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Antecedents and Consequences of Electronic Product Code Adoption and its Implications for Supply Chain Management: A Framework and Propositions for Future Research

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Although electronic product code (ePC) is a popular standard of inter-organisational communication for identifying and tracing trade items, its level of adoption varies among firms, many of which still confine their supply chain activities to manual processes and stand-alone operations. To provide a better understanding of ePC adoption, we surveyed the relevant literature and developed a theoretical framework, together with a set of research propositions, to account for the antecedents and consequences of ePC adoption for supply chain management (SCM). The framework and propositions provide the impetus for a research agenda that identifies the critical issues of technological adoption for SCM. We also discuss the implications of the theoretical framework for further research and provide recommendations on the adoption of ePC for SCM.
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INTRODUCTION

Logistics includes all activities involving the moving of products and information to, from, and between members of a supply chain encompassing suppliers, manufacturers, carriers, distributors, retailers, and customers (Lai and

Cheng, 2006). These activities include order processing, transportation, inventory management, warehousing, the handling of materials, packaging, and so forth. Partner firms in a supply chain join forces in managing their logistics activities, which are aimed at bringing goods, services, and information efficiently and effectively to the ultimate customers. Major manufacturers and retailers, such as Hewlett Packard and Seven Eleven, have successfully applied sound supply chain management (SCM) principles and best practices to their partner firms to achieve improvements in performance throughout their supply chains. SCM is concerned with managing upstream and downstream relationships and operations with suppliers and customers to deliver superior customer value at the least cost to the whole supply chain. The focus is on the integration of business processes, both within and between organisational boundaries, to increase the value of products and services to customers through cost-effective information, product, and financial flows in the supply chain (Wisner, 2003).

The literature tends to suggest that the integration of the internal functions of an organisation is important and that this should precede the forging of external links with suppliers and customers. A high level of integration is required in supply chains (Hewitt, 1994; Gunasekaran and Yusuf, 2002), in which information sharing amongst intra- and inter-organisation processes facilitates the autonomy of operations in a supply chain. Hammer (2001) argued that an important criterion to becoming a 'superefficient company' is the sharing of information; it is necessary that 'everyone shares the same version of all the information, (so that the) reconciliation task can be eliminated and assets can be deployed precisely and efficiently.' The 'bullwhip effect' in the supply chain (Lee and Billington, 1992; Lee *et al*, 1997) also illustrates the importance of sharing information in supply chains. To this end, information interchange is essential to the streamlining of business processes within an organisation and among its member firms in the supply chain, including suppliers, distributors, wholesalers, and retailers (Lai *et al*, 2005).

Previous studies have suggested that the widespread use of information technology, resulting from the availability of low-cost and high-power innovations in information sharing (eg, handheld scanners), and the establishment of industry-wide communications standards (eg, Universal Product Codes (UPC) and Universal Communications Standards (UCS)), enables firms in supply chains to develop additional external relationships (Clemons and Row, 1993; Bowersox and Daugherty, 1995). As a popular standard for identifying and tracing products, electronic product code (ePC) is useful for managing supply chain processes, reducing errors in data input, enhancing communication between firms, and increasing the traceability of trade items in supply

chains, all of which are fundamental to effective SCM in any industry. ePC is an enabling information technology for firms to improve performance in intra- and inter-organisational communication and information sharing with respect to identifying products, locations, and shipments of goods. To illustrate, an ePC tag is an identifier, in the form of a label, licence plate, or computer chip, which can be identified by a reader that is connected to a computer system to access information about the tagged object. An example of such an identifier is Radio Frequency Identification (RFID) technology, which has realised its potential to improve various supply chain operations, such as warehousing and supply chain security. For performance improvement, ePC can be deployed across the functional processes of an organisation – from sourcing to customer service, and across a range of tasks – in support of internal operations, as well as facilitating the coordination of the supply chain. Potential uses of ePC for logistics management include (i) asset management, tracking and maintenance, (ii) volume planning and automated data capture through shipping route, (iii) shipment route tracing and identification of package content, and (iv) automated customs (EPCglobal, 2004).

Although the popularity of applying ePC across industries to manage supply chain processes is growing, there seem to be few insights into the extent of ePC adoption for SCM. Yet, many firms still confine their supply chain activities to manual processes and stand-alone operations (Lai, 2002; Yeung *et al*, 2003). In such situations, information loss and operations costs are likely to incur as information is not shared in a timely manner and information integrity cannot be guaranteed. Indeed, prior studies have suggested that a high level of ePC adoption in a collective manner in a supply chain can benefit all the participating firms by facilitating information sharing (Monge *et al*, 1998; Chwelos *et al*, 2001). It is therefore highly desirable to understand the factors that affect ePC adoption in firms and their performance implications. However, to the best of our knowledge, there is no prior study that examines the following issues: (i) why ePC is (or is not) adopted, (ii) what factors affect the intensity (level) at which ePC is adopted in organisations, and (iii) the performance implications of the extent of ePC adoption for SCM. To advance knowledge in SCM, the antecedents that are conducive to the adoption of ePC, the performance consequences, and its implications for SCM need to be better understood. Therefore, this paper sets out to:

(i) establish a theoretical framework to explore the antecedents and consequences of adopting ePC in business processes from an SCM perspective;
(ii) develop a set of testable propositions on the links between the level of ePC adoption, its antecedents, and its performance implications;

(iii) propose measures for operationalising the adoption of ePC in organisations;
(iv) suggest directions for research on the adoption of ePC for SCM;
(v) provide recommendations on the adoption of ePC.

CONCEPTUAL BACKGROUND

Supply chain and the sharing of information

The supply chain of a firm collaborates with partner firms in the chain, backward with suppliers and forward with customers, to leverage a firm's strategic positioning and to improve its operating efficiency (Lambert and Cooper, 2000; Bowersox *et al*, 2002). At the strategic level, SCM is concerned with the strategic choice of partner firms to facilitate the five critical flows in a supply chain, namely information, product, service, finance, and knowledge flows. At the operational level, it involves inter-organisational processes that span organisational functions within the firm and link those of partner firms in the supply chain, which are deployed to coordinate and manage these five critical flows (Christopher, 1998; Lai *et al*, 2004). Owing to the trends of outsourcing non-core activities and global sourcing, companies are increasingly transacting and communicating with a large number of external parties, for example, suppliers and distributors, to deliver products and services that meet the needs of the market (Scannell *et al*, 2000; Mentzer *et al*, 2001). The integration of physical processes and the interchange of information are becoming essential to effective SCM (Alvarado and Kotzab, 2001; Gunasekaran and Ngai, 2004). To integrate inter-organisational processes in supply chains for better coordination and mutual benefit, information technologies and standards, for example ePC, are often applied between partner firms that are willing to commit to the supply chain and to exchanging information electronically (Riggins and Mukhopadhyay, 1994; García-Dastugue and Lambert, 2003).

Previous studies have suggested that effective communication and the sharing of information are key to the success of supply chains (Xu *et al*, 2001) and that an increasing number of organisations have adopted and implemented information technologies in order to cope with uncertainties in demand and supply in the market and to improve the performance of the chain (Patterson *et al*, 2003). The growing deployment of information technologies allows firms in the supply chain to reduce financial risks, lower costs, and improve quality by focusing on their core business, resulting in fewer relations to manage (Ellram and Cooper, 1990). Moreover, better economies of scale, a higher utilisation of capacity, and the formulation of more effective long-term plans can be achieved through the sharing of information between organisations

(Ellram and Cooper, 1990; Riggins and Mukhopadhyay, 1994) and with an integrated supply chain. These strategic and operational benefits can translate into competitiveness in costs and services for all the partner firms in the supply chain (Cooper *et al*, 1997).

Many studies have been conducted on best practices of SCM, such as the Efficient Consumer Response (ECR), Continuous Replenishment Process (CRP), Collaborative Forecasting, Planning, and Replenishment (CFPR), and Vendor Managed Inventory (VMI). The success of these practices depends on the effective flow of information across the firms in a supply chain (Lai *et al*, 2006). Responsive and error-free capturing of data, as well as unrestricted transfer of information between trading parties, are crucial to realising the full potential of the best practices with respect to reducing uncertainty, order cycle times, excessive inventories, and stock-out problems in a supply chain (Lee and Billington, 1992). It is often necessary to implement enabling technologies, such as ePC and Electronic Data Interchange (EDI), for the efficient and secure capture and transfer of data to satisfy the need of trading partners in a supply chain to share information (Williams, 1994).

Supply chain and ePC

The purpose of using ePC is to facilitate flows of physical products in the supply chain. The ability of firms to identify specific trade items accurately and in a cost-effective manner is critical to managing supply chain processes at the operational level. To ensure the accuracy and integrity of information, the best method is to minimise human intervention in the processes of capturing and transferring data. A popular method of entering data (Nixon, 1996), ePC in the form of computer-readable bar codes (or in other forms, such as RFID tags) enables different parties in the supply chain to identify products, organisations, locations, and shipments of goods with a unique number represented by a bar code. The information contained in a bar code can be retrieved electronically by a computer and transmitted to other computers via communications systems, for example, EDI (Bartko, 1996). Unlike other information technologies that often require manual input of data, the operational nature of ePC requires no manual input of data, thus preserving the integrity of the data and incurring a lower operations cost. Recently, the need for heightening the security of ocean containers after the disastrous event of 11 September 2001 (Noda, 2004) has called for the adoption of ePC, for example RFID, to prevent any container from being used as a weapon of destruction without impeding the smooth flows of containers (Greenemeier, 2004; Noda, 2004). Recognising the importance of port security, Hutchison Port Holdings Group, which is one of the world's largest independently owned port investor, developer and operator, has installed RFID sensors in four of the Group's major ports, to test the feasibility

of using RFID to improve the security of its container ports (Hille and Merchant, 2005). Moreover, fast and accurate flows of information resulting from the adoption of ePC enable firms in the supply chain to streamline their processes and enhance their ability to handle physical product flows in a cost-effective manner. A study on consumer packaged goods (CPG) companies, for example, The Home Depot, Procter and Gamble, Unilever, and Wal-Mart, found that CPG companies embracing ePC to collaborate with their trading partners can generate performance gains in growth, profitability, and consumer satisfaction (Chappell *et al*, 2002). In such case, ePC contributes to the fast and accurate capture and transfer of data, leading to increased traceability of trade items in a supply chain, that is, the ability to identify and trace products, which is fundamental to effective SCM in any industry.

RESEARCH FRAMEWORK

Although the advantages of adopting ePC to identify and trace products in supply chains are obvious, the literature is unclear on the factors that may affect the level of ePC adopted in organisations and on the performance implications of adopting ePC for SCM. To better understand the factors affecting the adoption of ePC in organisations and its performance implications from an SCM perspective, we propose a theoretical framework and a set of propositions on the relationships of the level of ePC adoption with its antecedents and consequences, as illustrated in Figure 1.

Rogers (1983) defined innovation as an idea, practice, or object that is perceived as new by an individual or by other units of adoption. This suggests that an innovation need not be a matter of newly invented products/processes, but rather something new to the organisation adopting and using it. The implication is that technological adoption is not just concerned with the technology itself, but also with the process of adoption. Thus, the conditions and factors that affect technological adoption play a significant role in attaining the desired results of the adoption of a technology.

In view of the increasingly popular approach of SCM for firms to achieve cost and service advantages, there is an urgent need to study the adoption of ePC for SCM and its implications for improving performance. Based on a synthesis of the literature on technological innovations, logistics and SCM, management information systems, and the diffusion of innovations, we identify five factors that are critical to determining the level at which ePC is adopted in organisations. The factors are (i) technological opportunism, (ii) complementary assets, (iii) organisational innovativeness, (iv) perceived advantages, and (v) institutional pressures. How and why these factors affect the adoption of

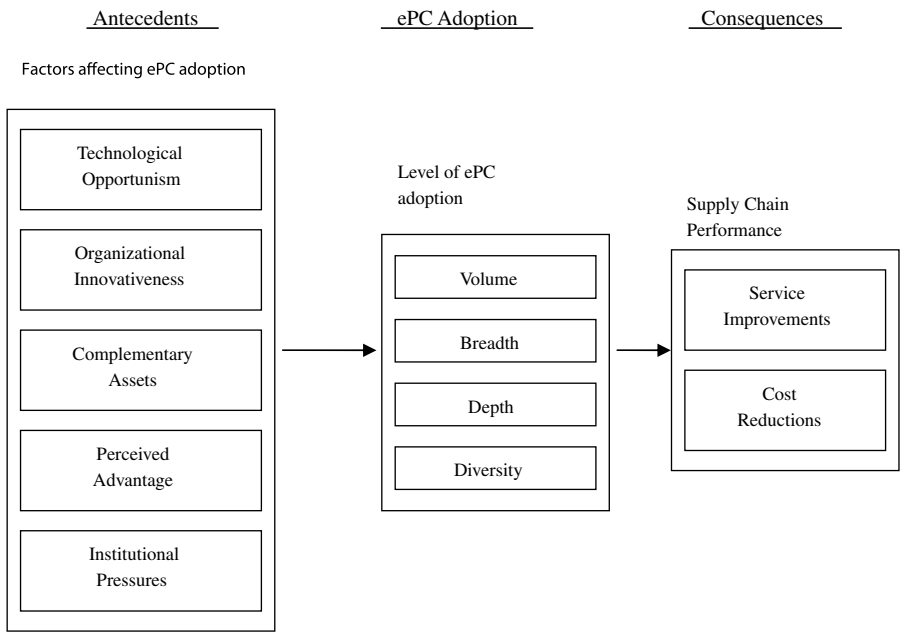

Figure 1: Antecedents and consequences of the adoption of ePC

ePC in organisations for SCM, and their potential effects are elaborated in the following.

Technological opportunism

Technological opportunism is the sense-and-response capability of organisations with respect to new technologies (Srinivasan *et al*, 2002). Technology-sensing capability refers to the ability of an organisation to acquire information on new technological knowledge and innovations (Srinivasan *et al*, 2002). It is a competence in sensing, identifying and evaluating new opportunities and potential threats to an organisation (Daft and Weick, 1984). Technology-response capability is an organisation's ability and willingness to respond to the new technologies it identifies in its environment that may influence the organisation (Srinivasan *et al*, 2002). It represents the firm's ability to exploit the opportunities and to mitigate the threats posed by the technology. When a technologically opportunistic organisation is aware of technological changes in its environment, it is presumed that the organisation is likely to adopt and use the technology and takes this investment as a potential source of growth (Mentzer *et al*, 2001). As a result of perceiving the adoption of technology as a

strategic act, a technologically opportunistic firm proactively adopts new technology and motivates its business units to utilise the technology to seek the greatest strategic benefits from the technology adoption. For example, when Wal-Mart began to demand its suppliers to implement RFID technology, retail analysts at Sanford C. Bernstein estimated that the firm could save as much as US$8 billion annually (Boyle, 2003). Other retailers such as Target and Albertson's have followed the trend of adopting RFID and started to test RFID applications in their supply chain activities. Following this line of reasoning, it can be speculated that firms that are technologically opportunistic tend to seek and adopt new technology, and that the extent of ePC adoption in the context of SCM is a manifestation of this postulation. Therefore, we propose that:

> Proposition 1: The technological opportunism of a firm is positively associated with its level of ePC adoption.

Organisational innovativeness

Chandy and Tellis (1998) suggested that firms must be able to overcome their inertia and to innovate to sustain their business. An increasing number of studies support the notion that innovativeness is the key to achieving superior organisational performance (Hurley and Hult, 1998). The innovativeness of an organisation is defined as the 'generation, acceptance, and implementation of new ideas, processes, products, and services (Thompson, 1965).' Zaltman *et al* (1973) argued that innovativeness is an organisational characteristic that refers to openness to new ideas as an aspect of a firm's culture, which is a measure of the organisation's orientation towards innovation. In the context of the adoption of information technology, prior studies have suggested that an organisation's existing proclivity towards innovativeness influences further innovation (Lee and Runge, 2001). In the context of SCM, organisational innovativeness reflects an organisation's willingness and ability to use technologies to enhance collaboration among partner firms in the supply chain. For example, suppliers of Wal-Mart should take measures to overcome their inertia of ePC adoption arising from their organisational characteristics such as organisational structure and management practices. They should seek to reap the benefits of adopting RFID by not just to satisfy Wal-Mart's requirements but also to better utilise the technology to improve their own logistics operations. Based on Hurley and Hult's (1998) definition of organisational characteristics, which refer to behaviour that is valued and promoted in an organisation, we reason that the innovative cultural characteristics of an organisation will promote the adoption of ePC for

intra-organisational and inter-organisational operations. Hence, we hypothesise that:

> Proposition 2: The organisational innovativeness of a firm is positively associated with its level of ePC adoption.

Complementary assets

Complementary assets are those that help an organisation to obtain value from technologies and positively affect the process of adopting technology (Tripsas, 1998; Rogers, 1983; Srinivasan *et al*, 2002). Complementary assets sustain the competence of an organisation. The ownership of complementary assets, particularly specialised and/or co-specialised assets, determines which organisations win or lose from a technology (Teece, 1986). For example, Paxko is a global manufacturer of paper, plastic and aluminum consumer products, and food service packaging. It has 12 manufacturing plants in North America, six in Europe, two in South America, and one in China. For systematic control and coordination of operations within and between its manufacturing plants, ePC adoption enables Paxko to improve its production, asset utilisation, inventory management, and labour productivity, for example, machineries and equipment are tagged to track their usage, location (within or borrowed from another plant), and maintenance (Chappell *et al*, 2003). The ePC-enabled systematic coordination of operations within and between plants serve as a complementary asset for the firms to collect detailed, accurate, and timely information for performance enhancement. Prior studies have suggested that when incumbent firms possess specialised complementary assets that retain their value despite shifts in technology, these assets protect the incumbents from the effects of the destruction of competence (Mitchell, 1989; Tripsas, 1998). The existence of a pre-existing base of knowledge or the capacity of an organisation to use a technology can lower the costs in an organisation of learning the technology (Cohen and Levinthal, 1990). Therefore, we conjecture that:

> Proposition 3: The complementary assets of a firm are positively associated with its level of ePC adoption.

Perceived advantage

Relative advantage is the degree to which a technology is perceived as better than the idea it supersedes (Rogers, 1983). It indicates the strength of the reward or punishment, which is measured in economic terms, and of the factors of social prestige, convenience, and satisfaction resulting from the implementation of a technology. An organisation is likely to implement a technology if it perceives that the technology offers relative advantages over its status quo

(Tornatzky and Fleischer, 1990). For example, in view of the perceived advantages of adopting RFID to improve its supply chain operations, Wal-Mart acted by demanding its top suppliers to implement RFID technology in an attempt to create an efficient and compatible base of trading partner in its supply chain. Given the traits of ePC that promote efficient and effective trade and product tracking among firms in a supply chain, organisations interested in achieving integration of their supply chains and in enhancing its capability are likely to adopt and broadly use ePC. Therefore, we speculate that:

> Proposition 4: A firm's perceived advantage of adopting ePC is positively associated with its level of ePC adoption.

Institutional pressures

King *et al* (1994) concluded in their study on the impact and regulatory role played by institutions involved in information technology innovation that institutional influences and regulations can be construed as the ideologies governing supply-push and demand-pull models, which are consistent with the scenarios prevalent in supply chains. At the inter-organisational level, institutional pressures from government, industry alliances, and social beliefs define socially acceptable conduct. The social pressures common to all firms in the same sector lead firms to exhibit similar structures and activities (DiMaggio and Powell, 1983). The adoption of RFID in the retail industry shows how institutional pressures affect the adoption of information technology (Lai *et al*, 2006). For example, a supplier that relies heavily on big retailers for businesses, such as Wal-Mart and Tesco, is likely to comply with the requests of their dominant customers on the adoption of RFID technology to retain their businesses. Organisational sociologists have long argued that firms adopt technologies because of institutional pressures from constituencies in their environments. As a technology spreads, a threshold is reached beyond which implementation is motivated by legitimacy rather than by the belief that it will improve performance (Meyer and Rowan, 1977). Thus, in the context of SCM, the adoption of an appropriate information technology such as ePC is a form of organisational response to institutional pressures (Lai *et al*, 2006). Accordingly, we hypothesise that:

> Proposition 5: The institutional pressures experienced by a firm are positively associated with its level of ePC adoption.

Performance implications of the Implementation of ePC

The essence of adopting ePC for SCM is to reduce the cost of operating and enhance the performance of the supply chain by integrating and sharing

intra-firm and inter-firm functions in product tracing and tracking (Brewer and Speh, 2000). Measuring performance in the context of SCM involves not only intra-organisational processes, but also understanding and meeting the performance expectations of members of the supply chain (Normann and Ramírez, 1993). ePC is a useful tool for firms to use in streamlining the logistics processes in their supply chains. For example, TAL apparel Ltd., the world's largest producer of dress shirts, has adopted ePC to reduce distribution expenses at its manufacturing bases in Hong Kong, Malaysia, Thailand, Taiwan, and the Chinese mainland (Hong Kong Article Numbering Association, 1999). ePC enables cross-docking practice, which reduces inventory, saves storage space, and increases the speed of delivery to stores. Upon adopting ePC, the firm gained the following operations benefits: the accuracy of deliveries reached 100%, the cycle time for orders fell from 4 months to 30 days, and the inventory of items to be replenished for customers was cut from 17 weeks to 7 weeks (Hong Kong Article Numbering Association, 1999). The widespread adoption of ePC will expand the ability of a user of ePC to identify and trace the firm's trade items more effectively within organisational boundaries and between trading partners in the supply chain. Empirical evidence suggests that the widespread adoption of EDI systems can deliver cost and service benefits (Mukhopadhyay, Kekre, and Kalathur, 1995). As an enabling mechanism of an EDI system, it is reasonable to assume that the adoption of ePC for SCM can lead to similar performance results. Therefore, we postulate the following:

> Proposition 6: The level of ePC adoption in organisations is positively related to supply chain performance improvements for the adopting organisations in the supply chain.

Further research issues

Achieving cost and service performance is perhaps the most basic principle of logistics management (Lai and Cheng, 2006). Logistics and shipping firms are keen on adopting electronic solutions to improve efficiency and meet customer requirements (Lu *et al*, 2005). Accordingly, the benefits that logistics practitioners can obtain from electronic commerce and its enabling technologies are receiving increasing research attention (Lu *et al*, 2006). To gain insights on technological adoption in the logistics context, especially on a subject related to interorganisational relationships, for which archival data are often unavailable, it is desirable to carry out large-scale, quantitative empirical investigations (Venkatraman and Ramanujam, 1987). Empirical verification of a theoretical framework and its associated propositions in further research needs careful research design and appropriate measurement items, which are elaborated below.

Measurement of theoretical constructs

Some previously validated measures for assessing the antecedents to the adoption of information technology innovations (cf. Moore and Benbasat, 1991; Capon *et al*, 1992; Chandy and Tellis, 1998; Hurley and Hult, 1998; Srinivasan *et al*, 2002; Teo *et al*, 2003) and for evaluating the performance of a supply chain (Lai *et al*, 2002) can be adapted in developing a questionnaire for empirical data collection. However, the terminologies may need adjustment for the theoretical constructs and objectives of further studies. Table 1 presents the various underpinning constructs of the theoretical framework on the adoption of ePC for SCM and the related references for their measurement for further research.

Measurement of the level of ePC adoption

The level of ePC adoption describes the level at which ePC is embedded in business processes. To evaluate the level at which ePC is adopted in organisations, the conceptual framework for the adoption of EDI developed by Massetti and Zmud (1996) can be deployed. The framework consists of four facets: (i) volume, (ii) diversity, (iii) breadth, and (iv) depth. The level of ePC adoption can be measured by identifying the process domains within which ePC is adopted and the degree of embeddedness within each specific process domain. ePC facilitates the flow of information within and across the boundaries of business units and streamlines the processes. Consistent with this view, each facet of the measurement can be dichotomised into two sub-facets – intra- and inter-organisation – to measure the degree to which ePC is adopted in business processes within an organisation. Tables 2 and 3 provide a definition of the four facets of using ePC, their measures, and interpretations, respectively. The details of the measures are elaborated below.

Volume

Volume measures the extent to which an organisation's objects, such as files, resources, and trade items, are tagged with ePC. At the intra-organisational level of investigation, volume is determined by dividing the total number of ePC-tagged objects by the total number of objects shared and distributed between business processes. At the inter-organisational level, volume is measured in the same mode, except that it is determined by the number of objects sent to or received from the organisation's partners in the supply chain. The facet of volume illustrates the organisation's dedication to systematising its objects internally and externally. The greater the percentage of the organisation's objects tagged with ePC, the greater the extent to which the organisation is adopting ePC. Likewise, the greater the percentage of ePC-tagged objects traded with, sent to, or received from partners in the supply chain, the more intensively the supply chain is utilising ePC.

Table 1: Definition and examples of the antecedents and consequences of adopting ePC

Proposition	Variable	Conceptual definition	Examples of items for operationalising measures	Relevant references
Proposition 1	Technological opportunism	The sense-and-respond capability of firms with respect to new technologies	First in the industry to detect technological developments; active in seeking technological changes; fast in detecting technological changes; allocates resources to seek innovations; responds quickly to technological changes; accepting new technologies; willing to implement new technologies	Srinivasan *et al* (2002)
Proposition 2	Organisational innovativeness	A measure of an organisation's orientation towards innovation	Innovation is readily accepted; management actively seeks innovative ideas; using innovations is encouraged in the company; company is the first to market new products; company is at the cutting-edge of innovations	Capon *et al* (1992); Hurley and Hult (1998)
Proposition 3	Complementary assets	The assets that assist a firm in obtaining value from new technologies and that positively affect the process of technological implementation	Market share; size of customer base; size of supplier base; amount of technological and financial resources; compatibility of existing technology/innovations/ processes in the organisation	Chandy and Tellis (1998); Tripsas (1998); Srinivasan *et al* (2002)
Proposition 4	Perceived advantage	The degree to which an innovation is perceived as better than an existing idea/practice	Improvement in productivity; improvement in inter-organisational communication; greater control over resources in the company; enhancement of overall effectiveness; streamlining processes	Moore and Benbasat (1991)
Proposition 5	Institutional pressures	The social pressure that emerges and defines socially acceptable firm conduct	Competitors benefit from the implementation; the implementation is perceived as favourable by suppliers/ customers in the industry; main trading partners have used the innovation	Srinivasan *et al* (2002); Teo *et al* (2003)
Proposition 6	Supply chain performance	The effectiveness of the services and operations of the supply chain	Delivery performance; order fulfilment; supply chain response time; production flexibility; cost reduction; value-added productivity; return processing cost; cash-to-cash cycle time; inventory days of supply; asset turns	Lai *et al* (2002)

Table 2: Definition of four facets of the adoption of ePC

Facet	Definition
Volume	The extent to which a firm's objects are tagged with ePC
Diversity	The extent to which different types of a firm's objects are tagged with ePC
Breadth	The extent to which a firm has used ePC in trading with each of its trading partners and in managing the objects within the firm
Depth	The extent to which a firm's business processes are linked with each other and intertwined with those of its trading partners with ePC-tagged objects

Table 3: Measures and interpretations of each facet on the adoption of ePC

Facet	Measurement level	Measure	Interpretation
Volume	Intra-organisational	Percentage of objects shared and distributed between internal business processes that are tagged with ePC	Intensity of the use of ePC within a firm
	Inter-organisational	Percentage of objects sent to or received from external parties that are tagged with ePC	Intensity of the use of ePC between firms in the supply chain
Diversity	Intra-organisational	Percentage of organisational subunits that handle ePC-tagged objects	Openness of an organisation to the use of ePC in its internal business processes
	Inter-organisational	Percentage of organisational subunits that transact with trading partners on ePC-tagged objects	Openness of an organisation to the use of ePC with trading partners
Breadth	Intra-organisational	Number of ePC-tagged objects shared and distributed cross-functionally and vertically	Degree to which the organisational structure fosters/hinders the use of ePC
	Inter-organisational	Number of trading partners that transact with the firm on ePC-tagged objects	Extent to which trading partners use ePC to trade with the firm
Depth	Intra-organisational	Number of internal business processes that deploy ePC	Extent to which a firm's business processes link with one another with ePC-tagged objects
	Inter-organisational	Number of internal business processes that transact on ePC-tagged objects with trading partners	Extent to which a firm's business processes link with those of its trading partners with ePC-tagged objects

Breadth

Breadth measures the extent to which an organisation adopts ePC in trading with external parties and in managing the objects within the organisation. It

describes how successful an organisation has been and how willing it is to establish linkages between internal business processes and between the organisation and its external parties through the utilisation of ePC. To identify the breadth that ePC has been adopted in an organisation, the number of ePC-tagged objects shared and distributed in cross-functional and vertical directions between business processes is measured. Therefore, the links between intra- and inter-organisational functions, which indicate the organisational structure, identify both the extent of the organisation's efforts to utilise ePC in internal processes and the strength of the coordination between the organisation and members of its supply chain.

Diversity

Diversity measures the extent to which the number of distinct types of objects in an organisation are tagged with ePC. The diversity in the adoption of ePC is an indication of the progress an organisation has made in comprehensively handling its objects with ePC. At the intra-organisation level, the diversity in the adoption of ePC can be measured by the variety of ePC-tagged objects routinely exchanged by business units. At the inter-organisational level, diversity is measured by the number of different types of ePC-tagged objects that the organisation exchanges with its trading partners.

Depth

Depth measures the extent to which a firm's business processes are linked with one another and are intertwined with those of its trading partners with ePC-tagged objects. Within an organisation, the depth of the adoption of ePC can be measured by the number of business processes that deploy ePC. It identifies how comprehensively business units use ePC for their daily operations. On the other hand, the external level of depth can be measured by the number of business processes that interact with external parties that use ePC.

IMPLICATIONS FOR MANAGERS

The theoretical framework and research propositions developed provide a number of important implications for managers. First of all, the propositions highlight the antecedents of the adoption of ePC in intra- and inter-organisational processes. The framework provides an overview of the factors that foster or hinder firms in adopting ePC for SCM.

Second, the theoretical framework allows firms to realise what organisational characteristics are desired to improve their capability in utilising ePC to gain improvements in performance. It also helps firms to gain a better

understanding of its capability and competency, which will enable them to formulate proper plans and actions for using ePC and other technologies and standards for SCM. For instance, a firm that aims to fully utilise ePC in its intra- and inter-organisational processes needs to recognise organisational characteristics, such as technological opportunism and innovativeness, and develop complementary assets and allocate the required resources to support the process of implementation.

Third, an implication of the proposed framework is that an organisation needs to strike a proper balance in adopting ePC in its intra- and inter-organisational processes. Emphasising the adoption of ePC in either intra- or inter-organisational processes can hinder the integration of the supply chain, which will eventually have a negative effect on supply chain performance. The operationalisation of the facets for measuring the level of adoption of ePC will help firms understand their strengths and weaknesses and identify the business processes in which they can increase the adoption of ePC to improve the performance of their supply chains.

Finally, the measurement items for ePC suggested in Table 3 can be used by users of ePC as a self-diagnostic tool to (i) evaluate the level of adoption within the firm and with its supply chain partners, (ii) identify the strengths and weaknesses of the adoption of ePC within the organisation and in the supply chain, (iii) benchmark the performance of the firm's supply chain, and (iv) formulate plans to design and implement effective strategies for the adoption of ePC.

IMPLICATIONS FOR RESEARCHERS

Our theoretical framework offers a comprehensive overview that conceptualises the adoption of ePC in organisations, and its antecedents and consequences. It leads to the development of research propositions on the adoption of ePC for SCM and provides directions for logistics research.

This study explains why ePC is adopted and the level of ePC adoption in organisations by identifying the antecedents that may affect ePC adoption. In line with prior studies, which argued that it is important for organisations to possess organisational characteristics, for example, organisational structure, that condition the success of innovation adoption for SCM (Kwon and Zmud, 1987; Bensaou, 1997; Pagell, 2004), this study has identified the factors that are pertinent to the level of ePC adoption to support physical flows in a supply chain. These factors are the prerequisites of ePC adoption. Hence, this study lays a foundation for future research on the barriers and conditions leading to the level of information technology adoption for SCM.

Considering a high level of ePC adoption in a supply chain is an essential component to facilitate fast and accurate flows of information to support the logistics processes of firms, this study contributes to the logistics literature by suggesting a measurement that embraces four dimensions of business processes for which ePC can be adopted to facilitate information flows. The measurement captures the complexity of linkages among business processes within and between firms, thereby enhancing the understanding of the extent to which ePC is embedded in business processes of firms.

Moreover, this study articulates that the level of ePC adoption consists of four dimensions, that is, volume, breadth, diversity, and depth. By incorporating a multidimensional measure of ePC adoption, this study gives an explanation of why firms that have adopted ePC for SCM may not attain the same outcome, such that without the adoption of ePC in all of the four facets may impede the information flows of a supply chain, thus hindering the improvement of cost and service performance. This study offers insight to future research that the adoption of technology for SCM should not be viewed as a single dimension measure; future studies should acknowledge the complexity of business processes of firms by examining the adoption of technology using a multidimensional measure.

Overall, we hope that the theoretical framework will enhance our understanding of the antecedents and consequences of ePC for SCM and encourage research in these areas.

CONCLUSIONS

This study advances the knowledge of SCM and the adoption of ePC in the SCM context. We have developed a theoretical framework for the adoption of ePC in SCM by identifying the antecedents that are pertinent to the intensity of the adoption of ePC, proposing measures for operationalising the extent of ePC adoption, and exploring the implications of adopting ePC for the performance of a supply chain. We speculate that all the antecedents have a positive impact on the extent of ePC adoption, which in turn improves the quality of the services and reduces the costs of operations in the supply chain. In other words, firms that are technologically opportunistic and innovative, and that possess complementary assets, recognise the advantages of adopting ePC, and face institutional pressures from members of its supply chain, are prone to adopting ePC more intensively in its intra- and inter-organisational processes. Furthermore, firms with a high level of ePC adoption are more likely to outperform firms that are not fully adopting ePC. We propose a set of facets and sub-facets of measures for the adoption of ePC in an attempt to assess the level at which the intra- and inter-organisational processes are embedded with ePC in the

supply chain. Moreover, this study highlights the importance of adopting ePC to achieve integration in the supply chain. From a managerial perspective, the research framework offers managers a theoretical overview of the factors that influence the level of ePC adoption and their performance implications.

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