, but if promising standards cannot be widely adopted, the benefits resulting from their invention will be curtailed (Fichman and Kemerer 1997). To fully realize the value of new standards, the diffusion and adoption of standards among firms is a critical step beyond standards development (Rogers 1995). Firms that adopt successful new standards can seize significant competitive edge (Katz and Shapiro 1994; Johnston and Vitale 1988), while firms that are "trapped" in an old standard or lag in utilizing new standards may lose competitive advantage (Shapiro and Varian 1999b). Thus, understanding standards adoption by firms stands out as an important research topic (Lyytinen and Rose 2003). In-depth study on this topic may help broaden our understanding about the entire process of standards making (David and Greenstein 1990).

Electronic data interchange (EDI)[1] systems have been adopted in a variety of industries since the 1970s (Iacovou et al. 1995; Riggins et al. 1994). More recently, the Internet, facilitated by the development of open standards such as the Transmission Control Protocol/Internet Protocol (TCP/IP) and eXtensible Markup Language (XML), has quickly become a popular platform for inter-firm coordination (Shapiro and Varian 1999a). Internet-based systems, which are open-standard IOS, are widely regarded as one of the most significant IOS innovations (Chatterjee et al. 2002). In this study, *open-standard IOS* refers to the kind of interorganizational system that uses open standards (e.g., XML-based data standards and TCP/IP as the communication protocol) and is built upon a public, open network (i.e., the Internet). According to a recent survey (Varian et al. 2002), open-standard IOS diffuse much faster among firms

[1] Electronic Data Interchange (EDI), is the interorganizational, computer-to-computer exchange of business documentation in a standard, machine-processable format. In general, EDI standards include the data standard (format of messages) and the communication protocol. EDI typically transmits data over private networks or value-added networks (VAN) (Emmelhainz 1993).

than EDI did, and is becoming the dominant network for business-to-business transactions. Figure 1 shows such a trajectory of IOS migration from proprietary standards to open standards.

[Insert Figure 1 about Here]

Along this trajectory, the migration from paper-based manual systems to paperless EDI has been studied extensively in the literature (e.g., Iacovou et al. 1995; Mukhopadhyay 1995; Ramamurthy et al. 1999; Teo et al. 2003). In contrast, the migration to open-standard IOS remains an under-studied area (Kauffman and Walden 2001). Given the open-standard nature of the Internet, potential adopters comprise a much broader trading community. Thus, the key characteristics of networks, namely *network effects*, should theoretically play a more significant role (Shapiro and Varian 1999a). Yet this has not been tested empirically in the literature.[2] Further, consistent with the notion of *path dependency* (Arthur 1989; Cohen and Levinthal 1990), a firm's prior experience with EDI might influence its adoption of new open-standard IOS. For example, prior use of EDI may facilitate a move to open-standard IOS because of a company's experience with technology-enabled inter-firm collaboration, or it might inhibit such a move because of the limited flexibility of existing EDI systems (Swanson 1994). However, empirical research that addresses path dependency is rare in the information systems (IS) standards literature. In our literature review, we found no empirical studies that incorporated different migration pathways, and thus we know very little about how the pattern of open-standard IOS adoption varies between firms with and without EDI experience.

Seeking to fill this gap, our research examines the migration from EDI systems to Internet-based IOS. Since the Internet, compared to pre-Internet technologies, is characterized by its open standards, public network and broad trading community (Shapiro and Varian 1999a), network effects are expected to be greater than those in the earlier generations of IOS (Brynjolfsson and Kahin 2000). Therefore, we draw upon network effect theory (Katz and Shapiro 1986; Shapiro and Varian 1999b) to study IOS migration (Figure 1). Key research questions that motivate our work are: What factors facilitate or inhibit firms' migration to open-standard IOS? To what extent is this migration influenced by network effects and adoption costs? How does prior EDI experience affect the adoption of open-standard IOS?

To better understand these issues, we develop a conceptual model grounded in the network effect theory in conjunction with a path dependency perspective. We derive a set of hypotheses from the model. To test the hypotheses, we analyze a large and unique dataset of 1,394 firms from 10 countries using structural

[2] Gurbaxani (1990) has shown empirically the impact of network effects on the adoption of BITNET, an open-standard precursor to the Internet.

equation modeling. The paper is organized as follows. We first describe the phenomenon of interest – the trajectory of IOS migration. Then, we present our theoretical perspectives, develop our conceptual model and derive corresponding hypotheses. This is followed by a description of the methodology and the results of our empirical analysis. The paper closes with discussions of findings, limitations, and implications for research and practice.

2. The Trajectory of IOS Migration

2.1. From Proprietary Standards to Open Standards

The phenomenon of interest in this study is organizational migration across interorganizational systems that are built on standards with relatively different degrees of openness. We start with defining key concepts. A standard is "a set of technical specifications adhered to by a producer, either tacitly or as a result of a formal agreement" (David and Greenstein 1990). Drawing upon this definition, we define IOS standards as a set of technical specifications that are agreed upon and used by IOS developers to describe data formats about products and services, which enable computer-to-computer communications. IOS standards differ with respect to the process of standards development and the scope of availability (David and Greenstein 1990). If a standard is developed and then available only to a closed set of firms that require a private communication platform and translation software[3], it is considered to be a *proprietary standard*. In contrast, if a standard is developed by or in an open community that uses public communication platforms and software, it is considered an *open standard* (David and Greenstein 1990). As defined earlier in the Introduction, *open-standard IOS* refers to the kind of interorganizational system that uses open standards (e.g. TCP/IP as the communication protocol, and XML or ebXML as data standards), and is built upon the open Internet for information exchange and business-to-business transactions such as sales, procurement, and customer services. Based on this definition, open-standard IOS differs from earlier proprietary IOS such as ASAP[4] and systems such as EDI that are relatively less open.

According to the literature (Johnston and Vitale 1988), a typical IOS consists of three parts: *content platform*, *delivery platform*, and *trading partner base*. These three parts characterize the relative openness

[3] The closed set of firms may be those who are members of the standard developer's community by virtue of purchase of equipment that operates with the standard, purchase of software based on the standard, or payment of a license fee. In other words, ownership of the standard belongs to the developer and hence it is proprietary. As will be discussed later, automated teller machine (ATM) networks and ASAP systems are examples of proprietary systems.

[4] The first Analytical Systems Automated Purchasing (ASAP) system was developed by the American Hospital Supply Corporation (AHSC) in 1960s. In 1985, AHSC was purchased by Baxter Travenol, which continued to enhance ASAP and launched several generations of ASAP systems. What this study discusses is the early ASAP platform characterized as a dedicated system with proprietary protocols (Venkatraman and Short 1992).

of an IOS. Using this three-part framework, we next analyze the relative openness of three generations of IOS: proprietary systems like ASAP, EDI, and Internet-based IOS. The purpose of adopting an IOS is to implement computerized communications with trading partners. Toward this end, an IOS adopter needs to have a *content platform* in place – computerized systems that translate private corporate data into a standardized data format recognizable by the IOS. Then, the standardized data are transported via a *delivery platform* – physical networks or "pipe" used for data transmission. Finally, the data are delivered to targeted trading partners in the trading partner base. The parts of proprietary IOS (ASAP), somewhat open IOS (EDI), and open-standard IOS (Internet-based) are illustrated in Figure 2.

[Insert Figure 2 about Here]

Shown in the left column of Figure 2, the ASAP system developed by the American Hospital Supply Corporation (AHSC) for the healthcare industry is a widely-cited proprietary IOS (Venkatraman and Short 1992). ASAP allowed a hospital to order its supplies by using its own computers that were linked to AHSC's mainframes via a telephone network. AHSC had ultimate control over data standards, participation, and access to information, and also held complete responsibility for planning, developing, maintaining, and managing ASAP (Johnston and Vitale 1988). Thus, the content platform in ASAP was built upon proprietary standards and included highly customized systems for communicating with AHSC only (Venkatraman and Short 1992). As a typical proprietary IOS, ASAP was designed to lock-in its adopters, resulting in a dedicated relationship between hospitals and their "Prime Vendor" - AHSC (Venkatraman and Short 1992).[5]

EDI, as shown in the middle column of Figure 2, differs from ASAP primarily in terms of its data standards and communication protocol. ANSI X12 published by American National Standard Institute (ANSI) and EDIFACT published by the United Nations Center for Administration Commerce and Transport (UNCACT), two of the most widely used EDI data standards, have been adopted in different industries. They were developed by open consortia, and thus were considered as open standards (David and Greenstein 1990). The use of open data standards lowers the asset specificity of EDI compared to the case of ASAP, since the content platform supports communications with a number of firms in the trading partner base. As to the delivery platform, EDI typically uses privately owned value-added network (VAN). Each EDI adopter subscribes a VAN mailbox, exchanging EDI messages via the mailbox with other VAN subscribers.

[5] We thank an anonymous referee for suggesting this proprietary standard as a comparison to EDI and Internet IOS.

An Internet-based open-standard IOS is shown in the right column of Figure 2. The defining feature of open-standard IOS is the use of XML—the *de facto* standard for generating markup languages over the Internet—to form the content platform. Based on XML, the World Wide Web Consortium (W3C) has released the Simple Object Access Protocol (SOAP), which is currently supported by the majority of the computer industry for Web services messaging. W3C has also released Web Service Description Language (WSDL) for describing attributes of products and services. Having been widely accepted across a variety of industries, SOAP and WSDL, among other XML-based standards, have promoted open-standard information exchange (Shapiro and Varian 1999a). Further, the delivery platform is the Internet, a public network with global connectivity based on open TCP/IP communication protocol. Thus, Internet-based IOS are characterized by openness of both the content and the delivery platforms. It is a new generation of IOS that is considered more open than EDI (Choudhury, Hartzel and Konsynski 1998).

In summary, as shown in Figure 2, ASAP, EDI, and the Internet-based IOS represent three generations in IOS standards evolution. As we introduced earlier, this study seeks to examine the migration from EDI to Internet-based IOS. Next we further discuss similarities and differences between these two generations of IOS.

2.2. A Comparison of EDI and Internet-based IOS

Although the data standards used in both EDI and Internet-based IOS are considered to be open standards, they differ in terms of the degree of openness, complexity, and partner-specific customization. An Internet-based IOS is more open than EDI, given the private VAN and more specific systems used in EDI (Ricker et al. 2002). Relative to EDI standards, XML-based standards are more likely to facilitate cross-industry coordination than EDI (Phillips and Meeker 2000). Also, EDI messages are based in rigid, complex structures to maximize information exchange efficiency, given the high communication costs at the time these standards were developed. Consequently, EDI standards have a complex, hard-to-learn format. Thus, the use of EDI requires special technical skills. In contrast, XML-based standards are self describing with a flexible, easy-to-learn format (Ricker et al. 2002). Consequently, as implementing EDI with new partners requires detailed technical negotiation based on these rigid and complex standards, EDI users often confront high degrees of partner-specific customization (Subramani 2004). In contrast, the newer Internet-based IOS require less customization, a key feature of open-standard systems (Chau and Tam 1997). These comparisons are summarized in Table 1.

[Insert Table 1 about Here]

Another major distinction between EDI and Internet-based IOS is their delivery platform and communication protocols: private value-added networks (VANs) vs. the TCP/IP-based public Internet. Different VANs often support different communication protocols. Some VANs charge additional fees for inter-network connection, and not all of the networks interconnect to every other network (Emmelhainz 1993). Thus, the lack of interoperability is a concern for EDI users. In contrast, the Internet, as a network of interconnected networks, uses the TCP/IP open standard and a unified network addressing scheme (Mendelson 1999). These features lead to global interoperability of disparate networks that make up the Internet. The difference in communication costs is remarkable (Ricker et al. 2002). In contrast to the low costs of Internet-based communication, the high per-message costs of VAN make EDI less suitable for small- and medium-sized enterprises (Iacovou et al. 1995).

Mainly because of the high degree of complexity and customization, the trading partner base of EDI is relatively narrow and typically limited to large firms. In contrast, Internet-based IOS generally has a broader trading partner base (Phillips and Meeker 2000). Particularly, certain XML-based standards, for example Universal Description Discovery and Integration Registry (UDDI) released by the Organization of the Advancement of Structured Information Standards (OASIS), enable indexing and searching *unknown* buyers and suppliers. This is very different from EDI where electronic connections are established only with *existing* partners. With potential to expand to the whole market and connect previously separated suppliers and buyers, Internet-based IOS facilitate the formation of a broad trading community with strong *network effects* (Bakos 1998).

3. Theoretical Perspectives

Having discussed IOS migration involving standards with different degrees of openness, we proceed to theoretical considerations for open-standard IOS adoption. We draw upon the economic perspective which views the adoption decision in terms of benefits and costs. In order to develop our model, we describe specific characteristics of open-standard IOS that influence the benefits and costs of adoption and use. First and foremost, we need to consider network effects which represent a key feature of IOS based on open standards (Shapiro and Varian 1999a). Then, the notion of path dependency (Cohen and Levinthal 1990) motivates us to study how prior EDI experience would affect the adoption of open-standard IOS. These theoretical issues, which will be incorporated in our conceptual model, are discussed in turn below.

3.1. Network Effects

The above discussion on open-standard IOS suggests that network effect theory (Katz and Shapiro 1985, 1994; Shapiro and Varian 1999a, 1999b) is an appropriate starting point to build our theoretical base. Network effect theory posits that the benefits adopters can derive from a network technology are positively associated with the size of the network (Katz and Shapiro 1986). According to this literature, there are both direct and indirect network effects. An example of *direct* network effects is the positive impact of the number of IOS adopters on the benefits that an individual adopter can achieve from information sharing over the IOS. An example of *indirect* network effects is the increase in compatible software and hardware solutions as the standard diffuses. The concept of network effects has been utilized by a number of analytical models in the IS literature (e.g., Riggins et al. 1994; Wang and Seidmann 1995). While these studies show that network effects theory helps improve our understanding about IOS adoption, the literature falls short of empirical testing of the theory (Brynjolfsson and Kemerer 1996; Gurbaxani 1990), especially in the context of Internet-based open standards (Kauffman et al. 2000).

In the limited empirical literature, a few studies on the banking industry have examined organizational characteristics and market conditions that affect the diffusion of automated teller machine (ATM) networks. For example, Hannan and McDowell (1984) used data on ATM adoption by banks to examine factors affecting adoption decisions. They found that larger banks and banks operating in more concentrated local markets were more likely to adopt ATM. Saloner and Shepard (1995) argued that the benefits of adopting a particular ATM network would be positively influenced by the number of locations and the number of users it serves, which is consistent with the results of Banker and Kauffman (1988). Extending this stream of research by incorporating the concept of shared networks, Kauffman et al. (2000) found support for the network externality hypothesis. That is, banks that can generate a larger shared network size tend to adopt ATM early. These studies demonstrated the usefulness of network effect theory for analyzing technology adoption.

However, an ATM network is different from open-standard IOS. Historically, a bank's efforts to develop its ATM network was self-contained, in that it was based on a network built by the bank itself and used by its own customers.[6] In this regard, ATM networks were akin to EDI systems which were typically implemented by a single large buyer (supplier) that required its key suppliers (buyers) to participate in its EDI network (Mukhopadhyay and Kekre 2002). In contrast, to establish open-standard IOS, all trading

[6] This was the case for early ATM networks, but they have now become more interoperable as interfaces between the networks are developed and common standards are developed. It is still true, however, that there are differences in the openness of the various networks.

partners must adopt compatible systems and provide Internet-based services for each other. Developing open-standard IOS requires joint efforts across firm boundaries, and the benefits of adopting open-standard IOS are thus contingent on the status of network adoption by other firms in the trading community (Zhu et al. 2003). Therefore, new variables reflecting the adoption status in a wide range of suppliers and business partners are needed to address the nature of open-standard IOS. Correspondingly, the scope of network effects is likely to be quite different.

3.2. Path Dependency

Path dependency in technology change (Cohen and Levinthal 1990; Arthur 1989) is another theoretical perspective relevant to the migration across different generations of IOS. From this perspective, a firm's ability and incentive to adopt newer technology are largely a function of its level of related experience with prior technologies (Cohen and Levinthal 1990). We apply this notion to the migration to open-standard IOS. Based on the literature, we conceptually propose the following path-dependent effects in the migration from EDI to Internet-based IOS.

First, it is likely that, when implementing and using a previous generation of IOS (i.e., EDI), firms have fostered skills for IOS implementation, and developed a deeper understanding about the economic and organizational impacts of IOS (Lyytinen and Robey 1999). Acquired primarily through learning-by-doing (Attewell 1992), such skills and knowledge are critical for successful adoption of new technology standards (Cohen and Levinthal 1990; Fichman and Kemerer 1997). Applying this perspective to our research setting, we expect two-fold effects. On the one hand, having developed technical and managerial skills for IOS implementation, firms with EDI experience may incur a lower level of *adoption costs*, i.e., the direct costs related to adopting Internet-based IOS such as hardware and software implementation. On the other hand, EDI users, with previous IOS experience, tend to have a better understanding of true costs, including the difficulty of process change. Consequently, the adoption behaviors of EDI users, compared to firms without EDI experience (i.e., non-users), will be based on a more balanced consideration of costs for newer standards.

Second, the existing literature on technology standards suggests that firms may be "trapped" in an old standard even though a newer, superior standard is available (Farrell and Saloner 1985). In the IOS context, EDI adoption requires substantial investments in hardware, software, and training (Iacovou et al. 1995; Emmelhainz 1993) and its implementation requires firms to develop special technical skills to cope with its complexity (Subramani 2004). Furthermore, EDI is generally used for long-term, dedicated inter-firm linkages (Mukhopadhyay and Kekre 2002). Together, these factors, including EDI-specific

investments and skills, as well as dedicated relationships, may translate into *switching costs*, which in turn might inhibit organizational migration to newer standards (Klemperer 1987; Beggs and Klemperer 1992). Switching costs are different from the adoption costs that we discussed above, in the sense that both EDI users and non-users have adoption costs for Internet-based IOS, but only EDI users confront the additional switching costs. The existence of switching costs will make EDI users more sensitive to adoption costs. This effect will be further discussed in hypothesis development.

Third, as suggested by prior research on IOS, strategic considerations arising from the deployment of *relationship-specific assets* play an important role in creating benefits from IOS adoption (Bakos and Brynjolfsson 1993). For instance, using data from 131 suppliers in a retailer's supply chain system, Subramani (2004) found that suppliers' relationship-specific investments played a significant mediating role linking EDI usage and EDI benefits. This finding implies that specialized assets can also be strategic assets. Christiaanse and Venkatraman (2002) found that the degree of electronic integration between travel agencies and American Airlines could be significantly explained by American Airlines' use of their relationship-specific, expertise exploitation system, SMARTS. According to this stream of research, relationship-specific assets might be a strategic component of path dependency, as suppliers may view proprietary IOS as being more conducive to the creation of relationship-specific investments in bilateral relationships (and thus enhance their benefits) than open standards.[7]

4. The Conceptual Model and Hypotheses

4.1. The Conceptual Model

Based on the above theoretical discussion, we develop a conceptual model for open-standard IOS adoption as shown in Figure 3. Consistent with our research purpose of studying the migration to open standards, we specify the *extent of open-standard IOS adoption* as the dependent variable. Drawing upon the economic perspective that views network adoption primarily in terms of benefits and costs (Kauffman et al. 2000), we specify *expected benefits* and *adoption costs* as two key independent variables to explain open-standard IOS adoption. Further, the theoretical discussion above leads us to believe that the expected benefits from open-standard IOS are strongly associated with network effects (Katz and Shapiro 1985; Shapiro and Varian 1999a), and have also been empirically identified as a significant factor to explain technology diffusion (Brynjolfsson and Kemerer 1996; Kauffman et al. 2000). Therefore, *network effects* are posited as another independent variable that can lead to IOS adoption directly and indirectly

[7] We thank an anonymous reviewer and the associate editor for pointing this out. A consideration of relationship-specific assets enhances the comprehensiveness of the argument, but, due to data limitations, we are unable to include this factor in our empirical analysis.

via expected benefits. Finally, because we want to understand path dependency in IOS migration (Cohen and Levinthal 1990), we specify *prior use of EDI* as a moderating variable that may influence the adoption pattern of Internet IOS. Within one unified model, the three independent variables and the moderating variable allow us to test network effects and path dependency in the migration from EDI to open-standard IOS. These variables are discussed in detail below.

[Insert Figure 3 about Here]

The Dependent Variable: Open-Standard IOS Adoption

In order to reflect the extent of open-standard IOS adoption, the dependent variable is conceptualized to include three inter-related dimensions: breadth, volume, and depth (Massetti and Zmud 1996). *Breadth* refers to the number of value chain activities for which a firm has adopted open-standard IOS (Porter 1985; Zhu et al. 2003); *Volume* refers to the extent (percentage) to which each of the major value chain activities has been conducted on the open-standard IOS (Chatterjee et al. 2002); *Depth* refers to the extent to which distinct information systems are integrated by the open Internet standards so that information can flow smoothly between back office systems within the company and between these systems with suppliers (Zhu and Kraemer 2002). The literature provides support for our conceptualization. Based on a comprehensive literature review, Massetti and Zmud (1996) proposed measuring EDI adoption by several distinct facets including breadth, volume, and depth, and they tested the usefulness of these dimensions via case research. Other studies on IOS adoption have demonstrated the usefulness of this conceptualization as well (e.g., Ramamurthy et al. 1999; Chatterjee et al. 2002). Based on the literature, we believe that these three dimensions should not be considered in isolation. Rather, they should be viewed as mutually reinforcing elements of network applications along the value chain. Thus, the three dimensions jointly provide a coherent and comprehensive representation for open-standard IOS adoption (Massetti and Zmud 1996).

The Independent Variables

The three independent variables represent benefits and costs of adopting open-standard IOS. Next, we define these variables, identify their sub-dimensions, and explain why we have selected them.

(1) Network Effects:

In the presence of *positive* network externality (Katz and Shapiro 1985), the value of an open-standard IOS increases with its size, and thus as a network grows in size, firms will use it more. Therefore, we propose network effects as a driver for the adoption of open-standard IOS (as represented by the top-left

box in Figure 3). Further, we also look into factors that contribute to network effects. In doing so, it is reasonable to consider how the size of open-standard IOS might be enlarged.

In general, the size of an open-standard IOS network grows as two types of firms join it—vertical partners in the upstream and downstream of the supply chain (trading community) and horizontal peers at the same level of the supply chain (Teo et al. 2003). Thus, open-standard network effects will increase as more trading partners and peers support and adopt the open-standard IOS. However, the impact of these two types of growth in network size is likely to be quite different. In the case of vertical partners, the network effects are likely to be immediate, while in the case of peer adoption, the effects occur later and stem from industry-wide diffusion. We define *trading community influence* as the extent to which a firm's customers, suppliers, and other vertical partners in the trading community are willing to use or support the open-standard IOS. We define *peer adoption* as the extent of open-standard IOS diffusion among horizontal peers in the same industry. These two variables, based on the above theoretical considerations, are then specified as forming a second-order construct, *network effects*, so as to represent the construct at a higher level. This specification is consistent with the categorization of network effects in the literature. That is, network effects comprise direct network effects and indirect network effects (Farrell and Saloner 1985; Katz and Shapiro 1985). Since trading community influence and peer adoption correspond to direct and indirect network effects respectively, this specification captures at least two of the major aspects of network effects.

(2) Expected Benefits:

We consider a firm's expected benefits as an important decision factor to explain open-standard IOS adoption, which is motivated by innovation diffusion theory (Rogers 1995). *Expected benefits* refer to the operational benefits a firm expects from adopting open-standard IOS. Drawing upon the IOS literature, we further conceptualize expected benefits as including cost reduction, market expansion, and value chain coordination (Iacovou et al. 1995). First, the Internet has been widely accepted as a technology for efficient information processing, which would help firms improve operational efficiency and reduce transaction costs, search costs, and other direct and indirect costs (Garicano and Kaplan 2001). Second, firms using EDI were only capable of exchanging information with known partners with established business relationships. Yet, by using open standards, firms are now able to search and connect to unknown firms that also support open standards (Phillips and Meeker 2000). Hence, the use of open-standard IOS would help the firm to expand into new markets and reach new customers (Lederer et al. 2001). Third, the open-standard Internet would make it easier for suppliers and partners to exchange data on inventory, delivery, and production schedules, thus improving value chain coordination.

Our specification is consistent with the network effect literature. Expected benefits, by our definition, are beyond the stand-alone benefits of a technology, since benefits derived via value chain coordination, market expansion, and cost reduction will be greater as network effects increase (Iacovou et al. 1995; Mukhopadhyay and Kekre 2002). We therefore expect strong associations among network effects, expected benefits, and open-standard IOS adoption. These relationships have been proposed or implied by theoretical research on network externality (Farrell and Saloner 1985, 1986), though they have not been tested empirically (Kauffman et al. 2000). Especially, few studies have explicitly tested how network effects would influence expected benefits, as most existing studies have proposed the direct linkage between network effects and adoption without measuring expected benefits. To better test the network effects theory, it is important to incorporate the three variables in one unified model. Our proposed model, as shown in Figure 3, fills this gap by including both the direct effect (network effects→open-standard IOS adoption) and the mediated effect (network effects→expected benefits→open-standard IOS adoption).

(3) Adoption Costs:

In addition to factors on the value side that drive open-standard IOS adoption (i.e., network effects and expected benefits), we must also consider variables on the cost side that may hinder open-standard IOS adoption. To identify specific cost variables, we start with *financial costs*, defined as required financial investments in implementing and using the open-standard Internet IOS (e.g., hardware and software for Internet access). Financial costs have been commonly cited as a factor in technology adoption (Iacovou et al. 1995; Ramamurthy et al. 1999). Second, we posit *managerial complexity*, defined as the level of difficulty and attendant risk associated with making process change and the organizational adjustments to accommodate the new open-standard IOS. Such changes must be led by the organization's managers (Chatterjee et al. 2002) and involve the risk that the changes will be more difficult than expected and exceed the available managerial and staff capabilities. As skills needed for smooth organizational and process changes are fostered mainly through a learning-by-doing process (Attewell 1992), it takes time and effort to handle the managerial complexities in open-standard IOS adoption. The complexity adds significant implementation risk that would raise the overall expected costs of adoption (Chau and Tam 1997). Thus, in addition to the monetary costs, the difficulty and attendant risk of the change management process are considered as a significant component of adoption costs. Third, we incorporate *transactional risk*, defined as risk and security concerns about transactions conducted over the Internet platform. In contrast to EDI that has been used and tested over several decades, the open-standard nature of the Internet IOS and its status of being a relatively new business platform bring unique issues about data

security and online transactions with parties that may have no prior relationship. These factors may entail additional costs to the use of Internet-based IOS (Sato et al. 2001). Finally, we consider *legal barriers*, defined as the lack of institutional frameworks and business laws governing the use of Internet IOS. Viewed as a significant barrier to open standards diffusion, an immature institutional framework would increase the costs of open-standard IOS in significant ways (Kraemer et al. 2002). For instance, the lack of legal protection of intellectual property on the Internet coupled with potential piracy of Internet-based initiatives, can increase the total costs to develop online initiatives. Thus far we have identified four variables – financial costs, managerial complexity, transactional risk, and legal barriers – to compose adoption costs. According to a recent survey (Varian et al. 2002), these factors represent key barriers to the adoption of Internet-based IOS. In our model, they are posited as first-order variables to form the second-order construct, adoption costs.

In summary, we have identified specific factors underlying network effects and adoption costs. There are two approaches to specifying their relationships with open-standard IOS adoption (Chin and Gopal 1995). The first approach views each factor as separately affecting the adoption construct. In essence, each factor is considered as "a unidimensional structure that is independent of the other" (Chin and Gopal 1995, p.49). The second approach, in contrast, treats factors underlying network effects (or adoption costs) as multidimensional entities of a higher-order construct (Chin and Gopal 1995; Bagozzi 1988). According to this approach, two second-order constructs, network effects and adoption costs, may be postulated as "emergent constructs that are formed from the first order factors" (Chin and Gopal 1995, p.49). We have chosen to use the second approach. The purpose of using second-order constructs is to theorize the construct at a higher level, and relate this construct to other constructs at a similar level (Rindskopf and Rose 1988). As noted by Chin (1998, p.x), "because a second order factor [construct] is modeled as being at a higher level of abstraction and reflected by first order factors, it needs to be related with other factors that are at a similar level of abstraction independent of whether these other factors are inferred from measured items or other first order factors." Since adoption costs and network effects are constructs at a similar level that together explain open-standard IOS adoption from a benefit/cost perspective, the specification of these second-order constructs is appropriate. We have also examined whether these second-order constructs fully mediate their respective first-order variables, and the results show that our model meets this criterion (Chin 1998).

The Moderating Variable: Prior Use of EDI

Motivated by our theoretical interest in testing path dependency in IOS migration (Cohen and Levinthal 1990), we incorporate a firm's prior experience with EDI into our model in Figure 3. As we discussed

earlier, firms with EDI experience tend to have gained useful experience with process changes and organizational restructuring associated with electronic IOS. On the other hand, EDI usage before the Internet may result in switching costs, making EDI users more sensitive to the costs of adopting Internet-based IOS. Thus, we expect that the effects of adoption costs will be different between firms with and without EDI experience. This line of reasoning leads us to consider EDI experience as a moderating variable that will be further discussed when we develop our hypotheses.

Control Variables

Finally, we include three control variables to account for contextual differences: *firm size*, *industry type*, and *information and telecommunication technology (ICT) penetration*. First, firm size may be positively related to innovation adoption, since large firms are more likely to possess slack resources (Rogers 1995). Second, industry type is used to control for industry-specific differences that may affect open-standard IOS adoption, as manufacturing and services-oriented industries differ in their potential to transform value chain activities to the open-standard IOS platform (Chatterjee et al. 2002). Third, national infrastructure, especially ICT penetration, may affect the diffusion of open-standard IOS by firms (Kraemer et al. 2002). The use of these variables in our model helps control for firm-level, industry-level, and country-level differences that might affect open-standard IOS adoption.

4.2. Hypotheses

Network Effects

We have conceptualized two dimensions of network effects: vertical *trading community influence* and horizontal *peer adoption*. Now we specify their relationships with network effects and open-standard IOS adoption. Clearly, interorganizational systems extend beyond firm boundaries. If the support of the trading community is low, IOS users can only interact with a limited number of trading partners, which will lead to low network effects. To increase network effects of open-standard IOS, firms need participation from their suppliers, customers, and other trading partners. As more partners in a trading community adopt open-standard IOS, a firm is more likely to be part of a larger network and thereby to derive larger benefits from open standards. “Building an alliance of customers, suppliers, and complementors to support one technology over another…can be the single most important tactic [to build up the network effects]” (Shapiro and Varian 1999b). Hence, we propose trading community influence as a significant dimension of open-standard network effects to be positively related to open-standard IOS adoption.

In addition, IOS diffusion among horizontal peers (Teo et al. 2003) may also affect the strength of network effects. As more peers adopt open-standard IOS, a larger network of IOS users will emerge, and several sources of network effects arise. First, a larger market for complementary goods (including hardware and software based on compatible standards) will emerge, which will accelerate the process of open-standard IOS implementation. Second, in the complementary goods market, the price will fall because of the increased competition and production scale economies (Farrell and Saloner 1985; Katz and Shapiro 1985). In particular, a variety of services for Internet applications, such as software development, website design, and consulting services, will help adopters assimilate new standards along their value chains (Westland 1992). These effects suggest that peer adoption is another significant dimension of network effects.[8] Specifying network effects as a higher-level construct including both trading community influence and peer adoption, we expect that network effects will drive firms' adoption of open-standard IOS. This leads to our first hypothesis:

H1: *Open-standard IOS adoption will be positively influenced by network effects.*

Expected Benefits

As defined earlier, *expected benefits* refer to the operational benefits a firm expects from adopting open-standard IOS, which includes cost reduction, market expansion, and value chain coordination. As shown in the literature, expected benefits have been recognized as a major driver of innovation adoption (Tornatzky and Klein 1982; Lyytinen and Rose 2003). Viewing open-standard IOS as a technology innovation (Chatterjee et al. 2002), we incorporate expected benefits as an adoption driver. As more trading partners are connected by an open-standard IOS, network effects may induce two-way, real-time information exchange and help improve value chain coordination (Zhu and Kraemer 2002). Greater expected benefits in these areas will lead to more proactive adoption of the open-standard IOS (Chau and Tam 1997; Ranganathan et al. 2001). This argument is consistent with the innovation diffusion literature (Rogers 1995; Tornatzky and Klein 1982). Thus, we propose that the expected benefits would drive firms to adopt open-standard IOS, which leads to the following hypothesis:

H2: *Open-standard IOS adoption will be positively influenced by expected benefits.*

From the above discussion, it becomes clear that expected benefits are a firm-level measure, indicating a firm's expectation of the benefits of open-standard IOS, while network effects indicate the strength of network externalities in a particular industry, which are more related to the nature of the industry. On the

[8] As an additional peer company joins the network, it may have a negative competitive effect. This negative effect might be small compared to the positive effects from network externalities. For example, IBM and other PC makers benefited from a large network effect derived from the open PC standards while Apple suffered due to its proprietary standards.

other hand, these expected benefits are not shaped in isolation. The strength of the network effects in its industry will affect a firm's expectation about the benefits of adopting the open standard (Kauffman et al. 2000). Hence, there is a relationship between network effects and expected benefits. If a firm expects stronger network effects in its industry, it would scale up its expected benefits of adopting open-standard IOS, as each of the three types of benefits discussed above is subject to network externality. In summary, network effects enabled by open standards would positively affect the firm's capabilities of cost reduction, market expansion, and value chain coordination. Thus, we put forward the following hypothesis:

H3: *Network effects will positively influence a firm's expected benefits from the open-standard IOS.*

Adoption Costs

Adoption costs set a barrier to innovation adoption (Rogers 1995). We have conceptualized four factors (financial costs, managerial complexity, transactional risk, and legal barriers) that compose adoption costs. Although adoption costs have long been posited as a barrier of innovation adoption (Tornatzky and Klein 1982), some researchers have argued that the higher costs could motivate firms to treat the innovation more seriously and diffuse it more actively within the organization so as to make it cost-effective (Zaltman et al. 1973). Thus, adoption costs may also be positively correlated with the extent of IOS adoption. However, this proposition has not been tested by empirical studies. In contrast, most of the studies in the existing literature provide support for the negative effect of adoption costs (e.g., Iacovou et al. 1995; Chau and Tam 1997; Ramamurthy et al. 1999). Hence, we propose to test the following hypothesis:

H4: *Open-standard IOS adoption will be negatively influenced by adoption costs.*

Prior Use of EDI

Besides the direct effect of adoption costs hypothesized above, we want to understand the moderating effect of prior IOS experience. In line with the notion of path dependency (Cohen and Levinthal 1990), prior experience with electronic IOS may result in a deeper understanding of the costs of IOS adoption. Consequently, when making decisions about Internet IOS adoption, EDI users would consider adoption costs more carefully than EDI non-users. This expectation is strengthened by another dimension of path dependency—the switching costs effect (Beggs and Klemperer 1992). EDI users, although possibly having lower adoption costs in certain areas such as hardware and software, confront costs of switching from EDI to Internet-based IOS. These additional switching costs may make EDI users more sensitive to the adoption costs than non-users. If this expectation is true, the negative effect of adoption costs on Internet IOS adoption will be more pronounced for EDI users than for non-users. Furthermore, EDI users have already established electronic inter-firm linkages, and these linkages often involve relationship-

specific investments. When facing high costs in adopting Internet-based IOS, they may choose to continue to use the existing platform for inter-firm coordination (Bensaou 1997). Thus, we will observe a more sensitive effect of adoption costs on Internet IOS adoption for EDI users. This leads to our final hypothesis:

H5: *The negative relationship between adoption costs and open-standard IOS adoption will be more significant for EDI users than non-users.*

5. Methodology

5.1. Data

To test the proposed conceptual model and hypotheses, we used a dataset generated from a large-scale international survey designed for studying the extent of Internet adoption by firms. We also supplemented the dataset with additional variables about ICT penetration from OECD (2002). The survey instrument was designed on the basis of a comprehensive literature review and interviews of managers, and was refined via several runs of pretests and revisions. Each of the items on the questionnaire was reviewed by an expert panel for its content, scope, and purpose (content validity). The survey was executed by International Data Corp. (IDC), a professional research firm that specializes in large-scale surveys within IT user communities in many countries.

The questionnaire was pilot tested by IDC via a telephone interview with 25 U.S. firms to solicit their opinions on the questionnaire and to identify any items they found to be ambiguous. After analyzing the responses, a number of minor revisions were made to the questionnaire, such as clarifying terms and adding instructions that the respondents thought helpful. The refined questionnaire was then translated into different languages (Chinese, French, German, Japanese, and Portuguese). The translations were checked and revised by country experts selected by IDC, by the survey design team, and by academic research partners in each country affiliated with the research project.

Then the survey was conducted in the United States and 9 other countries (Brazil, China, Denmark, France, Germany, Japan, Mexico, Singapore, and Taiwan) during the period of February–April 2002. The sample was stratified by firm size and country, with sites selected randomly within each size cell. In each country, the sample frame was obtained from a list source representative of the entire local market.[9] Eligible respondents were those individuals best qualified to speak about the firm's overall computing

[9] Dun & Bradstreet was used for Denmark, France, Germany, and the U.S., while Kompas was used for Brazil, Mexico, Taiwan and Singapore. The Census of Enterprises was used for China. The Teikoku Data Bank was used for Japan.

activities. For medium/large firms, the respondent was the CIO, CTO, vice president or a senior manager with IS responsibilities. For small firms, it was the CEO, president or managing director. Our final dataset contains 1,394 respondents. Table 3 shows the sample characteristics. Of the 1,394 respondents, 55.2% of firms (*N*=770) used EDI and 44.8% of firms (*N*=624) did not. As shown in Table 3, distribution of firm size reflects a balance of large and small businesses. We tested for non-response bias and no statistically significant differences were found. We also examined the so-called "common method bias" which can potentially occur in survey data (Podsakoff et al. 2003). The results of statistical tests suggest that there is no significant common method bias in our dataset.[10]

[Insert Table 3 about here]

Respondents in our sample include both IS and non-IS managers. One may suspect that IS managers would tend to over-estimate IS usage and benefits; hence we examined whether there is response bias in our dataset due to respondents' positions. We split the full sample into two groups: IS managers (CIO, CTO, VP of IS, IS manager/director, and other manager in IS department) and non-IS managers (CEO, president, COO, CFO, and other business managers). We used ANOVA to test whether the mean factor scores significantly differ between the two groups. Descriptive statistics and ANOVA results are shown in Table 4. The *p*-value of the ANOVA *t*-test for each variable is insignificant, which suggests that respondent's positions did not result in serious biases in our dataset.

[Insert Table 4 about here]

Finally, our sample includes manufacturing and wholesale/retail industries, with 51.5% of the firms in manufacturing and 48.5% in wholesale/retail. These two industries deal with physical products and have widely used electronic IOS for interorganizational coordination (Mukhopadhyay et al. 1995; Subramani 2004). Anecdotal evidence also suggests that firms in these two industries (e.g., Dell, Wal-Mart, and General Electric) lead in using open-standard network to streamline transactions along the value chain (Kauffman and Walden 2001). Thus, these two industries are appropriate testing fields for our conceptual model.

5.2. Measures

Measurement items are developed based on a comprehensive review of the literature as well as expert opinion. This included successive stages of theoretical specification, statistical testing, and refinement

[10] Using Harman's single-factor test (Podsakoff et al. 2003), we found that the majority of data variance cannot be accounted for by one general factor, indicating that common method effects are not a likely contaminant in our dataset.

(Straub 1989). Most constructs are operationalized by multiple items. The resultant constructs, as well as supportive references, are listed in Table 5. While detailed definitions for all measurement items are shown in the Appendix, we briefly highlight their operationalizations below.

[Insert Table 5 about here]

Consistent with our earlier conceptualization, *open-standard IOS adoption* is modeled as a second-order construct with three first-order dimensions—breadth, volume, and depth. *Breadth* is measured by the number of value chain activities, for which a firm has adopted the Internet and XML-based standards. *Volume* is measured by the percentage to which each of the major value chain activities (e.g., sales, customer services, and procurement) has been conducted on the open-standard Internet platform. Based on previous studies on data integration (Goodhue et al. 1992), *depth* is measured by the extent to which Internet standards have been integrated with back-office systems and databases, as well as with suppliers' databases (Zhu and Kraemer 2002).

Network effects are modeled as a second-order construct formed by two first-order factors: trading community influence and peer adoption. We specify three indicators to measure *trading community influence*—whether open-standard IOS is supported by suppliers, supported by customers, and required by government procurement (Ranganathan et al. 2001). *Peer adoption* is measured by the extent to which peer companies have adopted open-standard IOS (Tan and Fichman 2002). *Expected benefits* are measured by four items that reflect the potential benefits of open-standard IOS to reduce costs, expand current markets, enter new markets, and improve value chain coordination (Chau and Tam 1997; Ranganathan et al. 2001).

Adoption costs are modeled as a second-order construct formed by the following first-order constructs. First, *financial costs* are measured by two items—whether costs of Internet access and costs of implementing a Website are high. Second, *managerial complexity* is measured by two items that indicate the complexity to change business process and adjust organizational structure to accommodate the use of Internet IOS (Ranganathan et al. 2001; Chatterjee et al. 2002), and a third item asking the extent to which the firm lacks staff with managerial expertise on open-standard IOS. *Transactional risk* is measured by concerns over data security, privacy, and legal protection of online transactions via open-standard IOS, as suggested by Ranganathan et al. (2001) and Sato et al. (2001). Finally, *legal barriers* are measured by the extent to which firms perceive lack of legal support from business and tax laws as significant adoption barriers.

6. Data Analysis and Results

We conducted our data analysis using structural equation modeling (SEM) implemented in Partial Least Squares (PLS). We chose PLS for two reasons. First, our measurement model includes both reflective and formative constructs; PLS, with its components-based algorithms, can handle both formative and reflective constructs (Chin 1998). Second, PLS is more appropriate when the research model is at the early stage of development and has not been tested extensively (Teo et al. 2003). As our literature review suggests, empirical tests of network effects are still sparse in the literature. This work is a preliminary effort to test path dependency in the standards literature. Hence, PLS is the appropriate technique for our research purpose. We conducted the two-step analysis recommended by Gerbing and Anderson (1988) to first assess the measurement model and then test the hypotheses by fitting the structural model. The results are presented below.

6.1 Results of Measurement Model

To assess *reflective constructs* in our measurement model, we examined convergent validity, construct reliability, and discriminant validity (Straub 1989). *Convergent validity* assesses the consistency across multiple items. As shown in Table 6, all estimated standard loadings are significant (p<0.001) and of acceptable magnitude (Nunnally and Bernstein 1994), suggesting good convergent validity. *Construct reliability* measures the degree to which items are free from random error, and therefore yield consistent results. In our measurement model, all constructs have a composite reliability over the cutoff of 0.70 (Chin 1998). To test *discriminant validity*, the extent to which different constructs diverge from one another, we used Fornell and Larcker's (1981) criteria: The square root of the Average Variance Extracted (AVE) of multi-item reflective constructs should be greater than the absolute value of inter-construct correlations. As shown in Table 7, all of our multi-item reflective constructs meet this criterion. Such results suggest that the items share more common variance with their respective constructs than with other constructs. For *formative constructs*, weights of measurement items should be significant (Chin 1998). As shown in Table 8, the weights of all constructs are significant (p<0.001) and above the suggested cutoff of 0.30 (Chin 1998). Thus, formative constructs in our model are acceptable as well.

[Insert Table 6, Table 7, and Table 8 about here]

6.2 Results of Hypothesis Testing

Full Sample

To test the hypotheses proposed in Section 4.2, we first fitted our structural model on the full sample (N=1394). Results are shown in Figure 4. As indicated by path loadings, both network effects (b=0.17, p<0.001) and expected benefits (b=0.27, p<0.001) have a significantly positive effect on open-standard IOS adoption. This result confirms our theoretical expectation and provides support for both H1 and H2. The path from network effects to expected benefits is highly significant (b=0.54, p<0.001), indicating the significant role of network effects in driving up the expected benefits of open-standard IOS. This provides support for H3. The path from adoption costs to open-standard IOS adoption is significant and negative (b=-0.12, p<0.001). This is consistent with our theoretical expectation that adoption costs will inhibit open-standard IOS adoption, thus supporting H4.

[Insert Figure 4 about here]

We also examined sub-dimensions of the three second-order constructs. (1) As evident from the loadings of breadth, volume, and depth, each of these three dimensions of open-standard IOS adoption is significant (p<0.001) and of high magnitude, supporting our conceptualization of the dependent construct as a second-order structure. (2) As to the factors underlying network effects, we find that trading community influence (b=0.79, p<0.001) is a stronger determinant of network effects than peer adoption (b=0.36, p<0.001), though both are significant. (3) Among those factors comprising adoption costs, *managerial complexity* is shown to have the strongest impact (b=0.39, p<0.001). Other factors including financial costs, transactional risk, and legal barriers are found to significantly increase adoption costs (p<0.001), all of which are consistent with our theoretical predictions and support our second-order conceptualization.

Finally, the three control variables, firm size, industry type, and ICT penetration, have positive paths to open-standard IOS adoption, suggesting that larger firms, firms in retail/wholesale industry (as opposed to manufacturing firms), and firms in countries with higher ICT penetration are more likely to adopt open-standard IOS.[11]

Sample Split: EDI Users vs. Non-Users

[11] To examine the robustness of our results, we conducted several additional tests. First, we selected the two variables measuring trading community influence—customer support and supplier support, and dropped all firms that rated "5" on the two variables (based on a 5-point scale). This test was motivated by prior research showing that IOS adoption might be driven by mandatory requirements of a powerful buyer or supplier (Mukhopadhyay and Kekre 2002). Using the resulting sample of 1180 firms, we fitted the structural model again and obtained results consistent with the full sample results. Secondly, we tested whether our sample includes "extreme" cases that would severely affect the results. We dropped firms below 5% percentile and above 95% percentile in terms of the three dimensions of open-standard IOS adoption. After deleting those "extreme" cases, the results were still consistent with the full-sample results. Finally, to test if the significant results were driven by our large sample size, we randomly split the full sample into two subsamples with equal size. We once again obtained consistent PLS results. These results are available from authors upon request.

To further compare users and non-users of EDI in adopting open-standard IOS, we split the full sample into two subsamples, EDI users (N=770) and non-users (N=624), and ran the structural model on the two subsamples respectively. Results are shown in Figure 5, with estimates for EDI non-users reported in parentheses. As indicated by path estimates, the relationships of network effects and expected benefits with open-standard IOS adoption are significant and positive on both subsamples. The path from network effects to expected benefits is significant in each subsample, with a high path magnitude consistent with the full sample result. These empirical results indicate that network effects and expected benefits drive both EDI users and non-users to adopt open-standard IOS, and their impacts are significant and robust.

However, results shown in Figure 5 demonstrate a difference between EDI users and non-users. We find that for EDI users, adoption costs are a significant barrier to open-standard IOS adoption (b=-0.17, p<0.001); yet for non-users, adoption costs turn out to be non-significant (b=-0.02, p=0.72). This difference between EDI users and non-users seems to support H5 wherein we propose that the negative impact of adoption costs is more significant for EDI users than for non-users.

Differences between the two subsamples are further tested by statistically comparing each path coefficient in the structural model for EDI users with the corresponding path coefficient for EDI non-users. As suggested by Cohen and Cohen (1988) and illustrated by Venkatesh and Morris (2000), a t-test is used to examine the significance of difference in path coefficients between the two subsamples. It turns out that the only path that differs significantly between the two subsamples is from adoption costs to open-standard IOS adoption (t=2.64, p<0.01). All of the other paths have a non-significant t-test (p>0.10). This result provides further support for H5. In summary, by fitting the structural model on the full sample and subsamples, we have found support for all of the five hypotheses. We offer explanations for these results and discuss implications in the next section.

[Insert Figure 5 about here]

7. Discussion

7.1. Major Findings

Using large-scale empirical data, we tested our conceptual model and hypotheses, focusing on network effects and path dependency in firms' migration to open-standard IOS. The empirical results of the full sample and sample split lead to several findings. We discuss them in two categories: network effects and path dependency.

Network Effects

First, network effects and expected benefits are significant drivers of migration to open-standard IOS. This empirical finding confirms the theoretical importance of network effects.

Our empirical analysis on the full sample (Figure 4) demonstrates the significant impacts of network effects (p<0.001) and expected benefits (p<0.001) on firms' adoption of open-standard IOS. We also find a significant relationship from network effects to expected benefits (p<0.001). Together these results highlight the significant impact of network effects on open-standard IOS adoption, including both direct impact (b=0.17, p<0.001) and indirect impact mediated through expected benefits (b=0.54, p<0.001; and b=0.27, p<0.001, respectively). Following Igbaria et al. (1997), we find the total impact of network effects on open-standard IOS adoption to be 0.32 (=0.17+0.54×0.27), a magnitude that satisfies the criteria for a satisfactory explanatory variable in PLS methodology (Chin 1998). Thus, the PLS results based on large-scale empirical data (Figure 4) support our theoretical expectation that open-standard IOS adoption is significantly influenced by network effects.

Second, trading community influence is a key determinant for the strength of network effects, which is consistent with the open-standard nature of public Internet.

To gain a finer-grained understanding of factors influencing open-standard network effects, we tested its underlying factors. As shown in Figure 4, trading community influence, with a path magnitude as high as 0.79 (p<0.001), is a key determinant of the strength of network effects in a particular industry. This finding is consistent with the key characteristics of open-standard IOS (Shapiro and Varian 1999a). To derive network effects and realize the IOS benefits, a wide range of value chain partners need to provide compatible services based on open standards. Therefore the participation of the trading community is deemed critical when potential adopters evaluate the benefits from open-standard network effects. Compared to the existing literature on networks such as ATM and EDI, our results point to a broader scope of stakeholders that contribute to network effects. In contrast to an ATM network, building open-standard IOS requires the joint efforts of network users who are also network developers and content providers. In contrast to EDI, open-standard IOS connects trading partners, both down stream and up stream. This empirical finding may have useful implications for the adoption of other open standard systems such as wireless communication networks.

Path Dependency

Third, adoption costs are a significant barrier to open-standard IOS adoption, but EDI users and non-users treat this very differently. While adoption costs appear to be a significant barrier for EDI users,

EDI non-users do not seem to regard this as significant as EDI users. This result is consistent with the notion that standards migration is indeed path dependent.

The result of the sample split in Figure 5 demonstrates a difference between EDI users and non-users: The negative influence of adoption costs on open-standard IOS adoption is significant for EDI users, but *not* significant for non-users. The follow-up *t*-test further confirmed this difference to be statistically significant. We also tested the direct effect of EDI usage on adoption costs, which helps us better understand the role of path dependency. We specified prior use of EDI as an antecedent leading to adoption costs, and found the path to be significant and negative (b=-0.14, p<0.001). This result suggests that prior use of EDI helps EDI users reduce the level of adoption costs, which is consistent with path dependency in IOS migration. It is likely that firms with EDI experience have set up data standards and communication protocols, and have developed certain IOS technical and managerial skills (Lyytinen and Robey 1999). Thus they may have lower adoption costs for newer technologies (Cohen and Levinthal 1990). However, combined with the moderating effect of EDI usage shown in Figure 5 (i.e., the difference between EDI users and non-users), our analysis reveals an interesting paradox: *EDI users, with prior experience of using electronic IOS, tend to have lower adoption costs for open-standard IOS than EDI non-users; Yet, adoption costs are considered by EDI users as a significant barrier to open-standard IOS adoption, but do not appear to be a significant barrier for EDI non-users.*

While this may sound counter-intuitive, it can be explained by the notion of path dependency and organizational learning. Adopting and implementing IOS is a process of organizational learning (Lyytinen and Robey 1999; Attewell 1992), and firms that have experience with EDI implementation tend to gain a deeper understanding of electronic IOS about not only its benefits but also its *costs*, especially non-obvious costs related to process reengineering and organizational restructuring. As a result, they may engage in a more comprehensive analysis when assessing a potential migration from EDI to open-standard IOS. In contrast, firms without any EDI experience may be driven by concerns about falling behind on the technology curve (as well as tangible benefits of moving to open-standard IOS), and thus might be eager to adopt open-standard IOS without paying sufficient attention to the costs and risks.

An alternative explanation may be given from the perspective of switching costs. As discussed earlier, switching costs from EDI, as one dimension of path dependency, increase the total cost of migrating to the Internet-based IOS. Thus, facing additional switching costs that are beyond the adoption costs, EDI users would be more sensitive to costs of adopting open-standard IOS. Further and also consistent with the concept of "switching," the existence of a previous IOS (i.e., EDI) may bring less incremental value for EDI users and thus make them more mindful of the costs of a new IOS. In contrast, without

established IOS for inter-firm coordination, EDI non-uses may move proactively, showing less concern about adoption costs. This difference concurs with previous arguments in the literature that, "competence with older technologies may offer 'traps' which make it difficult to shift to new and potentially better technologies" (Swanson 1994, p.1082). Showing different migration patterns with different prior paths, this finding provides support for path dependency in IOS migration, and suggests that path dependency in standards migration is a complex and interesting research topic warranting further study.

Finally, managerial complexity is a key determinant of adoption costs.

Among the factors underlying adoption costs, managerial complexity is shown to be the most influential factor as indicated by its high path magnitude (b=0.39, p<0.001). This implies that the lack of managerial capability, instead of financial resources, to integrate the new standard into an organization's business processes represents the major difficulty for firms to migrate to open standards (Lyytinen and Robey 1999). The lack of managerial capability increases the risk that the needed changes will not be successfully implemented and/or will be implemented with far greater costs and fewer benefits than expected. This finding seems to highlight the critical role of managerial capability for the success of IOS adoption (Clark and Hammond 1997). To effectively migrate inter-firm coordination to an open-standard platform, firms need to shift their attention from technical skills to managerial capabilities for organizational change and reconfiguration to function with the open standards (Zhu and Kraemer 2002).

7.2. Limitations and Future Research

Our methodology required tradeoffs that may limit the use of the data and interpretation of the results. Below we discuss the key limitations of this study and corresponding avenues for further research. First, this study focused on the *adoption* of open-standard IOS, but did not examine the *development* of open standards. Thus, we cannot show what factors drive standards making. It might be useful to take a process-orientation to examine the whole process of standards development, adoption, and diffusion (David and Greenstein 1990). In the IOS setting, EDI standards and XML-based standards have been developed by industry-wide consortia, and the role of these consortia is deemed pivotal for the successful development and diffusion of IS standards. For instance, Grover (1993) recommended studying industry-based standard-making associations to enhance the understanding about the "how" and "why" of the decision processes leading to the adoption decision. Premkumar and Ramamurthy (1995) also suggested the strong linkage between the process of making of industry-based standards and their subsequent diffusion among users. We also believe further research along this line can shed light on the whole process of standards making and its influence on diffusion.

Second, our model was tested using a dataset that was not explicitly designed to examine the standards questions, even though the dataset has shown to be useful for that purpose. Nevertheless, some factors that would affect the migration to open-standard IOS were not available in the dataset, which limited our ability to test a more comprehensive model. Thus, our measures for key variables need to be refined in future data collection, and additional variables should be incorporated to better measure key constructs.

In particular, the following areas need refinement in further research. First, additional research on the key dimensions of open-standard IOS migration is needed. More data should be collected to measure the scope of business processes and trading partners involved in open-standard integration. As more diversified processes, such as manufacturing and procurement, are integrated, adopters are more likely to achieve benefits from open standards (Mukhopadhyay and Keker 2002). Second, to strengthen the network effect argument, future research might include more network-related variables; for example, the availability of compatible software in the market to reflect the effect of peer adoption (i.e., indirect network effects), and the average transaction costs in a larger network to reflect economies of scale (i.e., direct network effects). Third, future research could improve our understanding of path dependency by examining relationship-specific assets developed along IOS migration path. For instance, EDI users may have developed business processes and domain knowledge that are specific to EDI partners (Subramani 2004); these relationship-specific assets may be strategically important for bilateral relationships and in turn may affect the migration to open-standard IOS.

Finally, our study is based on a cross-sectional database, and thus can only show associations, but cannot test causality and capture the dynamics of the processes. However, the adoption of new technology standards represents a dynamic process that requires firms to reconfigure according to changing technology and business environments. To investigate the dynamic processes and paths of standards migration, a longitudinal study is needed. For example, we tested the effect of trading community influence on IOS adoption, but as firms use IOS more, customers and suppliers are likely to provide more support for the IOS. These dynamics need to be understood. While this study provides a basis for future research, there is clearly more work to be done. We believe there is a need for complementary research methods such as longitudinal studies (cases, field studies) that could amplify and enrich our findings.

7.3. Implications for Management

Our study results in several key insights for managers, and should help managers better understand the factors and conditions that affect the migration to open-standard IOS. Our results have highlighted the

expected benefits from open standards and significant network effects as salient features of the adoption decision for open-standard IOS. Managers in firms considering adoption should assess the extent to which such technologies and standards are supported by customers, suppliers, and other business partners in the trading community. The extent of such support will substantially determine the benefits that adopters can realize from adopting open-standard IOS. In particular, lead participants and coordinators of these trading communities must pay considerable attention to trading community development. This includes such activities as the provision of incentives to early adopters who are not likely to experience the benefits of network effects in the short-run, the development of common tools and databases that facilitate knowledge and information sharing to facilitate operational benefits, and implementation assistance to mitigate adoption costs.

Our study also identifies managerial capabilities as deserving of special attention. IOS involve considerable managerial complexity because they involve implementing new business processes that cross organizational and inter-organization boundaries as well as implementing new technologies. Thus, they are difficult to implement and there is a risk that they might not succeed. Getting IOS right is not simply a matter of managerial time and effort, but more importantly of capability in change management and project implementation. These capabilities are needed to mitigate technological implementation risk and organizational change risk, and to enhance the alignment between technologies and organizational structure and business process. Managers should invest in the creation of "organizational capital" compatible with open-standard IOS, such as open organization, open communication, and organization flexibility (Brynjolfsson et al. 2002).

Firms with less IOS experience need to ensure they conduct a comprehensive analysis of the cost-benefit equation. As shown by our results for open-standard IOS adoption, firms without EDI experience were mainly driven by the assessment of the benefits of the new technology *per se*, and were less focused on the impact of IOS adoption costs. Without a balanced consideration of technology characteristics, organizational barriers, and especially the environment where network technology will be used, adopters are less likely to assimilate the new standards.

Our study also offers implications for policy makers. As the diffusion of Internet technologies are hindered by institutional barriers, including inadequate legal protection for online transactions, ambiguous business laws, and security concerns, governments should establish an institutional environment that supports transactions over the open-standard IOS (King et al. 1994). This is particularly important at the early stages of open standard development in an economy. Governments could accelerate open standard

diffusion by establishing supportive business and tax laws to stimulate firm's adoption (Kraemer et al. 2002). Once diffusion reaches critical mass, network effects will begin to kick in, thus speeding up diffusion and driving organizational assimilation in value chain activities.

7.4. Contributions to Research

This study makes several contributions to the academic literature on technology standards. First, although there are a number of theoretical studies on IOS standards, this area lacks empirical examination of how network effects promote standards diffusion, as called for by several scholars (e.g., Kauffman et al. 2000; Brynjolfsson and Kemerer 1996). Our work provides an empirical test of the importance of network effects to the technology and standards adoption literature. The large, international dataset (1,394 firms) increases the generalizability of the results. Our work also teases out finer-grained relationships such as the positive influence of trading community on network effects, and the importance of managerial complexity as a key determinant of adoption costs.

Second, we explicitly compared different pathways of network migration. We find that prior use of EDI helps reduce adoption costs for open-standard IOS adoption, yet EDI experience tends to increase switching costs in standards migration. This result provides support for the notion of path dependency, and has implications for research on IOS standards in general. That is, focusing on various generations in the trajectory of standards evolution might result in insights for both research and management. This seems to be an interesting undertaking: Different generations of technologies and standards tend to co-exist in the market, such as the cable network, wireless technology, and ubiquitous systems (Lyytinen and King 2002), and firms should always evaluate the costs and benefits of migrating along different paths to incorporate changes in standards. While path dependency has been recognized as an important dimension, it has rarely been examined empirically; this study documents its considerable importance. Hence, a research design focusing on a wider scope of standards could be useful for examining standard migration (Shapiro and Varian 1999b).

Third, this study extends the existing literature of network technology (e.g., EDI, ATM). Our work focuses on an open-standard network that has broader impacts on a firm's value chain activities (compared to EDI), and examines a wider scope of partner efforts involved in establishing network effects (compared to ATM). Our conceptual model may also be useful to study other types of standards such as wireless communication standards.

Finally, this study has sought to build theoretical synergy by developing a research model incorporating theoretical perspectives of network effects, switching costs, and path dependency. Our empirical results demonstrate the usefulness of this integrative approach. Researchers have pointed out the insufficiency to solely rely on innovation diffusion theory for studying standards diffusion (Lyytinen and Damsgaard 2001); our integrative model helps fill in this gap.

8. Concluding Remarks

As more firms have sought to improve inter-firm coordination through the use of inter-organizational systems, new network standards have been developed. Facing standards evolution in the marketplace, firms need to evaluate their internal resources and the external environments in order to successfully adopt new open standards. Thus, there is a growing need to understand what factors are likely to affect a firm's choices along the trajectory of standards evolution. Drawing upon the economic perspectives of network effects and path dependency, this research develops a conceptual model to examine influential factors in the migration to open-standard IOS. Unlike much of the research in the standards literature, our study goes beyond conceptualization and theorization. We also have tested our conceptual model using a large and unique dataset of 1,394 firms. Our empirical results demonstrate the significant role of network effects and adoption costs in open-standard IOS adoption, confirming the usefulness of the theoretical perspectives. We further tested underlying factors that contribute to network effects and adoption costs. We find that trading community influence is a key determinant for the strength of network effects, while managerial complexity, as opposed to financial costs, is a more significant determinant of adoption costs. Thus, it appears that the capabilities of managers in change management and technology implementation are key to successful IOS. In addition, we find that firms with and without EDI experience treat adoption costs very differently. The difference shows that prior technology paths influence the adoption of newer standards, thus suggesting that IOS migration is indeed path dependent and subject to switching costs. Experience with older standards may "trap" the firm and make it difficult to shift to open and potentially better standards. We hope our work will stimulate more research in this important area.

References

Arthur, W.B. "Competing Technologies, Increasing Returns and Lock-in by Historical Events," *The Economic Journal* (99), 1989, pp.116-131.

Attewell, P. "Technology Diffusion and Organizational Learning: The Case of Business Computing," *Organization Science* (3:1), 1992, pp.1-19.

Bagozzi, R.P. "The Rebirth of Attitude Research in Marketing," *Journal of the Market Research Society* (30:2), 1988, pp.163-195.

Bakos, J.Y. "The Emerging Role of Electronic Marketplaces on the Internet," *Communications of the ACM* (41:8), 1998, pp.35-42.

Bakos, J.Y., and Brynjolfsson, E. "From Vendors to Partners: Information Technologies and Incomplete Contracts in Buyer Seller Relationships," *Journal of Organizational Computing* (3:3), 1993, pp.301-329.

Banker, R., and Kauffman, R.J., "Strategic Contributions of Information Technology: An Empirical Study of ATM Networks," Proceedings of the 9th *International Conference on Information Systems*, J. Degross and M. Olson (eds.), Minneapolis, MN, 1988, pp.141-150.

Beggs, A., and Klemperer, P. "Multi-period Competition with Switching Costs," *Econometrica* (60:3), 1992, pp.651-666.

Bensaou, M. "Interorganizational Cooperation: The Role of Information Technology: An Empirical Comparison of U.S. and Japanese Supplier Relations," *Information Systems Research* (8:2), 1997, pp.107-124.

Brynjolfsson, E., Hitt, L., and Yang, S. "Intangible Assets: Computers and Organizational Capital," *Brookings Papers on Economic Activity* (1), 2002, pp.137-199.

Brynjolfsson, E., and Kahin, B. *Understanding the Digital Economy*, MIT Press, Cambridge, MA, 2000.

Brynjolfsson, E., and Kemerer, C.F. "Network Externalities in Microcomputer Software: An Econometric Analysis of the Spreadsheet Market," *Management Science* (42:12), 1996, pp.1627-1647.

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

Chau, P.Y.K., and Tam, K.Y. "Factors Affecting the Adoption of Open Systems: An Exploratory Study," *MIS Quarterly* (21:1), 1997, pp.1-21.

Chin, W.W. "Issues and Opinion on Structure Equation Modeling," *MIS Quarterly* (22:1), 1998, pp.vii – xvi.

Chin, W.W., and Gopal, A. "Adoption Intention in GSS: Relative Importance of Beliefs," *Data Base* (26:2&3), 1995, pp.42-63.

Choudhury, V., Hartzel, K.S., and Konsynski, B.R. "Uses and Consequences of Electronic Markets: An Empirical Investigation in the Aircraft Parts Industry," *MIS Quarterly* (22:4), 1998, pp.471-507.

Christiaanse, E., and Venkatraman, N. "Beyond Sabre: An Empirical Test of Expertise Exploitation in Electronic Channels," *MIS Quarterly* (26:1), 2002, pp.15-38.

Cohen, J., and Cohen, P. *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences* (2nd ed.), Lawrence Erlbaum Associates, Hillsdale, NJ, 1988.

Cohen, W.M., and Levinthal, D.A. "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly* (35:1), 1990, pp.128-152.

David, P.A., and Greenstein, S. "The Economics of Compatibility Standards: An Introduction to Recent Research," *The Economics of Innovations and New Technology* (1:1/2), 1990, pp.3-41.

Emmelhainz, M.A. *EDI: A Total Management Guide*, Van Nostrand Reinhold, New York, 1993.

Farrell, J., and Saloner, G. "Standardization, Compatibility, and Innovation," *Rand Journal of Economics* (16:1), 1985, pp.70-83.

Farrell, J., and Saloner, G. "Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation," *American Economics Review* (76:5), 1986, pp.940-955.

Fichman, R.G., and Kemerer, C. "The Assimilation of Software Process Innovation: An Organizational Learning Perspective," *Management Science* (43:10), 1997, pp.1345-1363.

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

Gallaugher, J.M., and Wang, Y.M. "Understanding Network Effects in Software Markets: Evidence from Web Server Pricing," *MIS Quarterly* (26:4), 2002, pp.303-327.

Garicano, L., and Kaplan, N. "The Effects of Business-to-Business E-Commerce on Transaction Costs," *Journal of Industrial Economics* (49:4), 2001, pp.1-23.

Gerbing, D.W., and Anderson, J.C. "An Updated Paradigm for Scale Development Incorporating Unidimensionality and its Assessment," *Journal of Marketing Research* (25:2), 1988, pp.186-192

Goodhue, D.L., Wybo, M.D., and Kirsch, L.J. "The Impact of Data Integration on the Costs and Benefits of Information Systems," *MIS Quarterly* (16:3), 1992, pp.293-311.

Greenspan, A. "Testimony of Chairman Alan Greenspan: Federal Reserve Board's Semiannual Monetary Policy Report to the Congress before the Committee on Banking, Housing, and Urban Affairs," U.S. Senate, March 7, 2002. http://www.federalreserve.gov/boarddocs/hh/2002/march/testimony.htm.

Grover, V. "An Empirically Derived Model for the Adoption of Customer-based Interorganizational Systems," *Decision Sciences* (24:3), 1993, pp.603-639.

Gurbaxani, V. "Diffusion in Computing Networks: The Case of BITNET," *Communications of the ACM*, December 1990, pp.65-75.

Hacki, R., and Lighton, J. "The Future of the Networked Company," *McKinsey Quarterly* (3), 2001, pp.26–39.

Hannan, T., and McDowell, J. "The Determinants of Technology Adoption: The Case of the Banking Firm," *Rand Journal of Economics* (15:3), 1984, pp.328-335.
Iacovou, C.L., Benbasat, I., and Dexter, A.S. "Electronic Data Interchange and Small Organizations: Adoption and Impact of Technology," *MIS Quarterly* (19:4), 1995, pp.465–485.
Igbaria, M., Zinatelli, N., Cragg, P., and Cavaye, A.L.M. "Personal Computing Acceptance Factors in Small Firms: A Structural Equation Mode," *MIS Quarterly* (21:3), 1997, pp.279-302.
Johnston, H.R., and Vitale, M.R. "Creating Competitive Advantage with Interorganizational Systems," *MIS Quarterly* (12:2), 1988, pp.153-165.
Katz, M., and Shapiro, C. "Network Externalities, Competition, and Compatibility," *American Economic Review* (75:3), 1985, pp.424-440.
Katz, M., and Shapiro, C. "Technology Adoption in the Presence of Network Externalities," *Journal of Political Economics* (94:4), 1986, pp.822-841.
Katz, M., and Shapiro, C. "Systems Competition and Network Effects," *Journal of Economic Perspectives* (8:2), 1994, pp.93-115.
Kauffman, R.J., McAndrews, J., and Wang, Y.M. "Opening the 'Black Box' of Network Externalities in Network Adoption," *Information Systems Research* (11:1), 2000, pp.61-82.
Kauffman, R., and Walden, E. "Economics and Electronic Commerce: Survey and Directions for Research," *International Journal of Electronic Commerce* (5:4), 2001, pp.5-116.
King, J.L., Gurbaxani, V., Kraemer, K.L., McFarlan, F.W., Raman, K.S., and Yap, C.S. "Institutional Factors in Information Technology Innovation," *Information Systems Research* (5:2), 1994, pp.139-169.
Klemperer, P. "The Competitiveness of Markets with Switching Costs," *Rand Journal of Economics* (18:1), 1987, pp.138-150.
Kraemer, K.L., Gibbs, J., and Dedrick, J. "Environment and Policy Facilitators Shaping E-Commerce Diffusion: A Cross-Country Comparison," in *Proceedings of the 23rd International Conference on Information Systems*, L. Applegate, R. Galliers, and J.I. DeGross (eds.), Barcelona, Spain, 2002, pp.325-335.
Lederer, A.L., Mirchandani, D.., and Sims, K. "The Search for the Strategic Advantage from the World Wide Web," *International Journal of Electronic Commerce* (5:4), 2001, pp.117-133.
Lyytinen, K., and Damsgaard, J. "What's Wrong with the Diffusion of Innovation Theory? The Case of a Complex and Networked Technology," in *Proceedings of the IFIP 8.6. Conference*, Banff, Alberta, Canada, 2001.
Lyytinen K., and King J. "Around the Cradle of the Wireless Revolution: The Emergence and Evolution of Cellular Telephony," *Telecommunications Policy* (26), 2002, pp.97-100.
Lyytinen K., and Robey D. "Learning Failure in Information System Development," *Information Systems Journal* (9:2), 1999, pp.85-101.
Lyytinen, K., and Rose, G.M. "The Disruptive Nature of Information Technology Innovations: The Case of Internet Computing in Systems Development Organizations," *MIS Quarterly* (27:4), 2003, pp.557-595.
Massetti, B., and Zmud, R.W. "Measuring the Extent of EDI Usage in Complex Organizations: Strategies and Illustrative Examples," *MIS Quarterly* (20:3), 1996, pp.331-345.
Mendelson, H. "*A Note on Internet Technology*," Graduate School of Business, Stanford University, 1999.
Mukhopadhyay, T., and Kekre, S. "Strategic and Operational Benefits of Electronic Integration in B2B Procurement Processes," *Management Science* (48:10), 2002, pp.1301-1313.
Mukhopadhyay, T., Kekre, S., and Kalathur, S. "Business Value of Information Technology: A Study of Electronic Data Interchange," *MIS Quarterly* (19:2), 1995, pp.137-156.
Nunnally, J.C., and Bernstein, I.H. *Psychometric Theory*, McGraw Hill, New York, 1994.
OECD. ICT and economic growth: Evidence from OECD countries, industries and firms, the Organization for Economic Cooperation and Development, 2002.
Phillips, C., and Meeker, M. *The B2B Internet Report: Collaborative Commerce*, Morgan Stanley Dean Witter, 2000. http://www.morganstanley.com/techresearch
Podsakoff, P.M., MacKenzie, S.B., Lee, J.-Y., Podsakoff, N.P. "Common Method Bias in Behavioral Research: A Critical Review of the Literature and Recommended Remedies," *Journal of Applied Psychology* (88:5), 2003, pp.879-903.
Porter, M. *Competitive Advantage.* Free Press, New York, 1985.
Premkumar, G., and Ramamurthy, K. "The Role of Interorganizational and Organizational Factors on the Decision Mode for Adoption of Interorganizational Systems," *Decision Sciences* (26:3), 1995, pp.303-336.
Ramamurthy, K., Premkumar, G., and Crum, M.R. "Organizational and Interorganizational Determinants of EDI Diffusion and Organizational Performance: A Cause Model," *Journal of Organizational Computing and Electronic Commerce* (9:4), 1999, pp.253-285.

Ranganathan, C., Teo, T.S.H., Dhaliwal, J.S., and Ang, J.S. "Facilitators and Inhibitors for Deploying Business-to-Business E-Commerce Applications: A Multi-Method, Cross-Cultural Study," in *Proceedings of the 22nd International Conference on Information Systems*, V. Storey, S. Sarkar, and J.L. DeGross (eds.), New Orleans, 2001, pp.593-600.

Ricker, J., Munro, D., and Hopeman, D. XML and EDI – Peaceful Co-Existence, XML Solutions Crop., 2002. http://www.tdan.com/i011hy01.htm.

Riggins, F.J., Kriebel, C.H., and Mukhopadhyay, T. "The Growth of Interorganizational Systems in the Presence of Network Externalities," *Management Science* (40:8), 1994, pp.984-998.

Rindskopf, D., and Rose, T. "Some Theory and Applications of Confirmatory Second-Order Factor Analysis," *Multivariate Behavior Research* (23:1), 1988, pp.51-67.

Rogers, E.M. *Diffusion of Innovations* (4th ed.), Free Press, New York, 1995.

Saloner, G., and Shepard, A. "Adoption of Technologies with Network Effects: An Empirical Examination of the Adoption of Automated Teller Machines," *Rand Journal of Economics* (26:3), 1995, pp.479-501.

Sato, S., Hawkins, J., and Berentsen, A. "E-Finance: Recent Developments and Policy Implications," in *Tracking a Migration: E-Commerce and the Terms of Competition in Industries*, The BRIE-IGCC E-conomy Project, Brookings Institution Press, Washington, D.C., 2001, pp.64-91.

Shapiro, C., and Varian, H. *Information Rules: A Strategic Guide to the Network Economy*, Harvard Business School Press, Boston, MA, 1999a.

Shapiro, C., and Varian, H. "The Art of Standards Wars," *California Management Review* (41:2), 1999b, pp.8-32.

Straub, D. "Validating Instruments in MIS Research," *MIS Quarterly* (13:2), 1989, pp.147-169.

Subramani, M. "How Do Suppliers Benefit from IT Use in Supply Chain Relationships," *MIS Quarterly* (28:1), 2004, pp.45-74.

Swanson, E.B. "Information Systems Innovation among Organizations," *Management Science* (40:9), 1994, pp.1069-1092.

Tan, S.S.L., and Fichman, M. "Adoption of Web-Based Transactional Banking: Efficiency-Choice and Neo-Institutional Perspectives," in *Proceedings of the 23rd International Conference on Information Systems*, L. Applegate, R. Galliers, and J.I. DeGross (eds.), Barcelona, Spain, 2002, pp.143-152.

Teo, H.H., Wei, K.K., and Benbasat, I. "Predicting Intention to Adopt Interorganizational Linkages: An Institutional Perspective," *MIS Quarterly* (27:1), 2003, pp.19-49.

Tornatzky, L.G., and Klein, K. "Innovation Characteristics and Innovation Adoption-Implementation: A Meta-Analysis of Findings," *IEEE Transactions on Engineering Management* (EM-29:1), 1982, pp.28-45.

Varian, H., Litan, R.E, Elder, A., and Shutter, J. *The Net Impact Study*, 2002. http://www.netimpactstudy.com/NetImpact_Study_Report.pdf

Venkatesh, V., and Morris, M.G. "Why Don't Men Ever Stop to Ask for Directions? Gender, Social Influence, and Their Role in Technology Acceptance and Usage Behavior," *MIS Quarterly* (24:1), 2000, pp.115-139.

Venkatraman, N., and Short, J.E. "Baxter Healthcare: Evolution from ASAP to Valuelink in the Hospital Supplies Marketplace," in *Proceedings of the 25th Hawaii International Conference on Systems Sciences*, V. Milutinovic, and B.D. Shriver (eds.), Kauai, Hawaii, 1992, pp.666-677.

Wang, E.T.G., and Seidmann, A. "Electronic Data Interchange: Competitive Externalities and Strategic Implementation Polices," *Management Science* (41:3), 1995, pp.401-418.

Westland, J.C. "Congestion and Network Externalities in the Short Run Pricing of Information Systems Services," *Management Science* (38:7), 1992, pp.992-1009.

Zaltman, G., Duncan, R., and Holbek, J. *Innovations and Organizations*, John Wiley, New York, 1973.

Zhu, K., and Kraemer, K.L. "E-Commerce Metrics for Net-Enhanced Organizations: Assessing the Value of E-Commerce to Firm Performance in the Manufacturing Sector," *Information Systems Research* (13:3), 2002, pp.275-295.

Zhu, K., Kraemer, K.L., and Xu, S. "Electronic Business Adoption by European Firms: A Cross-country Assessment of the Facilitators and Inhibitors," *European Journal of Information Systems* (12:4), 2003, pp.251-268.

Table 1. EDI versus Internet-based IOS

	EDI	Internet-based IOS
Content platform		
Data standards	Open standards (e.g., ANSI X12, EDIFACT), but less open than XML	Open standards (XML-based standards, EbXML)
Complexity	High	Low
Customization	Highly partner-specific	Less partner-specific
Delivery platform		
Communication protocols	VAN (private)	Internet (open, TCP/IP-based)
Interoperability	Low	High
Communication costs	High	Low
Trading partner base		
Scope	Relatively narrow, with existing partners	Broad, with existing and new partners, hence strong network effects

Table 2. Literature Review of Empirical Research on IS Standards

Study	Phenomenon	Theory	Methodology	Major Finding
Brynjolfsson and Kemerer 1996	Spreadsheet packages	Network effects	Hedonic regression	Consumers are willing to pay a premium for spreadsheet package with a larger installed base.
Kauffman et al. 2000	ATM	Network effects	Hazard model	Banks in markets with a larger network size tend to adopt ATM earlier.
Gurbaxani 1990	Computing network (BITNET)	Network effects, innovation diffusion	S-curve regression	Network effects have significantly facilitated the diffusion of BITNET.
Saloner and Shepard 1995	ATM	Network effects	Hazard model	ATM adoption delays decline in the number of branches and the value of deposits.
Gallaugher and Wang 2002	Web server software	Network effects	Hedonic regression	There is a positive relationship between software price and market share.
Chau and Tam 1997	Open systems	Innovation diffusion	Survey, Logit regression	Open systems adoption is influenced by the technological, organizational, and environmental contexts.

Table 3. Sample Characteristics, N=1394

Category	Percent	Category	Percent
EDI Adoption		*Industry*	
EDI Users	55.2	Manufacturing	51.5
EDI Non-Users	44.8	Retail / wholesale distribution	48.5
Country		*Number of Employees*	
Brazil	9.4	<100	14.3
China	9.5	100 – 300	19.5
Denmark	9.4	300 – 500	13.6
France	9.1	500 – 1,000	15.8
Germany	9.3	1,000 – 3,000	15.4
Japan	11.1	3,000 – 5,000	5.9
Mexico	9.6	5,000 – 10,000	4.5
Singapore	9.3	>10,000	11.0
Taiwan	9.3	*Respondent Title*	
United States	13.9	President, Managing Director, CEO	3.2
Annual Revenue ($ million)		CIO/CTO/VP of IS	16.6
<1	4.9	IS Manager, Director, Planner	35.9
1 – 10	20.2	Other Manager in IS Department	20.8
10 – 50	27.9	Business Operations Manager, COO	5.1
50 – 100	12.4	Administration/Finance Manager, CFO	8.0
100 – 500	18.8	IS Analyst, Network Administrator	4.6
500 – 1000	7.2	Others (Marketing VP, Other Manager)	5.8
> 1000	8.6		

Table 4. Summary Statistics

	Full Sample		IS Managers		Non-IS Managers		ANOVA
	Mean	S.D.	Mean	S.D.	Mean	S.D.	T (*p*-value)
Breadth	0.79	0.49	0.78	0.48	0.81	0.49	0.98 (0.33)
Volume	0.17	0.23	0.17	0.22	0.19	0.26	0.73 (0.47)
Depth	2.80	1.26	2.79	1.26	2.85	1.29	0.65 (0.51)
Trading Community Influence	3.62	1.40	3.65	1.40	3.51	1.41	1.47 (0.14)
Peer Adoption	2.91	1.33	2.91	1.32	2.91	1.36	0.05 (0.96)
Expected Benefits	4.29	1.36	4.32	1.36	4.21	1.37	1.29 (0.19)
Financial Costs	3.05	1.25	3.03	1.25	3.13	1.24	1.36 (0.18)
Managerial Complexity	3.50	1.24	3.4	1.23	3.53	1.26	0.45 (0.65)
Legal Barriers	2.82	1.31	2.81	1.30	2.86	1.36	0.57 (0.57)
Transaction Risk	2.71	1.41	3.71	1.41	3.70	1.40	0.09 (0.93)

Table 5. References for Model Constructs		
Constructs	**Type**	**References**
Second-Order Constructs		
Open-Standard IOS Adoption	Reflective	Massetti and Zmud 1996; Chatterjee et al. 2002
Network Effects	Formative	Katz and Shapiro 1986; Shapiro and Varian 1999a
Adoption Costs	Formative	Iacovou et al. 1995; Ramamurthy et al. 1999
First-Order Constructs		
Breadth	Reflective	Zhu et al. 2003; Massetti and Zmud 1996
Volume	Reflective	Chatterjee et al. 2002; Ramamurthy et al. 1999
Depth	Reflective	Zhu and Kraemer 2002
Expected Benefits	Reflective	Rogers 1995; Chau and Tam 1997; Ranganathan et al. 2001
Trading Community Influence	Formative	Ranganathan et al. 2001; Teo et al. 2003; Shapiro & Varian 1999b
Peer Adoption	Single item	Tan and Fichman 2002; Teo et al. 2003
Financial Costs	Reflective	Iacovou et al. 1995; Rogers 1995
Managerial Complexity	Reflective	Ranganathan et al. 2001; Chatterjee et al. 2002
Legal Barriers	Reflective	Kraemer et al. 2002
Transactional Risk	Reflective	Ranganathan et al. 2001; Sato et al. 2001
Firm Size	Single item	Zhu et al. 2003; Teo et al. 2003
Industry Type	Single item	Chatterjee et al. 2002
ICT Penetration	Reflective	Kraemer et al. 2002

Table 6. Reflective Constructs: Reliability and Convergent Validity			
Constructs	**Range of Standardized Loadings**	**Significance (*p*-value) of Loadings**	**Composite Reliability**
Open-Standard IOS Adoption	0.63-0.88	All <0.001	0.79
Breadth	0.50-0.66	All <0.001	0.76
Volume	0.53-0.81	All <0.001	0.74
Depth	0.84-0.87	All <0.001	0.84
Expected Benefits	0.71-0.83	All <0.001	0.85
Financial Costs	0.79-0.84	All <0.001	0.80
Managerial Complexity	0.73-0.76	All <0.001	0.80
Legal Barriers	0.85-0.87	All <0.001	0.83
Transactional Risk	0.76-0.86	All <0.001	0.79
ICT Penetration	0.92-0.97	All <0.001	0.95

Table 7. Reflective Constructs: Discriminant Validity

Constructs	Correlation Matrix †								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Breadth	***0.58***								
(2) Volume	0.39	***0.70***							
(3) Depth	0.37	0.22	***0.86***						
(4) Expected Benefits	0.31	0.14	0.25	***0.77***					
(5) Financial Costs	-0.02	-0.01	0.06	0.16	***0.82***				
(6) Managerial Complexity	-0.05	0.05	-0.04	0.17	0.50	***0.74***			
(7) Legal Barriers	-0.05	-0.05	0.02	0.20	0.44	0.34	***0.86***		
(8) Transactional Risk	0.02	-0.01	0.03	0.24	0.44	0.36	0.54	***0.81***	
(9) ICT Penetration	0.07	0.07	0.05	-0.16	0.02	-0.07	-0.19	-0.18	***0.89***

† Diagonal elements in the correlation matrix are the square roots of AVE (average variance extracted), which, for discriminant validity, should be greater than the absolute value of the inter-construct correlations (off-diagonal elements).

Table 8. Formative Constructs

Constructs	Items	Weights
Network Effects	Trading Community Influence	0.79***
	Peer Adoption	0.36***
Trading Community Influence	Support from Suppliers	0.48***
	Support from Customers	0.54***
	Requirement in Government Procurement	0.33***
Adoption Costs	Financial Costs	0.31***
	Managerial Complexity	0.37***
	Legal Barrier	0.33***
	Transactional Risk	0.30***

***p<0.001; **p<0.01; *p<0.05.

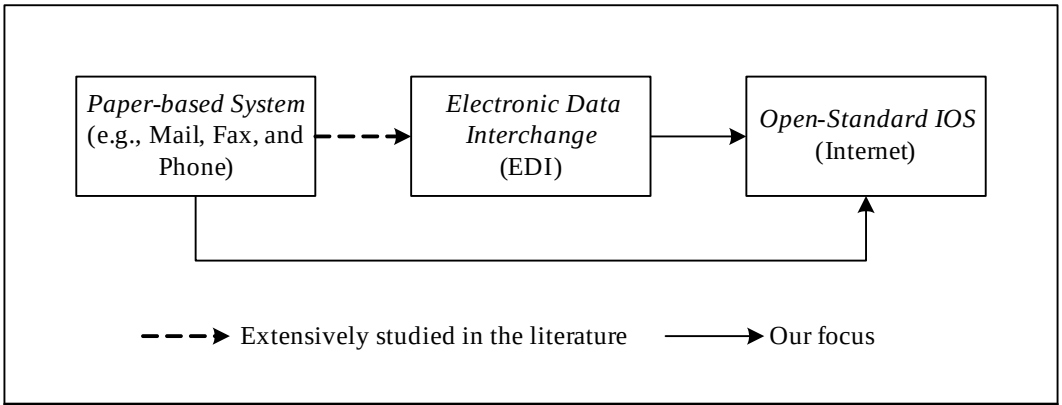

Figure 1. The Trajectory of IOS Migration

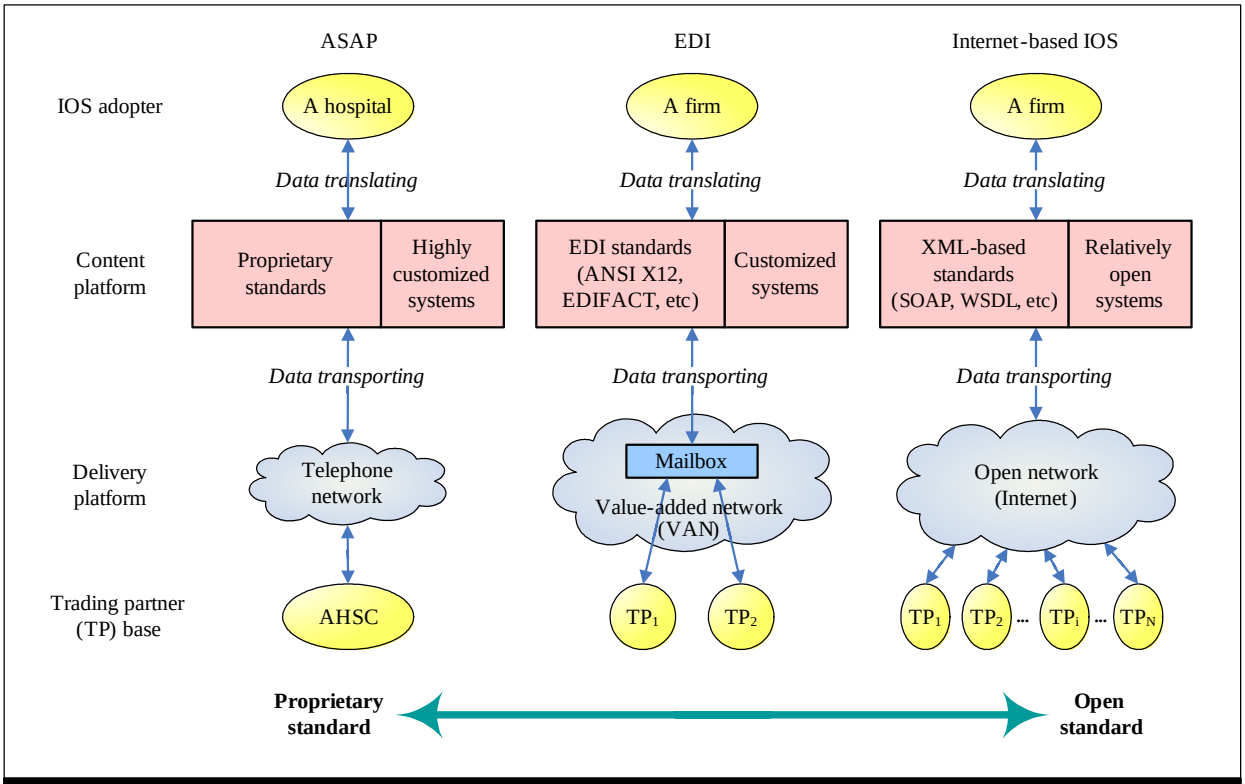

Figure 2. IOS Migration: From Proprietary Standard to Open Standard

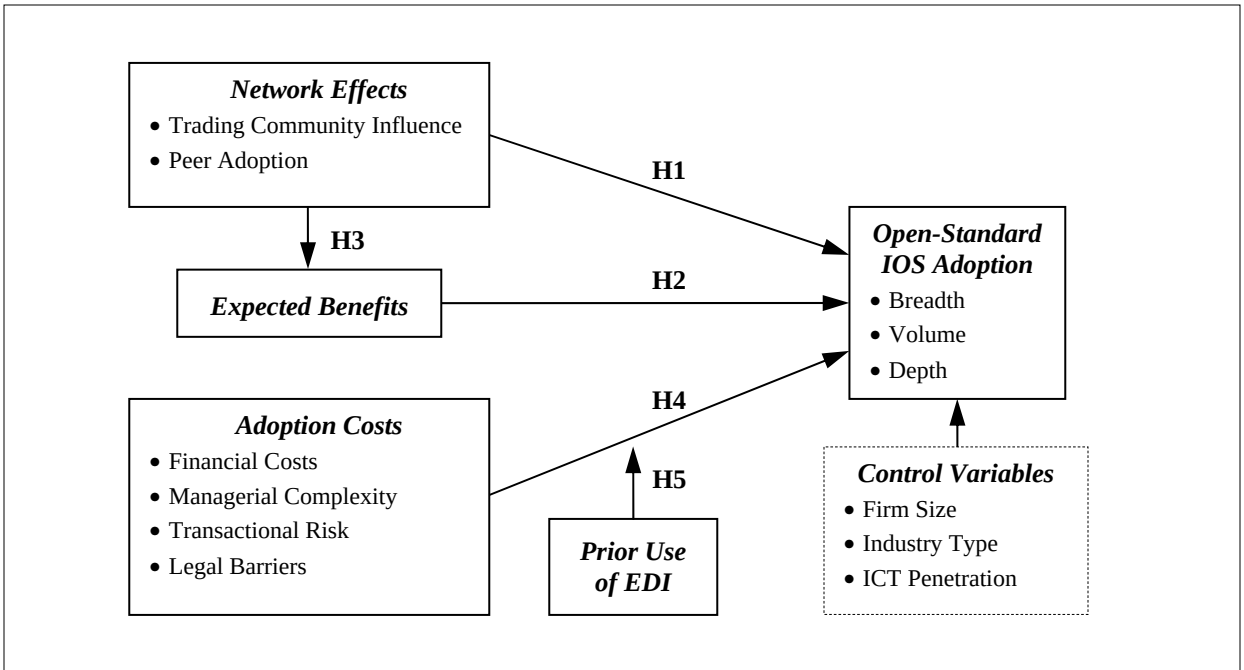

Figure 3. The Conceptual Model

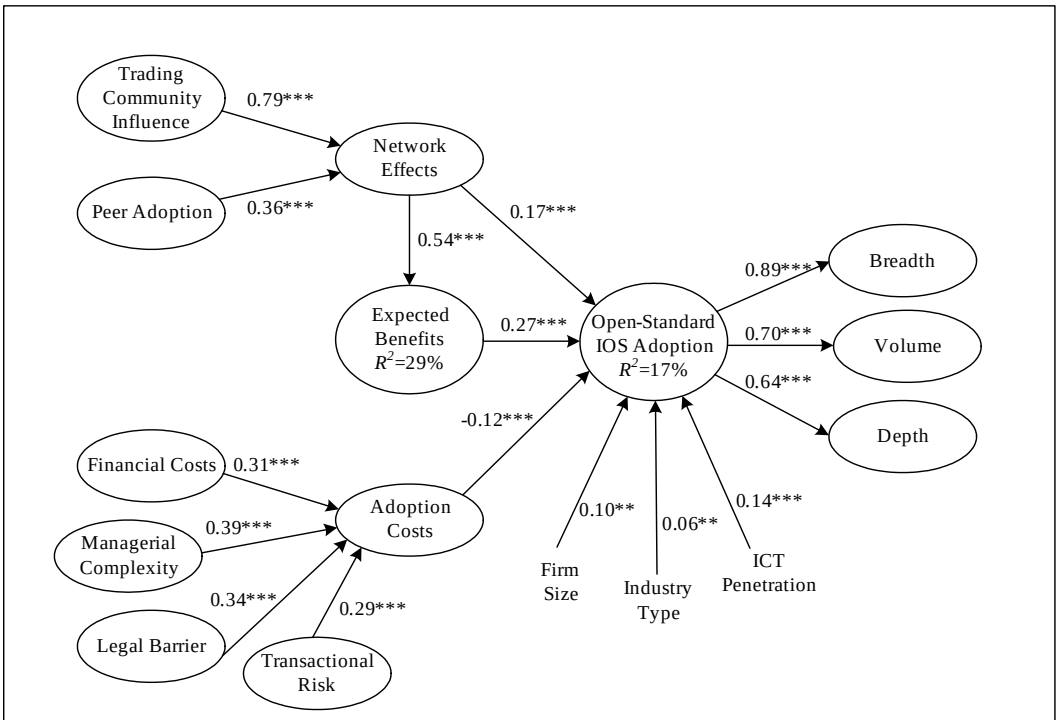

Figure 4. PLS Results : The Full Sample (*N*=1394)

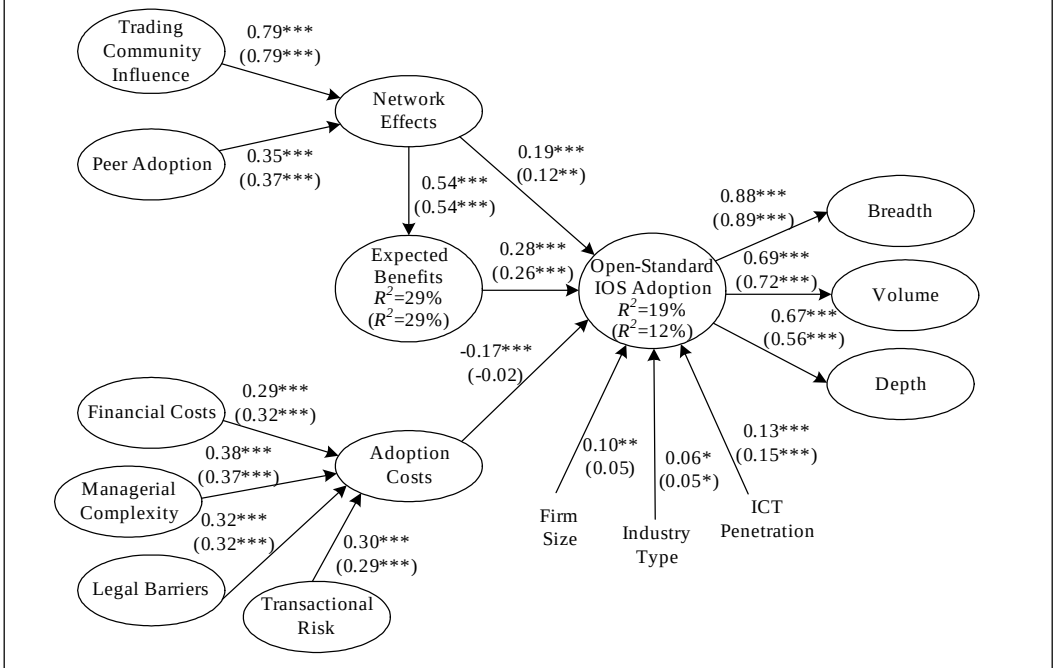

Figure 5. PLS Results : EDI Users (*N*=770) vs. Non-Users (*N*=624)

Appendix. Measurement Items	
Breadth—Open-standard IOS Adoption *(Yes; No)*	Improving coordination with suppliers/business partners
Has your firm used the Internet and XML-based standards for…	Expanding market for existing product/service
Online sales?	Entering new business or markets
Online procurement?	Reducing costs
Customer service and support?	**Financial Costs** *(5-point Likert scale)*
Providing product information?	Costs of Internet access are high
Exchanging operational data with suppliers?	Costs of implementing Internet IOS are high
Exchanging operational data with business customers?	**Managerial Complexity** *(5-point Likert scale)*
Integrating business processes with suppliers/business partners?	It is a complex and difficult task for your firm to…
Volume—Open-standard IOS Adoption *(percentage)*	Integrate the use of the Internet IOS in the overall business process
Percent of total sales conducted online ("online" means "on the Internet")	Make organizational changes to accommodate the Internet IOS
Percent of total customer services conducted online	Find staff with expertise of using the Internet IOS
Percent of total procurement ordered online	**Legal Barriers** *(5-point Likert scale)*
Depth—Open-standard IOS Adoption *(5-point Likert scale)*	Business laws do not support the use of the Internet
The degree your firm has integrated the Internet and XML-based standards	Taxation does not support the use of the Internet
With back office enterprise systems and databases	**Transactional Risk** *(5-point Likert scale)*
With suppliers' databases	Your firm is concerned about data security and privacy on the Internet
Trading Community Influence *(5-point Likert scale)*	Online transactions are not sufficiently protected by laws (e.g., default)
The degree that Internet usage has been promoted by…	**Firm Size**
Support from suppliers	Number of employees in your firm (logarithm-transformed)
Support from customers	**Industry Type**
Requirement in government procurement	Is your firm in manufacturing, or wholesale/retail industry?
Peer Adoption *(5-point Likert scale))*	**ICT Penetration** *(OECD 2002)*
The extent that peer companies used the Internet to conduct businesses	Telephone mainlines per 1000 people
Expected Benefits *(5-point Likert scale)*	Internet users per 1000 people
Your firm expects the following benefits of using open-standard IOS…	PCs per 1000 people