Supply Chain Management: An International Journal

The rise of the “next-generation bar code”: an international RFID adoption study

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Research paper

The rise of the "next-generation bar code": an international RFID adoption study

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Abstract

Purpose – The present study is concerned with the determinants of RFID adoption among a group of early standards adopters. Despite the extensive discussion of the technological characteristics and expected benefits of RFID in the literature, only little is known about the drivers and barriers of RFID implementations in practice. This holds particularly for the later stages of the adoption process after an initial decision in favor of the technology was made. This paper aims to fill this gap by an analysis of a set of factors on the adoption of RFID, which have been shown to be relevant for the adoption of other forms of IT, such as ERP systems and EDI.

Design/methodology/approach – Based on a review of prior works, this paper constructs and empirically tests a structural model including factors related to the technology, the organization, and its environment.

Findings – The results suggest that top management support, perceived technology costs, and forces within the supply chain exert a significant influence on the adoption process. The study also finds that benefit perceptions have a significant but negative influence, which might be explained by the different modes of adopting RFID. The influence of a number of other factors known from the literature could not be supported by the study.

Originality/value – Prior works considered factors influencing the initial adoption decision among non-adopters. In contrast with these, the focus is set on research on early adopters that have already made a decision in favor of RFID standards. The data underlying this study were collected from EPCglobal, an international association of RFID adopters covering the whole supply chain.

Keywords Radio frequency identification, Electronic product code, IT adoption, Diffusion of innovations, Standards

Paper type Research paper

Introduction

The growing interest in radio frequency identification (RFID) on the part of the retail industry and beyond in recent years has sparked an intensive debate in academia and practice on the benefits to be expected (Lee and Özer, 2007). Some of the largest retailers in the world have put much effort into convincing their suppliers, logistics service providers as well as companies from other industries of the positive impact of RFID on supply chain performance. There is nevertheless some indication that the initial enthusiasm for RFID has at least partly given way to a more disillusioned assessment (Lacy, 2005; *The Economist*, 2007; Roberti, 2009). It becomes increasingly evident that the overall adoption rate in the industry lags behind the initial expectations (Brown and Bakhru, 2007; Edwards, 2008). Barriers often voiced in the trade press and at practitioner events include unclear benefits, prohibitive hardware and integration costs, the complexity of the technology, and the lack of mature and proven standards.

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Supply Chain Management: An International Journal
16/5 (2011) 328–345
 [ISSN 1359-8546]
[DOI 10.1108/13598541111155848]

Received: December 2010
Revised: May 2011
Accepted: May 2011

From an academic perspective, RFID adoption is still an under-researched issue despite the strong interest in the implementation and practical use of RFID on the part of the research community. Only few researchers have so far conducted quantitative empirical studies of the factors influencing the diffusion of the technology in practice. In particular, there is a lack of studies that concentrate not only on the adoption decision among non-adopters, but rather on the drivers and barriers that influence the subsequent adoption process after a decision in favor of RFID was made. The purpose of this paper is to fill this gap by an analysis of RFID as a special case of information technology for the implementation of interorganizational systems. We investigate the influence of a set of adoption factors, which have shown to be relevant for the adoption of other forms of IT (e.g. ERP systems and EDI), and compare the results to the findings from prior RFID adoption research. The underlying set of survey data was gathered from members of EPCglobal, an industry organization for the development and dissemination of RFID standards. The data were used to test a structural model of RFID adoption based on the widely established technology-organization-environment (TOE) framework by Tornatzky and Fleischer (1990).

The remainder of the paper is organized as follows. In the next section, we provide a short overview of RFID standards and the profile of the EPCglobal organization. We continue with a review of the related works on IT adoption theory and RFID adoption in particular. Based on the literature review, we develop our research model and formulate a number of hypotheses to be tested empirically. Then we describe our data collection process and the results of the structural model test. The paper closes with a discussion of theoretical implications, managerial implications, limitations, and suggestions for further research.

Technological background

RFID is a technology for the automatic identification by radio of physical objects such as industrial containers, palettes, or sales units (Attaran, 2007). The identification event takes place over transponders located in or on the respective objects, which can be addressed without physical contact, over the so-called "air interface", by the antenna on a scanner device. Transponders are manufactured in different shapes and styles, operate in various frequency ranges and have either their own battery or are provided with energy from the electromagnetic field of the scanner. In contrast to the traditional barcode, RFID differentiates itself through the possibilities for bulk registration, identification without line of sight, unambiguous identification of each individual object, data storage on the object as well as robustness towards environmental influences and destruction (Finkenzeller, 2003; Shepard, 2005).

The hype surrounding RFID in recent years was particularly driven by the activities of the Auto-ID Center, a project founded in 1999 at the Massachusetts Institute of Technology (MIT), in cooperation with numerous industrial sponsors. The main result of the Auto-ID Center was the "electronic product code" (EPC), a worldwide unambiguous code for the designation of arbitrary physical goods, which should ensure the interoperability of the technology in broad supply chain applications (Sarma *et al.*, 2000). In October 2003, the Auto-ID Center was terminated according to plan and transformed into an international research network, now known as the Auto-ID Labs and EPCglobal Inc., a subsidiary of the global supply chain standards organization GS1 responsible for commercializing EPC technology (Sarma, 2006). In the following years, EPC became the technical foundation for the multiple RFID initiatives of large retailers such as Wal-Mart and Metro as well as for industrial enterprises such as Novartis or the US Department of Defense (Pramatari, 2007).

On top of the EPC, a whole family of hardware and software standards has been developed, which is known as the "EPC Network" (EPCglobal, 2009) for the collection, filtering, and distribution of EPC-related data across organizations. The EPC Network is administered by EPCglobal in the form of a subscriber-driven organization. Any company intending to use EPC labels on their products must subscribe to the EPC Network and pay annual fees depending on revenues. In turn, the company is assigned a unique EPC Manager ID, which is part of all EPC numbers issued by that subscriber. Moreover, the company has the right to participate in more than 40 technology- and business-oriented working groups (e.g. industry action groups, technical action groups, cross industry adoption, and implementation groups). The purpose of these groups is to discuss technological requirements and to develop business cases to further refine EPC-related standards and promote the worldwide introduction of the EPC Network.

The membership figures of EPCglobal have shown strong growth within the past years (cf. Figure 1). Membership has increased from 20 members in 2004 to 1,430 members in 2009, most of them based in the US followed by Germany and Japan. A profile of the EPCglobal member base by region and industry is depicted in Figure 2. Roughly one third of the members can be characterized as typical retail suppliers (i.e. consumer goods, food and beverage, and footwear and apparel), whereas the share of retailers makes up only 2 percent. However, retailers among EPCglobal members include five of the world's ten largest retail companies – Wal-Mart, Carrefour, Tesco, Metro, and Target – with common revenues of more than US$739 billion in 2007 (Deloitte, 2009). In total, the share of EPCglobal members makes up one-third of the top 250 retailers' sales in 2007 worldwide. Notwithstanding its roots in the retail industry, EPCglobal was also able to attract members from other industries, e.g. healthcare and life science, aerospace and defense, and automotive.

Figure 1 EPCglobal growth

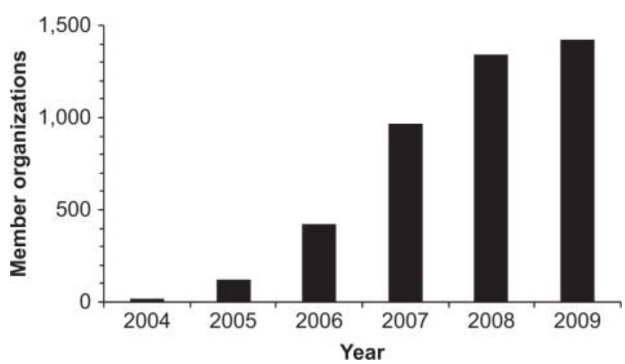
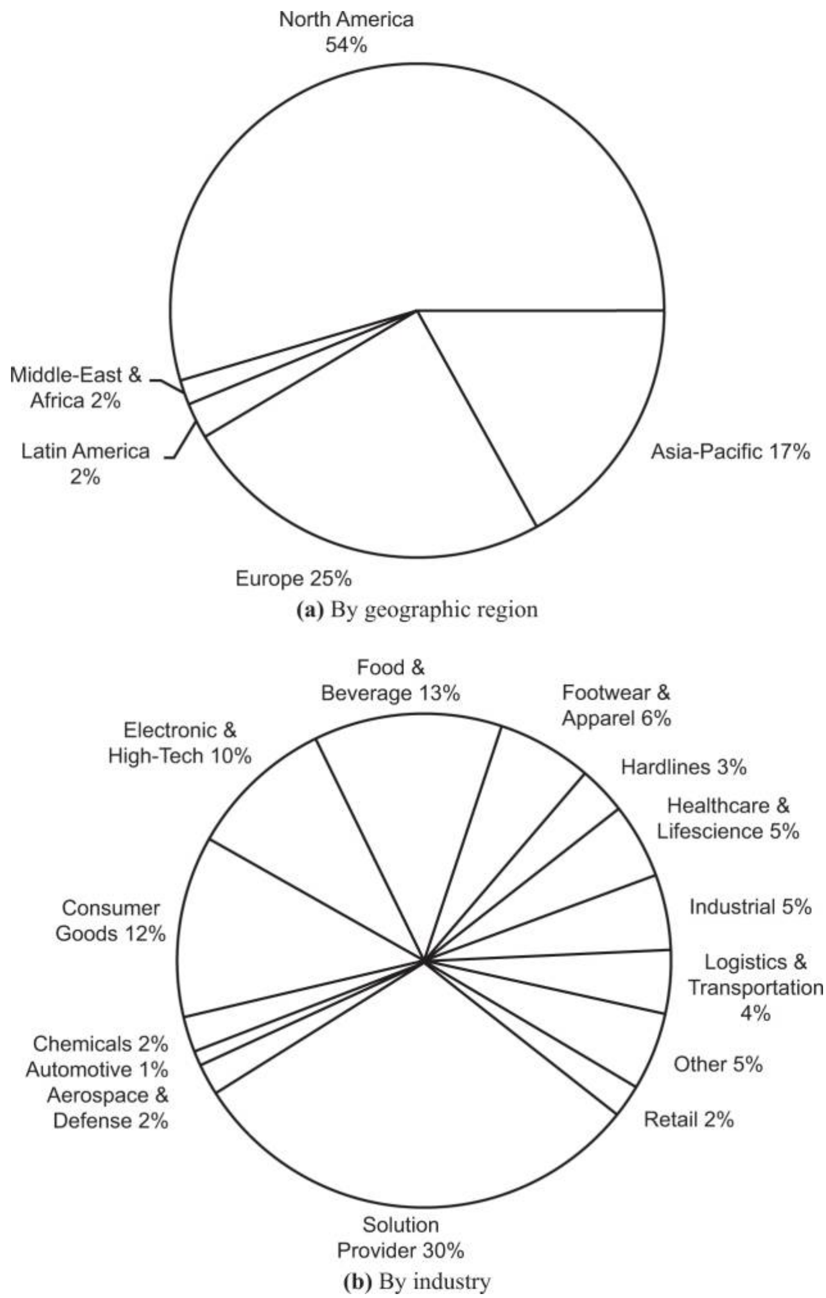


Figure 2 Profile of EPCglobal member organizations



Theoretical background

IT adoption research

The organizational adoption of novel information technologies is one of the classical issues in information systems, operations, and technology management research. The majority of existing IT adoption studies follows a "factor approach" (Kurnia and Johnston, 2000; Jeyaraj *et al.*, 2006), which assumes that a number of predicting variables identified at a particular time determine adoption decisions of an organization. The paradigm underlying the resulting variance models usually traces back to Rogers' "diffusion of innovations" (DOI) theory (Rogers, 2003), which posits that adoption is determined by five perceived attributes of an innovation: the relative advantage, compatibility, complexity, trialability, and observability. Although Rogers' original concept primarily focused on individual level adoption, later studies showed its applicability to organization-level implementations as well (Attewell, 1992; Brancheau and Wetherbe, 1990). DOI theory considers adoption decisions from the rationalistic perspective of "strategic choice" (Child, 1972; Midgley and Dowling, 1993), where adoption is voluntary and aims at improving organizational efficiency and performance. Past research has shown strong empirical support for DOI-based adoption models and that they are appropriate for studying a variety of IT innovations (Moore and Benbasat, 1991; Zhu *et al.*, 2006).

While the original DOI theory concentrates on the characteristics of an innovation as the driving forces of its adoption, other researchers have proposed to complement these by contextual factors known from organizational or institutional theory (Yang and Jarvenpaa, 2005), e.g. network externalities or competitive pressure, which may explain differences in the adoption behavior between organizations considering the same technical innovation. Kwon and Zmud (1987) classified these contexts in five categories: individual, structural, technical, task-related, and environmental factors. Another classification was developed by Tornatzky and Fleischer (1990), who distinguish between three elements of the technological innovation decision:

1 *The technological context*, which describes existing technologies in use and technical skills in the organization.
2 *The organizational context*, which refers to internal measures such as its size or support by top management.
3 *The environmental context*, in which the organization is embedded (i.e. business partners, competitors, industry, society).

Today, the "technology-organization-environment" (TOE) framework has become a widespread theoretical perspective on IT adoption and has been tested for a variety of technologies in the literature (Zhu *et al.*, 2004).

The necessity to investigate contextual factors in addition to technological characteristics is particularly evident for the case of interorganizational systems (IOS), where adoption is influenced by numerous interdependencies among different parties (Power, 2005). A substantial amount of research in this area has been presented in recent years with a strong focus on EDI. Iacovou *et al.* (1995) develop a model of EDI adoption in small organizations that draws upon seven case studies. They find that organizational readiness, external pressure, and perceived benefits are the three major factors of adoption practices. Chwelos *et al.* (2001) empirically confirm the significance of these factors using a sample of 268 firms. Premkumar *et al.* (1994) collected data from 201 US firms and identified the relative advantage, costs, and technical compatibility as important predictors. Premkumar *et al.* (1997) set their focus on the transportation industry and conducted a survey among 181 firms. The results of their analysis indicate that the firm size, competitive pressure, customer support, and top management support are also factors that need to be considered. Kuan and Chau (2001) used the TOE framework to show how the importance of direct benefits, cost, technical competence, industry pressure, and government pressure differ between small and large firms. Further examples of EDI adoption research were given by Chau and Hui (2001), Jun and Cai (2003), Sánchez and Pérez (2005), Seyal *et al.* (2007), and Teo *et al.* (2003). An excellent review of these and other studies was provided by Robey *et al.* (2008), and we refer the reader to this work for a more detailed discussion of the current state of knowledge on EDI adoption.

Prior research on RFID adoption

In contrast to EDI, the research on RFID adoption is still in its infancy with the first publications in 2002. Many of the early scholarly papers were general review articles that discuss the technological characteristics of RFID, applications in the supply chain, and implementation challenges. Often-cited examples are the works by Angeles (2005), Jones *et al.* (2004), Kärkkäinen and Holmström (2002), McFarlane and Sheffi (2003), and Srivastava (2004). Critical adoption factors are usually discussed in these works by drawing the parallel between RFID and EDI, the bar code, or other technologies for the implementation of IOS. Factors mentioned therein include benefits, costs, standards, compatibility, firm size, technological knowledge, and the availability of a common infrastructure for RFID data exchange. A study focusing on external factors on the industry level was presented by Prater *et al.* (2005), who discuss RFID adoption and implementation barriers in grocery retail.

The first empirical studies concentrated specifically on one or more cases of RFID implementation (Lee and Chung, 2006; Brown and Russel, 2007; Loebbecke and Huyskens, 2008; Sharma *et al.*, 2007; Huber *et al.*, 2007). It was only recently that researchers started using the survey method to collect empirical data on RFID adoption from larger samples of organizations. An overview of related works is given in Table I. The fraction of adopters in the respective samples is usually low. None of the studies considered the differences between the perceptions of adopters and non-adopters. Some authors dropped responses from firms already using RFID, and concentrate explicitly on the intention to adopt RFID among non-adopters. Vijayaraman and Osyk (2006) are the only ones who report the number of EPCglobal members among their respondents (15 percent). DOI theory, often in conjunction with the TOE framework, poses the theoretical background for most of the studies. The papers using the advanced techniques of structural equation modeling (SEM) report a total variance explained by the respective models of 42 percent (Goswami *et al.*, 2008), 67.92 percent (Madlberger, 2009), and 79 percent (Lee and Shim, 2007); Tsai *et al.* (2010) do not report the R^2 statistic. Their samples comprise 110 to 134 organizations and are in each case limited to a specific industry (e.g. healthcare) and country (e.g. Singapore and Austria).

The adoption factors investigated in these prior works correspond to those known from earlier research on EDI adoption. Perceived benefits and costs, technological complexity, firm characteristics, and external pressure are examples of factors that could be confirmed for the case of RFID as expected from theory. Notwithstanding the fact that earlier studies were able to improve our understanding of the determinants of an organization's initial decision in favor of RFID, a research gap exists regarding the subsequent adoption process. A positive adoption decision alone does not guarantee long-term assimilation and actual use of a technological innovation within the organization (Sharma *et al.*, 2008). However, the drivers and barriers of the later stages of adoption, which might change fundamentally over time, have so far not received much attention. Against this background, the present study aims to shed light on this under-researched issue by a study based on an international community of early RFID adopters covering the whole supply chain.

Research model

Conceptual framework

In the following, we describe the research model and its hypotheses underlying this study. On the one hand, RFID obviously shares many fields of application with other technologies used in the supply chain. On the other hand, it distinguishes itself from these through a number of specific

Table I Overview of prior survey-based works on RFID adoption

Reference	Sample	Industry	Country	Methodology	Investigated adoption factors
Chang *et al.* (2008)	81 companies, 16.7 percent response rate, 25 percent adopters	Logistics	Taiwan	Factor analysis	Uncertainty of environment; degree of competition in marketplace; pressure of transaction partners; interorganizational dependency; industry environment of suppliers; organizational scale; fundamental establishment IT; burden of cost integration of supply chain strategy; support and participation of top executives; complexity; compatibility; visible profit; visible obstacle; mutual standard
Goswami *et al.* (2008)	110 companies, 22 percent response rate, 0 percent adopters	Manufacturing, logistics	Singapore	SEM (PLS)	Recognition of real options; institutional influence; institutional regulation; mindfulness
Lee and Shim (2007)	126 hospitals, 14.6 percent response rate, 3.2 percent adopters	Healthcare	USA	SEM (LISREL)	Performance gap; market uncertainty; vendor pressure; perceived benefits; presence of champions; financial resources; technology knowledge
Leimeister *et al.* (2007)	114 CIOs, 25 percent response rate, 7 percent adopters	–	Germany	Correlation analysis	Company characteristics; RFID experience; RFID potentials; perceived strategic importance
Lin and Ho (2009)	574 logistics service providers, 31.9 percent response rate, 8 percent adopters	Logistics	China	Regression analysis	Explicitness of technology; accumulation of technology; encouragement for innovation; quality of human resources; governmental support; environmental uncertainty
Madlberger (2009)	113 companies, 12.6 percent response rate, 0 percent adopters	Manufacturing, retail	Austria	SEM (PLS)	Performance gap; internal benefits; interorganizational benefits; expected future costs; firm size; applied IS in logistics
Sharma *et al.* (2008)	101 RFID program managers and senior executives	–	–	Regression analysis	Coercive pressures; mimetic pressures; normative pressures; top management support; IS capabilities; IS infrastructure; financial readiness; direct/indirect benefits; standard convergence; privacy
Shih *et al.* (2008)	134 MBA students, 27 percent response rate, 0 percent adopters	–	Taiwan	Factor analysis	Operation efficiency; manufacturing efficiency; supply chain efficiency; market environment; investment cost; technology characteristic; organization environment
Strüker and Gille (2008)	153 CEOs, CIOs, and heads of logistics, 30.8 percent adopters	–	Germany	Chi-square test, Mann-Whitney-U test	Firm size; integration; costs/benefits; functionality; security/privacy
Tsai *et al.* (2010)	134 retail managers, 31.4 percent response rate, 2 percent adopters	Retail	Taiwan	SEM (LISREL)	Relative advantages; complexity; supply chain integration; organizational readiness
Vijayaraman and Osyk (2006)	211 companies, 14 percent response rate, 5 percent adopters	Warehousing	USA	Descriptive statistics, *T*-test	Compliance requirement; costs; benefits; integration; understanding; standards
Whitaker *et al.* (2007)	354 companies, 70.8 percent response rate, 12.7 percent adopters	–	USA	Regression analysis	IT application deployment; IT budget; firm revenue; industry

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features, such as the ability to create real-time visibility over previously unobservable physical operations (Lee and Özer, 2007). These fundamental differences between innovations require researchers to repeatedly test theories for the case of novel IT to confirm known determinants and identify new ones (Fichman, 1992; Lai and Guynes, 1994; Swanson, 1994). Therefore, the proposed model draws on findings from our review of the adoption literature, which serve as foundation for our theoretical hypothesis development. We consider nine influence factors in three contexts, which have shown to be important predictors of IOS adoption. The overall model structure reflects the logic of the TOE framework, which has been used in several works on IOS adoption.

Technological factors

The degree of technological complexity denotes the difficulties associated with understanding, implementing, and using an innovation (Rogers, 2003; Seymour *et al.*, 2007). A high level of complexity can therefore raise doubts within an organization as to the success and benefits of new technology and delay or even prevent its adoption. In the case of RFID, skills regarding the physical characteristics of RF communications, the integration of RFID components with an organization's IT infrastructure, and the transformation of business processes to make use of the new data quality are required to efficiently deploy the technology. Owing to the novelty of RFID, the corresponding IT and process capabilities may not be present even within IT-intensive organizations (Thiesse *et al.*, 2009). The complexity of RFID is therefore likely to have a negative influence on the adoption of RFID (Bradford and Florin, 2003; Premkumar and Roberts, 1999; Premkumar *et al.*, 1997; Tornatzky and Klein, 1982):

H1. Perceived complexity negatively influences the adoption of RFID.

The compatibility of an innovation is reflected in its perceived compatibility with existing values, experiences, strategic orientation, deployed infrastructure, and the essential needs of an organization (Brown and Russel, 2007; Premkumar *et al.*, 1997; Rogers, 2003; Tornatzky and Klein, 1982). The technological compatibility of IT innovations with regard to hardware and software facilitates the integration into the existing infrastructure of an organization. For the adoption of RFID, for example, the presence of a flexible IT infrastructure is crucial to be able to integrate a large number of reader devices and the associated middleware components with minimal effort. If this is not the case, there may be a slower adoption and diffusion within the organization and thus also within the entire value chain (Brown and Russel, 2007). Moreover, every innovation, especially new IT, brings changes with it, for example, to other IT systems of the organization, procedures and processes, or organizational structures. Accordingly, the better a technology can be integrated into the organization, the greater are the chances that a benefit from its adoption can quickly be generated. Similarly, a higher level of satisfaction among users can be expected (Bradford and Florin, 2003). Therefore, the RFID adoption decision is likely to be positively influenced by a high level of compatibility with the respective organization (Premkumar and Roberts, 1999; Premkumar *et al.*, 1997):

H2. Perceived compatibility positively influences the adoption of RFID.

The perceived benefits of a technological innovation encompass the expected advantages for the organization and the extent to which it is perceived as better than the technology to be substituted (Brown and Russel, 2007; Premkumar *et al.*, 1997; Rogers, 2003; Tornatzky and Klein, 1982). Impacts resulting from the use of a new technology can be distinguished into direct impacts on operational processes (e.g. reduced operating costs and improvements in data quality) and indirect impacts, which affect management processes and may lead, for example, to an increase in competitiveness or an improved image of the organization (Chwelos *et al.*, 2001; Iacovou *et al.*, 1995; Kuan and Chau, 2001; Sharma *et al.*, 2008). The ways IT creates these impacts on firm performance can be categorized into process automation, informatization, and transformation (Mooney *et al.*, 1996). As regards RFID, several applications areas and benefits were discussed in all three categories in the related literature (Ngai *et al.*, 2008; Thiesse and Condea, 2009; Liao *et al.*, 2011). The benefits generated by automation are mainly the result of the substitution of manual labor. For operational processes, this means time and personnel cost savings, whereas in terms of administrative processes, the IT benefits manifest themselves through the simplification of the monitoring and reporting activities. In contrast, the value of process informatization arises from the ability of IT to efficiently collect, store and distribute data. RFID not only helps organizations to gather data more efficiently but also improves the respective level of detail and timeliness, which may lead to greater flexibility and better decision-making in the management of supply chains (Thiesse *et al.*, 2009). Transformational effects, again, lead to an increase in value resulting from the technology and a simultaneous change in the business process. All considered, an organization's perception of the mentioned benefits have the potential to exert a positive influence on the adoption decision:

H3. Perceived benefits positively influence the adoption of RFID.

The cost of IT adoption encompasses primarily the cost of installing the necessary hardware and software as well as the deployment of an infrastructure between partner organizations. With regard to RFID, the most substantial cost drivers are the cost of equipping physical goods with transponder labels, installing reader devices at critical read points along the supply chain, and integrating these components with existing systems (Brown and Russel, 2007; Sharma *et al.*, 2008). Additional costs arise from training the staff and redesigning work routines (Papastathopoulou *et al.*, 2007; Premkumar *et al.*, 1997; Tornatzky and Klein, 1982). Furthermore, the question of the cost and benefit sharing among the supply chain partners has for a long time been seen as one of the major barriers to the rapid adoption of RFID. It is particularly the suppliers to the international retail giants that often voiced the fear of bearing the cost of RFID while their customers would keep the benefits for themselves (Seymour *et al.*, 2007). Against this background, it can be expected that the perceived cost of RFID would negatively influence adoption:

H4. Perceived costs negatively influence the adoption of RFID.

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Organizational factors

The size of an organization is a critical factor for the adoption of innovations. Large organizations are usually more capable of mobilizing the necessary capital and hedging against risks. Failures can thus be better compensated, so that the companies experiment more often with innovations and their application possibilities. In addition, the probability is higher than in an organization with many employees, the necessary knowledge on how to introduce and use an innovation already exists. In contrast, smaller organizations, although often regarded as a creative and open to new ideas, can often not raise the financial resources for the use of novel IT (Premkumar and Roberts, 1999; Premkumar *et al.*, 1997; Iacovou *et al.*, 1995; Grover and Goslar, 1993). In the case of RFID, it was most of all the large retailers and consumer goods manufacturers who conducted the first well-publicized trials and promoted the development of standards to establish the technology in the supply chain. It therefore seems obvious to assume a positive relationship between the firm size and the adoption of RFID:

H5. Firm size positively influences the adoption of RFID.

The support of the executive board is usually a crucial prerequisite for the adoption of an innovation (Liang *et al.*, 2007). The main reasons are that it is ultimately the top managers who make the adoption decision as well as the fact that IT investment decisions often come with organization-wide impacts. The management is often in a better position to recognize the strategic potentials of an innovation and to develop long-term visions. Moreover, the visible support of senior managers within the organization may also positively affect the behavior of employees and thus determine the success or failure of the innovation adoption decision (Thong *et al.*, 1996). Clear signals from the top management level within the organization emphasize the importance of innovation (Bradford and Florin, 2003). Of particular importance for innovation adoption is the support of management in the case of network technologies and if partner organizations need to be convinced (Premkumar and Roberts, 1999; Premkumar *et al.*, 1997). This also applies to RFID because the strategic benefits are expected through the improved co-ordination and more efficient interorganizational processes among supply chain partners. The deployment of RFID and its integration with existing processes can be lengthy, so the continued support of top management is essential (Sharma *et al.*, 2008). This support can, for example, manifest itself through management participation in various planning, design, development, and implementation activities, and thus promote adoption (Bruwer, 1984):

H6. Top management support positively influences the adoption of RFID.

The resistance of a company's employees or the fear of change can be influential factors within an organization. Employees could be confused because they may be unable to deal with the new technology or lose their jobs due to the automation of previously manual tasks (Chowdhury *et al.*, 2008). This has in turn an impact on their motivation and productivity, and thus also on their expectations regarding the adoption of an innovation. The potential outcome is massive resistance within the organization to the point of stigmatization of a technology (Seymour *et al.*, 2007). It can therefore be assumed that the fear of employees negatively influences the adoption of an innovation:

H7. The employees' fears from RFID negatively influence its adoption.

Environmental factors

Environmental factors encompass a variety of influences from the outside of the organization on its adoption decisions, which have different origins. On the one hand, suppliers and customers within the supply chain can be the driving forces of IT adoption. RFID is regarded by many as a technology that will intensify cooperation and coordination among business partners by an increased level of visibility over physical processes along the logistical chain (Lee and Özer, 2007). The common vision of using RFID as a means for closer integration of organizations can therefore exert a positive influence on its adoption:

H8. Forces within the supply chain positively influence the adoption of RFID.

On the other hand, it may be a number of additional forces beyond immediate supply chain partners that trigger adoption decisions. Organizations might feel competitive pressure by an increasing number of other adopters in the same industry, which ultimately turns rapid adoption into a strategic necessity (Chwelos *et al.*, 2001; Iacovou *et al.*, 1995; Kuan and Chau, 2001; Premkumar *et al.*, 1997; Sharma *et al.*, 2008). The potential of improving an organization's relative position in the market by the deployment of RFID poses another example of the role of competition. Pressure to adopt an innovation or a particular standard may also arise from industry associations or strong lobbyists. Moreover, external pressure can be the consequence of mandates issued by one or more particularly powerful companies but also by governmental regulations (Chwelos *et al.*, 2001; Premkumar *et al.*, 1997; Rogers, 2003; Sharma *et al.*, 2008). It is especially smaller organizations that are often more vulnerable to external pressure than large ones (Premkumar and Roberts, 1999). Hence, external pressure is likely to affect RFID adoption positively:

H9. External pressure positively influences the adoption of RFID.

Data collection and analysis

Instrument development

To test the research model and the associated hypotheses proposed above, we designed a questionnaire on the basis of an extensive review of the IOS adoption literature. The measurement scales were operationalized by adopting items from existing scales wherever possible and adapting them to the specific context of RFID. An overview of the instrument and the sources used for the scale development is given in Table II. Instead of modeling the dependent variable as a mere binary variable – as is common in most adoption studies – we follow the approach taken by Chwelos *et al.* (2001), which better suits a study of organizations in the process of adopting a new technology. As detailed in the appendix, all variables were measured using multi-item five-point Likert scales.

Table II Construct operationalization

Construct	Items	Sources
Adoption decision	2	Brown and Russel (2007), Chwelos *et al.* (2001)
Complexity	3	Brown and Russel (2007), Premkumar and Roberts (1999)
Compatibility	3	Bradford and Florin (2003), Brown and Russel (2007), Premkumar and Roberts (1999), Papastathopoulou *et al.* (2007)
Benefits	11	Bradford and Florin (2003), Chwelos *et al.* (2001), Kuan and Chau (2001)
Costs	5	Brown and Russel (2007), Premkumar and Roberts (1999)
Firm size	2	Brown and Russel (2007), Premkumar and Roberts (1999), Zhu *et al.* (2006)
Top management support	5	Bradford and Florin (2003), Brown and Russel (2007), Premkumar and Roberts (1999)
Employee fears	2	Brown and Russel (2007), Papastathopoulou *et al.* (2007)
External pressure	5	Bradford and Florin (2003), Chwelos *et al.* (2001), Iacovou *et al.* (1995)
Supply chain forces	3	Chwelos *et al.* (2001), Premkumar and Roberts (1999), Zhu *et al.* (2006)

The content validity was guaranteed by a two-step process. First, each item was reviewed by a panel of RFID experts from three different research institutions for its content, scope, and purpose. Their feedback led to various changes in the item wording and an overall restructuring of the questionnaire. Second, the revised questionnaire was distributed among 43 members of the RFID working group of the German car manufacturers' association (VDA). The questionnaire was consistently rated by these company representatives as comprehensive and complete. The opportunity for free suggestions for improvements was used as well, but these comments did not give reason to further changes of the survey instrument.

Sample and descriptive statistics

The data for our main study were collected from EPCglobal subscribers worldwide following the principles of survey design by Dillman (2007). Starting with a complete list of member organizations, we dropped all entries that did not come into question as potential or actual adopters of RFID (e.g. EPCglobal country organizations, academic institutions). Our questionnaire was then sent out to the respective company's contact person as stated in the EPCglobal member database. The survey got official support from EPCglobal by making available their mailing list. In a first step, 1,237 organizations were asked to respond by mail, e-mail, or fax. Two reminders were sent to non-respondents before the data collection period eventually ended after three months.

In total, we obtained responses from 167 companies. From these, eight were not usable due to incomplete questionnaires and were excluded from the analysis. Accordingly, our sample included 159 organizations, yielding a response rate of 13 percent, which is consistent with the previously reviewed RFID adoption studies and other research work on IOS adoption. Sample characteristics including a profile of the respondents are given in Table III. The classification of companies regarding their industry was adapted from the EPCglobal subscriber database to assess the congruence of our sample to the population from which it was drawn. On the downside, a closer inspection of the EPCglobal classification revealed some smaller inconsistencies that have to be kept in mind when interpreting the figures. The group of "solution providers", for example, includes many companies that are not only providers but also users of RFID technology, such as semiconductor manufacturers that implemented RFID for production lot tracking. We therefore decided not to exclude these organizations from our analysis of technology adopters. Another example is the large group labeled as "Others", which includes companies coming from a variety of industries, e.g. agriculture, media, and utilities.

To test for non-response bias, we compared early with late respondents as suggested by Armstrong and Overton (1977). A t-test with constructs from all three contexts of our research model did not reveal any significant differences at the 0.05-level. Accordingly, non-response bias does not appear to be a problem.

Following Rogers' (2003) classification of adopter types, 17 percent of respondents characterized their organization as "innovator" and 37 percent as "early adopter". A total of 86 percent use bar codes for automatic identification purposes, with 70 percent using the EAN/UPC symbology. Regarding the use of RFID, 47 percent stated that the technology was already used in some form; an additional 16 percent have already conducted tests and made plans for future deployment. Only 3 percent currently do not consider an evaluation or implementation of RFID. Among the organizations that have implemented RFID, 61 percent already use EPC-compliant systems. When asked about the reasons for adopting EPC standards and joining EPCglobal, 40.3 percent of the respondents stated future or expected customer requirements as the main driver behind their decision followed by a customer's mandate and an internal decision process (see Figure 3).

Measurement model

We used SPSS/AMOS 17 for the statistical data analysis. Several steps were taken prior to testing the structural model. We started with a principal components analysis (PCA) using Equamax rotation to identify the factorial structure of our data. In contrast to our research model, a 12-factor structure was identified. The results indicate that items from the benefits construct load on two different factors. An examination of the content of the respective items led us to the conclusion that it is necessary to distinguish between the company-internal benefits from RFID (e.g. cost reduction, reduced error rates) and benefits from its use among the supply chain partners (e.g. increased service levels, faster response to orders). This distinction is consistent with prior studies (e.g. Madlberger, 2009; Shih *et al.*, 2008). Accordingly, we decided to reformulate *H3* as follows:

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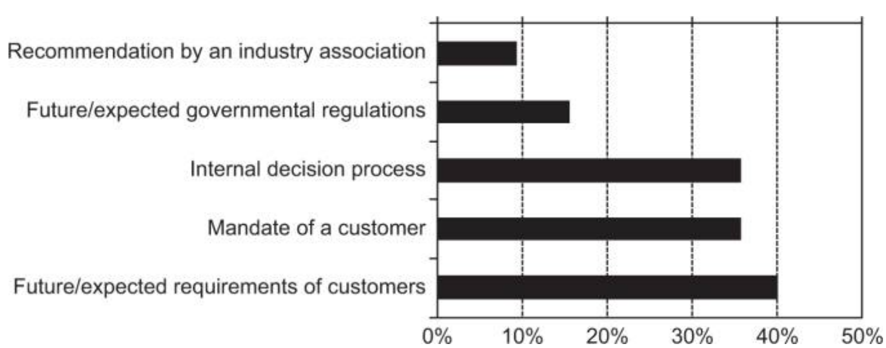
Table III Sample characteristics

	n	%		*n*	%
Organizations			***Respondents***		
Industry			***Number of employees***		
Consumer goods	22	13.8	< 100	27	17.0
Food and beverage	15	9.4	100 < 1,000	27	17.0
General merchandise and apparel	5	3.1	1,000 < 5,000	23	14.5
Retail and leisure	4	2.5	5,000 < 10,000	13	8.2
Automotive and transportation	2	1.3	10,000 < 50,000	28	17.6
Consumer electronics and high-tech	15	9.4	50,000 < 100,000	13	8.2
Aerospace and defense	1	0.6	100,000 < 150,000	7	4.4
Healthcare and life sciences	16	10.1	150,000 < 250,000	9	5.7
Logistics and distribution	11	6.9	> 250,000	11	6.9
Industrial manufacturing	10	6.3	No answer	1	0.6
Chemicals and resources	2	1.3			
Solution provider	34	21.4	***Management level***		
Other	22	13.8	Executive	23	14.5
			Senior	44	27.7
Supply chain function			Middle	62	39.0
OEM	31	19.5	No answer	30	18.9
Supplier	73	45.9			
Logistician	16	10.1	***Age***		
Trader/retailer	10	6.3	20-29	12	7.5
Other	28	17.6	30-39	35	22.0
No answer	1	0.6	40-49	55	34.6
			50-59	37	23.3
Company headquarters			> 60	10	6.3
North America	81	50.9	No answer	10	6.3
Europe	47	29.6			
Asia Pacific	26	16.4	***Department***		
Middle East and Africa	3	1.9	General management	29	18.2
Latin America	2	1.3	Production	7	4.4
			Marketing and sales	26	16.4
Annual sales volume			After-sales and customer service	3	1.9
<$100,000	8	5.0	R&D	30	18.9
$100,000 < $500,000	6	3.8	IT	32	20.1
$500,000 < $1 m	5	3.1	Logistics	16	10.1
$1 m < $5 m	5	3.1	Other	15	9.4
$5 m < $10 m	6	3.8	No answer	1	0.6
$10 m < $100 m	20	12.6			
$100 m < $500 m	12	7.5			
$500 m < $1 bn	13	8.2			
$1 bn < $10 bn	31	19.5			
$10 bn < $25 bn	15	9.4			
$25 bn < $40 bn	7	4.4			
>$40 bn	24	15.1			
No answer	7	4.4			

Figure 3 Reasons for adopting EPC standards



H3a. Benefits from company-internal applications positively influence the adoption of RFID.

H3b. Benefits from applications in the supply chain positively influence the adoption of RFID.

We also found that two items (EP1, EP2) from the external pressure construct clearly load on a different factor than the other three. However, this first factor did not show sufficient internal consistency measured by Cronbach's Alpha, and the corresponding items were therefore dropped. Furthermore, four items associated with other constructs (CPX3, CPA1, BE8, and CO1) showed factor loadings below 0.5 and were dropped, too. The alpha values for the remaining factors all met the cut-off value of 0.7 as recommended by Nunnally (1978). No problematic cross-loadings could be observed. The results of this analysis step are summarized in Table IV. The Kaiser-Meyer-Olkin measure of sampling adequacy (Kaiser, 1974) was checked as well for our sample. The resulting value of 0.7 indicates that we can assume to have yielded reliable factors (Hutcheson and Sofroniou, 1999; Pallant, 2001).

Table IV Factor loadings, Cronbach's alpha, and descriptive statistics

Factor	Item	Loading	α	Mean	SD
Adoption decision	AD1	0.82	0.75	2.37	1.01
	AD2	0.66			
Complexity	CPX1	0.91	0.83	4.12	0.96
	CPX2	0.89			
Compatibility	CPA2	0.90	0.88	2.35	1.12
	CPA3	0.90			
Company-internal benefits	BE1	0.87	0.84	2.02	0.79
	BE2	0.63			
	BE3	0.76			
	BE4	0.55			
Supply chain benefits	BE5	0.68	0.77	1.83	0.70
	BE6	0.76			
	BE7	0.53			
	BE9	0.76			
	BE10	0.63			
	BE11	0.69			
Costs	CO2	0.62	0.80	2.94	0.88
	CO3	0.79			
	CO4	0.81			
	CO5	0.71			
Firm size	FS1	0.92	0.85	5.94	2.63
	FS2	0.91			
Top-management support	TMS1	0.73	0.92	2.38	1.12
	TMS2	0.73			
	TMS3	0.74			
	TMS4	0.66			
	TMS5	0.74			
Employee fears	EF1	0.75	0.75	4.16	0.97
	EF2	0.85			
External pressure	EP3	0.72	0.71	2.62	0.90
	EP4	0.79			
	EP5	0.57			
Supply chain forces	SCF1	0.77	0.70	3.65	1.01
	SCF2	0.67			
	SCF3	0.71			

We continued with verifying the fit of the internal structure of our model through the more rigorous validity criteria of a confirmatory factor analysis. For this purpose, we ensured the convergent validity by examining the item reliability, composite reliability, and average variance extracted (AVE). First, the item reliability was assessed by comparing the squared standardized regression weights with the recommended minimum value of 0.707 (Hair *et al.*, 1998). This step led to a further purification of our scales. We decided to exclude six items, which did not surpass this threshold (BE2, BE7, BE9, BE11, TMS1, and SCF3) because we felt that the content validity of the corresponding constructs would not substantially be diminished. Second, the composite reliability was examined, which indicates to what extent items measure their respective construct well. All factors exceeded the cut-off value of 0.6 (Bagozzi and Yi, 1988). Third, we calculated AVE values and found that these were greater than 0.5 for each construct with the exception of "external pressure", which was excluded from further analysis. As shown in Table V, the square root of the respective AVE was also larger than the correlations between the constructs, adequately demonstrating discriminant validity (Fornell and Larcker, 1981).

Structural model

The overall fit measures were computed to assess the fit of our structural model to the data. Due to a small sample size to model size ratio, we used Swain's (1975) correction to the chi-square variate, as recommended by Herzog *et al.* (2007). The goodness-of-fit criteria used and their recommended cut-off values include $\chi^2/\mathrm{df} < 2$, $\mathrm{TLI} > 0.95$, $\mathrm{CFI} > 0.95$, Gamma Hat > 0.95, and $\mathrm{RMSEA} < 0.06$ (Carmines and McIver, 1981; Hu and Bentler, 1999). The results for our model come very close to or exceed these commonly accepted standards ($\chi^2/\mathrm{df} = 1.33$, $\mathrm{TLI} = 0.944$, $\mathrm{CFI} = 0.957$, Gamma Hat $= 0.961$, $\mathrm{RMSEA} = 0.046$), showing that the model provides an acceptable fit to the data.

The results of the hypothesis evaluation are given in Figure 4. The squared multiple correlation of the dependent variable indicates that our model explains 65 percent of its variance. From the path coefficients together with the corresponding *p*-values, we see that *H4*, *H6*, and *H9* can be supported, whereas *H1*, *H2*, *H3a*, *H5*, and *H7* must be rejected. The path between the supply chain benefits and adoption turned out to be significant, too. However, the coefficient indicates a negative relationship between the two variables, which contradicts *H3b*. We checked for multicollinearity effects in our model using variance inflation factor (VIF) analysis because counterintuitive results of this kind can be a consequence of multicollinearities, which magnify or obscure the relationships between constructs. The VIFs range between 1.25 and 2.84, which is far below the standard 10.0 cut-off (Myers, 1990; Tabachnick and Fidell, 2001), and we concluded that no significant undesirable multicollinearity was present.

Discussion

Research implications

The objective of the present study was to identify the determinants of RFID adoption with the help of a structural model, which incorporates factors related to the technology,

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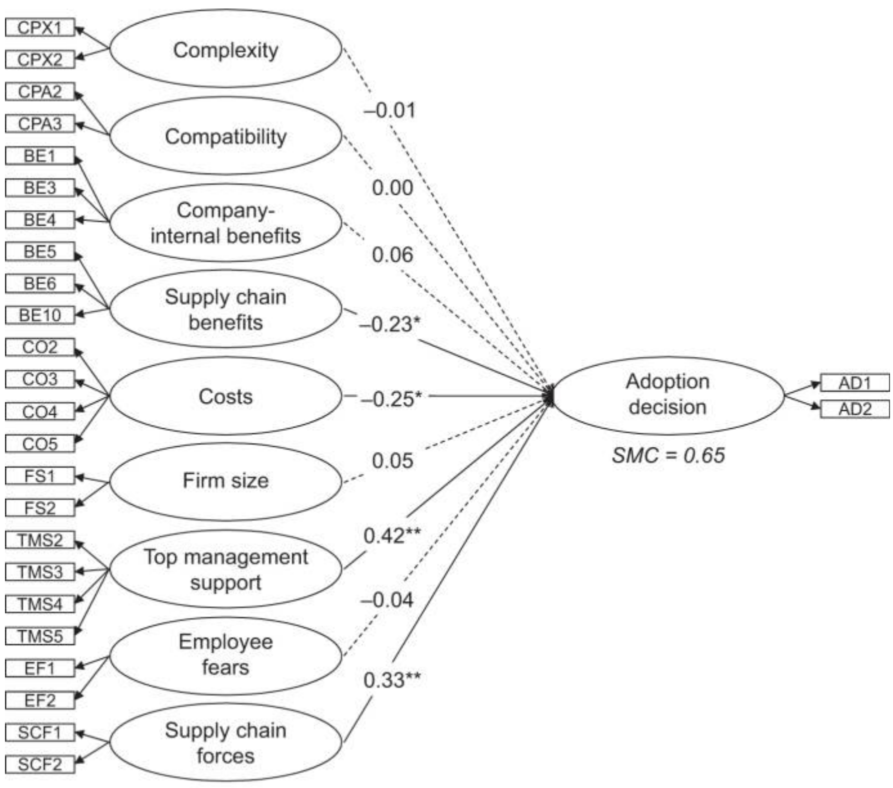
Table V Composite reliability, average variance extracted, and correlation matrix

	CR	AVE	Correlations AD	CPX	CPA	BEC	BES	CO	FS	TMS	EF	SCF
AD	0.82	0.62	0.79									
CPX	0.89	0.72	−0.15	0.85								
CPA	0.92	0.79	0.31	−0.17	0.89							
BEC	0.77	0.53	0.18	−0.07	0.30	0.73						
BES	0.87	0.70	0.03	−0.01	0.16	0.60	0.84					
CO	0.80	0.50	−0.53	0.24	−0.19	−0.23	−0.14	0.71				
FS	0.92	0.77	0.31	0.07	0.18	0.11	0.15	−0.11	0.88			
TMS	0.95	0.81	0.70	−0.12	0.43	0.23	0.26	−0.50	0.32	0.90		
EF	0.90	0.60	−0.23	0.42	−0.20	0.00	−0.15	0.31	−0.16	−0.25	0.78	
SCF	0.91	0.63	0.59	−0.08	0.26	0.29	0.20	−0.21	0.36	0.52	−0.11	0.79

Notes: The diagonal reports the square roots of the average variance extracted (AVE); AD – adoption decision, CPX – complexity, CPA – compatibility, BEC – company-internal benefits, BES – supply chain benefits, CO – costs, FS – firm size, TMS – top management support, EF – employee fears, SCF – supply chain forces

Figure 4 Results of the model test



Notes: Solid lines indicate significant paths, dotted lines indicate nonsignificant paths. SMC = squared multiple correlation; * $p < 0.05$; ** $p < 0.01$

the organization, and its environment. Our results contribute to the adoption literature in two ways. First, we were able to identify adoption factors for RFID as a special case of a technology for the implementation of interorganizational information systems. In contrast to other studies, our research focus was set on the determinants of the adoption process after an initial decision in favor of RFID was already made. Second, our analysis was builds upon a unique data set of early adopters of the EPC Network, a family of RFID standards based on the so-called "electronic product code" numbering scheme for the identification of arbitrary physical goods in the supply chain. The results of the hypotheses tests allow for drawing conclusions that contribute to the existing body of adoption literature.

We were able to confirm the importance of a number of factors, which have been proposed in prior works as critical for IT adoption. Top management has shown to exert the strongest influence on RFID adoption, which highlights the role of top executives' belief in the business potential of a novel information technology even after the strategic adoption decision. Second, the technology costs are still perceived as a barrier despite the massive decline of prices for hardware and software components in recent years. A possible explanation might be that more experienced companies are becoming aware that RFID is not a plug-and-play technology but rather requires substantial efforts regarding staff training and integration with operational systems. Moreover, we could show that RFID adoption is also positively enforced by the activities of organizations seeking to improve the cooperation among their supply chain partners with the help of the new technology. Regarding these three factors, we were able to confirm their importance for IT adoption in line with prior works (e.g. Lee and Shim, 2007; Madlberger, 2009; Sharma *et al.*, 2008; Strüker and Gille, 2008; Vijayaraman and Osyk, 2006).

A fourth factor that proved significant is the perception of RFID benefits. Our results suggest that it is necessary to distinguish between the benefits related to company-internal operations and the benefits related to interorganizational business processes, such as increased service levels and responsiveness to customer orders. This distinction was proposed by other researchers, too (e.g. Madlberger, 2009; Shih *et al.*, 2008). However, while the influence of company-internal benefits could not be supported, supply chain benefits turned out to be negatively associated with the adoption decision, which seems to contradict established theory at first (e.g. Madlberger, 2009; Tsai *et al.*, 2010). A conceivable explanation for this phenomenon may nevertheless be found in the fact that RFID adoption in the firm is not a homogeneous phenomenon but rather can take a variety of forms. As pointed out by Attaran (2007) and Hardgrave *et al.* (2007), three different options regarding RFID adoption can be observed in practice. Organizations that do not see RFID as a source of business value but merely as a necessity because of the current or future market needs are likely to pursue a simple "slap-and-ship" strategy where tags are placed on logistical units before shipping to a designated customer. In this case, adoption is limited to the investment in transponder labels and a small number of reader devices, which allows for very rapid but shallow assimilation. In contrast, a form of deeper assimilation is "data understanding", which denotes an increased level of visibility over physical processes through the generation of novel performance indicators based on RFID data. Third, companies can choose to make use of RFID as an enabler of drastically changed or entirely new processes. RFID-enabled shelf replenishment in retail store provides an example, where the technology allows the retailer to distinguish between backroom and sales-floor inventory. This can lead to a complete elimination of manual reviews and their replacement with system-triggered shelf replenishments, hence yielding increased product availability and higher sales. However, this deepest form of assimilation also comes with extensive efforts as regards to process redesign, IS integration, and change management (Thiesse *et al.*, 2009). As a consequence, companies that seek to draw a maximum of business value from RFID are more likely to spend more time on initial testing and development before the final adoption decision is made, which may explain the negative correlation found in our data. This finding was already conjectured by Sharma *et al.* (2008), but no prior study has so far been able to support it.

The influence of a number of other factors known from prior research could not be supported by the study, which may partly be due to the fact that we only investigated organizations that had already made a decision in favor of a RFID standard. It is particularly the technological complexity and compatibility that seem to take a back seat as soon as organizations have decided to adopt RFID, be it voluntarily or not. This result contradicts studies of non-adopters (e.g. Lee and Shim, 2007; Lin and Ho, 2009; Tsai *et al.*, 2010). The data suggest that with the acceptance of standards, the role of technological factors loses importance, whereas organizational and environmental factors attract notice to decision-makers. Standardization might also explain that our hypothesis regarding the role of firm size could not be supported though the role of this variable has been highlighted in other IT-adoption studies (e.g. Strüker and Gille, 2008). Small organizations are less likely to adopt an emerging technology because they usually do not possess the necessary resources for extensive knowledge building and testing. However, established standards lower this barrier and reduce the risks of new technology deployments, which makes adoption more attractive even to smaller firms. Finally, our results do not give rise to the concern that the employees' fears from RFID due to its complexity and the threat of job losses might have a negative impact on its adoption.

Managerial implications

Besides the theoretical perspective, our study allows for drawing conclusions relevant to management practice. Because our results highlight the importance of top management support for RFID adoption, members of a project team responsible for RFID implementation in their organization should make sure they have sponsors on the top management level. These should be involved into every phase of the project and continuously be informed about technological advances, feasibility tests, business case analyses, success reports from other companies, etc. The role of top management in RFID adoption is particularly critical if no quick results from company-internal implementations can be expected because even small changes in cost perceptions in combination with a lack of strategic standing may easily endanger the continuation of the project. Another reason for involving top executives early is the highly political nature of RFID projects if the creation of business value from the technology requires close coordination with suppliers or customers. Besides, cooperation with partners also offers the opportunity to reduce the impact of the technology cost on the adoption decision through joint agreements on cost sharing models.

Another means to counter the risks associated with RFID implementations is the consideration of standards. Our results may be interpreted such that the adoption of an established standard to a large extent neutralizes technology-related barriers, for example, the perceived complexity and compatibility. This is because standards predetermine several system parameters, reduce search costs associated with technology selection, and reduce the technological know-how needed for the system design and deployment. One option for promoting the use of standards is to become a member of an industry association like EPCglobal. Taking an active role in the early stages of the standardization process allows organizations to move forward quickly on the learning curve and to exert influence on the shaping of future standards. A second option is to cooperate with other companies in the context of industry initiatives, which are driven by a small group of powerful actors in the supply chain. Presumably the most prominent and best-publicized example is Metro Group's so-called "future store initiative", which encompasses various pilot implementations and a test lab open to the public. These initiatives pose a cost-efficient means to observe and to try the technology in a real-world environment.

From the perspective of EPCglobal and the protagonists of RFID standards (i.e. Wal-Mart, Metro, and other industry behemoths), the study might indicate that their past efforts in the establishment of a common RFID standard with the help of industry-driven working groups have been partially successful. We conclude from our results that EPCglobal's existence and its visibility beyond the retail industry changed the perception of RFID regarding technological barriers to adoption. However, the hope that RFID adoption is now mostly driven by a clear understanding of its value cannot be confirmed. The importance of top management support, for instance, indicates that adoption is still more dependent on beliefs than on proven benefits. For this to change, EPCglobal should further intensify its development of the business case for RFID with a specific focus on quick and quantifiable wins to foster adoption.

Past experiences from the history of the bar code, where the creation of value on a large scale from its use for better integrating the supply chain took almost 20 years, can provide a valuable lesson here. Despite the current prevalence of the bar code, its success was not assured from the outset. Among the obstacles to implementation in the 1970s were consumer resistance to the elimination of item price marking, high scanner equipment costs, and the manufacturers' initial reluctance to redesign product labels. In the long run, however, the industry-wide acceptance was driven by a strong business case that relied on "hard" and quantified benefits, which were likely to quickly result in a positive return on investment. By keeping the business case focused on easily justified savings based on real data, the proponents of barcode standards were eventually able to respond to the cost concerns of the grocery retailers, manufacturers, and distributors. In addition, a second lesson can be learned regarding the question to what extent the diffusion of RFID and EPC standards will continue across industry boundaries. In the case of the bar code, it took about ten years before the technology originally developed for grocery retail was also deployed in the automotive and other industries. This adoption, however, referred only to the base technology layer, whereas virtually each industry decided to develop its own set of application-oriented bar code standards. To speed up the cross-industry adoption of RFID and to avoid a fragmentation of the standards landscape, EPCglobal should take great care to involve all target industries in its action groups to ensure the fit of their standards with a variety of application requirements beyond retail.

Limitations and further research

Even though every effort has been made to ensure the validity of our findings, the present study comes with limitations that are partly typical for the entire stream of adoption research and partly specific to our research. With regard to the first, it is important to interpret our results in the context of the research paradigm underlying the vast majority of innovation adoption studies. This so-called "factor approach" posits that greater innovation-related needs and abilities lead to a greater quantity of innovation in terms of frequency, earliness, or extent of adoption (Jeyaraj *et al.*, 2006). The resulting variance models are to some extent prone to a number of well-known theoretical biases. These include the implicit assumption that all adoption is good and that adopters make rational decisions (Rogers, 2003; Fichman, 2004; Robey *et al.*, 2008). Furthermore, typical methodological biases are the consequence of data sets based on unreliable self reports and the fact that non-adopters are traditionally understudied. The latter holds in particular for the present study, which is based on a survey conducted among a group of standards adopters.

More specific limitations include our focus on the EPC Network (i.e. in contrast to RFID technology in general), which seems justified given the importance that the EPC family of standards has gained in the context of logistical operations. However, it should be noted that many other areas of application exist beyond the supply chain (e.g. access control, ticketing), which are dominated by other standards such as ISO 15693. Moreover, while the size of our sample is sufficient for testing the constructed structural model, 159 responding organizations are not enough to investigate the differences in the adoption behavior between different geographic regions, industries, or positions in the supply chain. As the worldwide diffusion of RFID technology continues, the opportunity for gathering larger samples should be seized for in-depth comparisons of the role of adoption factors between different groups of organizations. Third, our study was limited to a set of factors, which have been shown to explain a substantial portion of the variance in the dependent variable. However, future studies might identify additional factors that we did not consider in our model. On the one hand, the existing literature on interorganizational systems encompasses a plethora of constructs that researchers could attempt to confirm for the case of RFID. On the other hand, explorative case studies of adopting organizations might be useful to reveal entirely new RFID-specific factors.

We also see opportunities for future research using fundamentally different theoretical and methodological approaches. For example, it is evident that the role of adoption determinants can change over time. It would thus be interesting to compare our results to those from studies that consider other phases in the adoption process. The importance of the time factor also calls for studies that look beyond the limitations of variance models and try to develop process models of the causal chain of events that eventually lead to RFID adoption. Similarly, the different forms of RFID adoption (i.e. shallow vs. deep assimilation) and their impacts on firm performance might become interesting areas for further research endeavors.

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References

Angeles, R. (2005), "RFID technologies: supply chain applications and implementation issues", *Information Systems Management*, Vol. 22 No. 1, pp. 51-65.

Armstrong, J.S. and Overton, T.S. (1977), "Estimating non-response bias in mail surveys", *Journal of Marketing Research*, Vol. 14 No. 3, pp. 396-402.

Attaran, M. (2007), "RFID: an enabler of supply chain operations", *Supply Chain Management: An International Journal*, Vol. 12 No. 4, pp. 249-57.

Attewell, P. (1992), "Technology diffusion and organizational learning: the case of business computing", *Organization Science*, Vol. 3 No. 1, pp. 1-19.

Bagozzi, R.P. and Yi, Y. (1988), "On the evaluation of structural equation models", *Journal of the Academy of Marketing Science*, Vol. 16 No. 1, pp. 74-94.

Bradford, M. and Florin, J. (2003), "Examining the role of innovation diffusion factors on the implementation success of enterprise resource-planning systems", *International Journal of Accounting Information Systems*, Vol. 4 No. 3, pp. 205-25.

Brancheau, J.C. and Wetherbe, J.C. (1990), "The adoption of spreadsheet software: testing innovation diffusion theory in the context of end-user computing", *Information Systems Research*, Vol. 1 No. 2, pp. 115-43.

Brown, A. and Bakhru, A. (2007), "Information systems innovation research and the case of RFID", in McMaster, T., Wastell, D., Ferneley, E. and DeGross, J. (Eds), *Organizational Dynamics of Technology-based Innovation: Diversifying the Research Agenda*, Springer, Boston, MA, pp. 363-76.

Brown, I. and Russel, J. (2007), "Radio frequency identification technology: an exploratory study on adoption in the South African retail sector", *International Journal of Information Management*, Vol. 27 No. 4, pp. 250-65.

Bruwer, P.J.S. (1984), "A descriptive model of success for computer-based information systems", *Information and Management*, Vol. 7 No. 2, pp. 63-7.

Carmines, E. and McIver, J. (1981), "Analyzing models with unobserved variables: analysis of covariance structures", in Bohrnstedt, G.B. (Ed.), *Social Measurement: Current Issues*, Sage Publications, Beverly Hills, CA, pp. 65-115.

Chang, S.-I., Hung, S.-Y., Yen, D.C. and Chen, Y.J. (2008), "The determinants of RFID adoption in the logistics industry: a supply chain management perspective", *Communications of the AIS*, Vol. 23, pp. 197-218.

Chau, P.Y.K. and Hui, K.L. (2001), "Determinants of small business EDI adoption: an empirical investigation", *Journal of Organizational Computing and Electronic Commerce*, Vol. 11 No. 4, pp. 229-52.

Child, J. (1972), "Organizational structure, environment and performance: the role of strategic choice", *Sociology*, Vol. 6 No. 1, pp. 1-22.

Chowdhury, B., Chowdhury, M.U. and D'Souza, C. (2008), "Challenges relating to RFID implementation within the electronic supply chain management: a practical approach", in Lee, R. (Ed.), *Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing*, Springer, Heidelberg, pp. 49-59.

Chwelos, P., Benbasat, I. and Dexter, A.S. (2001), "Empirical test of an EDI adoption model", *Information Systems Research*, Vol. 12 No. 3, pp. 304-21.

Deloitte Touche Tohmatsu LLC (2009), "Global powers of retailing", Deloitte Touche Tohmatsu LLC, available at: http://public.deloitte.com/media/0460/2009GlobalPowersofRetail_FINAL2.pdf (accessed 13 November 2009).

Dillman, D.A. (2007), *Mail and Internet Surveys: The Tailored Design Method*, John Wiley, New York, NY.

(*The*) *Economist* (2007), "Radio silence", *The Economist*, 9 June, pp. 20-1.

Edwards, J. (2008), "EPC's tipping point", *RFID Journal*, Vol. 5 No. 5, pp. 11-17.

EPCglobal (2009), "The EPCglobal Architecture Framework Version 1.3", available at: www.epcglobalinc.org/standards/architecture/architecture_1_3-framework-20090319.pdf (accessed 13 November 2009).

Fichman, R.G. (1992), "Information technology diffusion: a review of empirical research", paper presented at 13th International Conference on Information Systems, Dallas, TX.

Fichman, R.G. (2004), "Going beyond the dominant paradigm for information technology innovation research: emerging concepts and methods", *Journal of the Association for Information Systems*, Vol. 5 No. 8, pp. 314-55.

Finkenzeller, K. (2003), *RFID Handbook*, John Wiley, New York, NY.

Fornell, C. and Larcker, D.F. (1981), "Evaluating structural equation models with unobservable variables and measurement errors", *Journal of Marketing Research*, Vol. 18 No. 3, pp. 39-50.

Goswami, S., Teo, H.H. and Chan, H.C. (2008), "Real options from RFID adoption: the role of institutions and managerial mindfulness", paper presented at 7th International Conference on Information Systems, Paris.

Grover, V. and Goslar, M.D. (1993), "The initiation, adoption, and implementation of telecommunications technologies in US organizations", *Journal of Management Information Systems*, Vol. 10 No. 1, pp. 141-63.

Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. (1998), *Multivariate Data Analysis*, Prentice Hall, Upper Saddle River, NJ.

Hardgrave, B.C., Armstrong, D.J. and Riemenschneider, C.K. (2007), "RFID assimilation hierarchy", 40th Annual Hawaii International Conference on System Sciences, Big Island, HI.

Herzog, W., Boomsma, A. and Reinecke, S. (2007), "The model-size effect on traditional and modified tests of covariance structures", *Structural Equation Modeling*, Vol. 14 No. 3, pp. 361-90.

Hu, L. and Bentler, P. (1999), "Cutoff criteria for fit indices in covariance structure analysis: conventional criteria versus new alternatives", *Structural Equation Modeling*, Vol. 6 No. 1, pp. 1-55.

Huber, N., Michael, K. and McCathie, L. (2007), *Barriers to RFID Adoption in the Supply Chain*, IEEE RFID Eurasia, Istanbul.

Hutcheson, G. and Sofroniou, N. (1999), *The Multivariate Social Scientist: Introductory Statistics Using Linear Models*, Sage Publications, Thousand Oaks, CA.

Iacovou, C., Benbasat, I. and Dexer, A.S. (1995), "Electronic Data Interchange and small organizations: adoption and impact of technology", *MIS Quarterly*, Vol. 19 No. 4, pp. 465-86.

Jeyaraj, A., Rottman, J.W. and Lacity, M.C. (2006), "A review of the predictors, linkages, and biases in IT innovation adoption research", *Journal of Information Technology*, Vol. 21 No. 1, pp. 1-23.

Jones, P., Clarke-Hill, C., Shears, P., Comfort, D. and Hillier, D. (2004), "Radio frequency identification in the UK: opportunities and challenges", *International Journal of Retail & Distribution Management*, Vol. 32 No. 3, pp. 164-71.

Jun, M. and Cai, S. (2003), "Key obstacles to EDI success: from the US small manufacturing companies' perspective", *Industrial Management & Data Systems*, Vol. 103 No. 3, pp. 192-203.

Kaiser, H.F. (1974), "An index of factorial simplicity", *Psychometrika*, Vol. 39, pp. 31-6.

Kärkkäinen, M. and Holmström, J. (2002), "Wireless product identification: enabler for handling efficiency, customisation and information sharing", *Supply Chain Management: An International Journal*, Vol. 7 No. 4, pp. 242-52.

Kuan, K.K.Y. and Chau, P.Y.K. (2001), "A perception-based model for EDI adoption in small businesses using a technology-organization-environment framework", *Information & Management*, Vol. 38 No. 8, pp. 507-21.

Kurnia, S. and Johnston, R.B. (2000), "The need for a processual view of inter-organizational systems adoption", *Journal of Strategic Information Systems*, Vol. 9 No. 4, pp. 295-319.

Kwon, T.H. and Zmud, R.W. (1987), "Unifying the fragmented models of information systems implementation", in Boland, R.J. and Hirschheim, R.A. (Eds), *Critical Issues in Information Systems Research*, John Wiley, New York, NY, pp. 227-51.

Lacy, S. (2005), "RFID: plenty of mixed signals", *BusinessWeek Online*, 31 January, available at: www.businessweek.com/technology/content/jan2005/tc20050131_5897_tc024.htm (accessed 13 November 2009).

Lai, V.S. and Guynes, J.L. (1994), "A model of ISDN (integrated services digital network) adoption in US corporations", *Information & Management*, Vol. 26 No. 1, pp. 75-84.

Lee, C.P. and Shim, J.P. (2007), "An exploratory study of radio frequency identification (RFID) adoption in the healthcare industry", *European Journal of Information Systems*, Vol. 16 No. 6, pp. 712-24.

Lee, H.L. and Özer, Ö. (2007), "Unlocking the value of RFID", *Production and Operations Management*, Vol. 16 No. 1, pp. 40-64.

Lee, I. and Chung, H. (2006), "What should we watch over to adopt RFID for pharmaceutical supply chain in Korea?", paper presented at 8th International Conference on Advanced Communication Technology, New York, NY.

Leimeister, J.M., Knebel, U. and Krcmar, H. (2007), "RFID as enabler for the boundless real-time organisation: empirical insights from Germany", *International Journal of Networking and Virtual Organisations*, Vol. 1 No. 4, pp. 45-64.

Liang, H., Saraf, N., Hu, Q. and Xue, Y. (2007), "Assimilation of enterprise systems: the effect of institutional pressures and the mediating role of top management", *MIS Quarterly*, Vol. 31 No. 1, pp. 59-87.

Liao, W.-P., Lin, T.M.Y. and Liao, S.-H. (2011), "Contributions to radio frequency identification (RFID) research: an assessment of SCI-, SSCI-indexed papers from 2004 to 2008", *Decision Support Systems*, Vol. 50 No. 2, pp. 548-56.

Lin, C.-Y. and Ho, Y.-H. (2009), "RFID technology adoption and supply chain performance: an empirical study in China's logistics industry", *Supply Chain Management: An International Journal*, Vol. 14 No. 5, pp. 369-78.

Loebbecke, C. and Huyskens, C. (2008), "A competitive perspective on standard-making: Kaufhof's RFID project in fashion retailing", *Electronic Markets*, Vol. 18 No. 1, pp. 30-8.

McFarlane, D. and Sheffi, Y. (2003), "The impact of automatic identification on supply chain operations", *International Journal of Logistics Management*, Vol. 14 No. 1, pp. 1-18.

Madlberger, M. (2009), "A model of antecedents of RFID adoption intention in the supply chain", paper presented at 42nd Hawaii International Conference on System Sciences, Big Island, HI.

Midgley, D.F. and Dowling, G.R. (1993), "A longitudinal study of product form innovation: the interaction between predisposition and social messages", *Journal of Consumer Research*, Vol. 19, pp. 611-25.

Mooney, J.G., Gurbaxani, V. and Kraemer, K. (1996), "A process-oriented framework for assessing the business value of information technology", *The DATA BASE for Advances in Information Systems*, Vol. 27 No. 2, pp. 68-81.

Moore, G.C. and Benbasat, I. (1991), "Development of an instrument to measure the perception of adopting an information technology innovation", *Information Systems Research*, Vol. 2 No. 3, pp. 191-222.

Myers, R.H. (1990), *Classical and Modern Regression with Applications*, Duxbury Press, Boston, MA.

Ngai, E.W.T., Moon, K.K.L., Riggins, F.J. and Yi, C.Y. (2008), "RFID research: an academic literature review (1995-2005) and future research directions", *International Journal of Production Economics*, Vol. 112 No. 2, pp. 510-20.

Nunnally, J. (1978), *Psychometric Theory*, McGraw Hill, New York, NY.

Pallant, J. (2001), *SPSS Survival Manual*, Open University Press, Canberra.

Papastathopoulou, P., Avlonitis, G.J. and Panagopoulos, N.G. (2007), "Intraorganizational information and communication technology diffusion: implications for industrial sellers and buyers", *Industrial Marketing Management*, Vol. 36 No. 3, pp. 322-36.

Power, D. (2005), "Determinants of business-to-business e-commerce implementation and performance: a structural model", *Supply Chain Management: An International Journal*, Vol. 10 No. 2, pp. 96-113.

Pramatari, K. (2007), "Collaborative supply chain practices and evolving technological approaches", *Supply Chain Management: An International Journal*, Vol. 12 No. 3, pp. 210-20.

Prater, E., Frazier, G.V. and Reyes, P.M. (2005), "Future impacts of RFID on e-supply chains in grocery retails", *Supply Chain Management: An International Journal*, Vol. 10 No. 2, pp. 134-42.

Premkumar, G. and Roberts, M. (1999), "Adoption of new information technologies in rural small businesses", *International Journal of Management Sciences*, Vol. 27 No. 4, pp. 467-84.

Premkumar, G., Ramamurthy, K. and Crum, M. (1997), "Determinants of EDI adoption in the transportation industry", *European Journal of Information Systems*, Vol. 6 No. 2, pp. 107-21.

Premkumar, G., Ramamurthy, K. and Nilakanta, S. (1994), "Implementation of electronic data interchange: an innovation diffusion perspective", *Journal of Information Systems*, Vol. 11 No. 2, pp. 157-86.

Roberti, M. (2009), "Why aren't more US retailers adopting RFID?", *RFID Journal*, Vol. 6 No. 5, pp. 6-9.

Robey, D., Im, G. and Wareham, J.D. (2008), "Theoretical foundations of empirical research on interorganizational systems: assessing past contributions and guiding future directions", *Journal of the Association for Information Systems*, Vol. 9 No. 9, pp. 497-518.

Rogers, E.M. (2003), *Diffusion of Innovations*, The Free Press, New York, NY.

Sánchez, A.M. and Pérez, M.P. (2005), "EDI and the moderator effect of interorganizational cooperation in the supply chain", *Journal of Organizational Computing an Electronic Commerce*, Vol. 15 No. 2, pp. 83-104.

Sarma, S. (2006), "A history of the EPC", in Garfinkel, S. and Rosenberg, B. (Eds), *RFID*, Addison-Wesley, Upper Saddle River, NJ, pp. 37-55.

Sarma, S., Brock, D.L. and Ashton, K. (2000), "The networked physical world", MIT, Cambridge, MA, available at: www.autoidlabs.org/uploads/media/MIT-AUTOID-WH-001.pdf (accessed 13 November 2009).

Seyal, A.H., Rahman, M.N.A. and Mohammad, H.A.Y.H.A. (2007), "A quantitative analysis of factors contributing to electronic data interchange adoption among Bruneian SMEs", *Business Process Management Journal*, Vol. 13 No. 5, pp. 728-46.

Seymour, L., Lambert-Porter, E. and Willuweit, L. (2007), "RFID adoption into the container supply chain: proposing a framework", paper presented at 6th Annual ISOnEworld Conference, Las Vegas, NV.

Sharma, A., Citurs, A. and Konsynski, B. (2007), "Strategic and institutional perspectives in the adoption and early integration of radio frequency identification (RFID)", paper presented at 40th Hawaii International Conference on System Sciences, Big Island, HI.

Sharma, A., Thomas, D. and Konsynski, B. (2008), "Strategic and institutional perspectives in the evaluation, adoption and early integration of radio frequency identification (RFID): an empirical investigation of current and potential adopters", paper presented at 41st Hawaii International Conference on System Sciences, Big Island, HI.

Shepard, S. (2005), *Radio Frequency Identification*, McGraw-Hill, New York, NY.

Shih, D.-H., Chiu, Y.-W., Chang, S.-I. and Yen, D.C. (2008), "An empirical study of factors affecting RFID's adoption in Taiwan", *Journal of Global Information Management*, Vol. 16 No. 2, pp. 58-80.

Srivastava, B. (2004), "Radio frequency ID technology: the next revolution in SCM", *Business Horizons*, Vol. 47 No. 6, pp. 60-8.

Strüker, J. and Gille, D. (2008), "The SME way of adopting RFID technology: empirical findings from a German cross-sectoral study", paper presented at 16th European Conference on Information Systems, Galway.

Swain, A.J. (1975), "Analysis of parametric structures for variance matrices", doctoral dissertation, Department of Statistics, University of Adelaide, Adelaide.

Swanson, E.B. (1994), "Information systems innovation among organizations", *Management Science*, Vol. 40 No. 9, pp. 1069-92.

Tabachnick, B.G. and Fidell, L.S. (2001), *Using Multivariate Statistics*, Pearson, Needham Heights, NJ.

Teo, H.H., Wei, K.K. and Benbasat, I. (2003), "Predicting intention to adopt interorganizational linkages: an institutional perspective", *MIS Quarterly*, Vol. 27 No. 1, pp. 19-49.

Thiesse, F. and Condea, C. (2009), "RFID data sharing in supply chains: what is the value of the EPC network?", *International Journal of Electronic Business*, Vol. 7 No. 1, pp. 21-43.

Thiesse, F., Al-Kassab, J. and Fleisch, E. (2009), "Understanding the value of integrated RFID systems: a case study from apparel retail", *European Journal of Information Systems*, Vol. 16 No. 6, pp. 592-614.

Thong, J.Y.L., Yap, C.-S. and Raman, K.S. (1996), "Top management support, external expertise and information systems implementations in small businesses", *Information Systems Research*, Vol. 7 No. 2, pp. 248-67.

Tornatzky, L.G. and Fleischer, M. (1990), *The Processes of Technological Innovation*, Lexington Books, Lexington, MA.

Tornatzky, L.G. and Klein, K. (1982), "Innovation characteristics and innovation adoption-implementation: a meta-analysis of findings", *IEEE Transactions on Engineering Management*, Vol. 29 No. 1, pp. 28-45.

Tsai, M.-C., Lee, W. and Wu, H.-C. (2010), "Determinants of RFID adoption intention: evidence from Taiwanese retail chains", *Information and Management*, Vol. 47 Nos 5/6, pp. 255-61.

Vijayaraman, B.S. and Osyk, B.A. (2006), "An empirical study of RFID implementation in the warehousing industry", *International Journal of Logistics Management*, Vol. 17 No. 1, pp. 6-20.

Whitaker, J., Mithas, S. and Krishnan, M.S. (2007), "A field study of RFID deployment and return expectations", *Production and Operations Management*, Vol. 16 No. 5, pp. 599-612.

Yang, G. and Jarvenpaa, S. (2005), "Trust and radio frequency identification (RFID) adoption within an alliance", paper presented at 38th Annual Hawaii International Conference on System Sciences, Big Island, HI.

Zhu, K., Dong, S., Xu, S.X. and Kraemer, K.L. (2006), "Innovation diffusion in global contexts: determinants of post-adoption digital transformation of European companies", *European Journal of Information Systems*, Vol. 15 No. 6, pp. 601-16.

Zhu, K., Kraemer, K.L., Xu, S. and Dedrick, J. (2004), "The complementarity of information technology infrastructure and e-commerce capability: a resource-based assessment of their business value", *Journal of Management Information Systems*, Vol. 21 No. 1, pp. 167-202.

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Appendix

Table AI Measurement instrument

Construct	Item	Content
Adoption decision	AD1	At what stage of RFID technology deployment is your organization currently engaged? – Currently using RFID technology (e.g. in manufacturing) – Have evaluated, and plan to adopt – Have evaluated, but do not plan to adopt – Currently evaluating (e.g. in a pilot study) – Not considering
	AD2	If you are expecting that your company will use RFID technology in the future, how soon do you think it will happen (implementations – no pilot tests)? – < 1 year – 1 year < 2 years – 2 years < 5 years – 5 years – Not at all
Complexity		Please rate the following statements regarding the complexity of RFID technology (five-point Likert scale: "strongly agree"/"strongly disagree")
	CPX1	The skills needed to implement and to use RFID technology are too complex for our company
	CPX2	The skills necessary to use RFID technology are too complex for our employees
	CPX3	Integrating RFID in our current work practices will be a challenge
Compatibility		Please rate the following statements regarding compatibility of RFID systems (five-point Likert scale: "strongly agree"/"strongly disagree")
	CPA1	RFID technology will only be acceptable for our company once there is an agreed set of global standards in place
	CPA2	RFID technology will be compatible with our company's current hardware and software infrastructure
	CPA3	RFID technology will be compatible with our company's IT culture
Benefits		Please rate the importance of achieving the following benefits of RFID in terms of your organization's decision whether or not to adopt RFID (five-point Likert scale: "very important"/"not at all important")
	BE1	Increased productivity
	BE2	Increased accuracy
	BE3	Improved operations efficiency
	BE4	Improvements in process management and cycle times
	BE5	Reduced stock-outs
	BE6	Reduced inventory levels
	BE7	Reduced error rates
	BE8	Overhead cost reduction
	BE9	Improved customer service
	BE10	Reduced inventory costs
	BE11	Faster response to orders
Costs		Please rate the following statements regarding the costs of RFID (five-point Likert scale: "strongly agree"/"strongly disagree")
	CO1	The most important factor for our company is low tag prices
	CO2	The costs of adopting RFID are far greater than the benefits
	CO3	The costs for training and reengineering work practices are very high
	CO4	The costs of maintaining RFID technology will be prohibitively high
	CO5	The costs of implementing RFID for our suppliers will be high
Firm size	FS1	What is the annual sales volume (across the whole group)? – < $100,000 – $100,000 < $500,000 – $500,000 < $1 m – $1 m < $5 m – $5 m < $10 m – $10 m < $100 m – $100 m < $500 m – $500 m < $1 bn – $1 bn < $10 bn – $10 bn < $25 bn – $25 bn < $40 bn – > $40 bn

(continued)

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Table AI

Construct	Item	Content
	FS2	How many employees does your company employ (across the whole group)? – <100 – 100 < 1,000 – 1,000 < 5,000 – 5,000 < 10,000 – 10,000 < 50,000 – 50,000 < 100,000 – 100,000 < 150,000 – 150,000 < 250,000 – >250,000
Top management support		Please rate the following statements regarding the support of RFID by the management of your company (five-point Likert scale: "strongly agree"/"strongly disagree")
	TMS1	Our top management provides strong and involved leadership when it comes to information systems in our company
	TMS2	Our top management supports the implementation of RFID technology
	TMS3	Our top management has a desire to portray our company as a leader in the use of RFID technology
	TMS4	Our top management is willing to take the risk (financial and organizational) involved in adopting RFID technology
	TMS5	Our top management has established clear goals and a clear picture of how RFID technology can help these goals
Employee fears		Please rate the following statements regarding your company's employees' attitudes towards RFID (five-point Likert scale: "strongly agree"/"strongly disagree")
	EF1	Employees of our company will fear the adoption of RFID because they feel they might lack the skills to use the technology
	EF2	Employees of our company will fear the adoption of RFID technology because of possible job losses
Supply chain forces		Please rate the following statements regarding the use of RFID for collaboration among partners in your supply chain (five-point Likert scale: "strongly agree"/"strongly disagree")
	SCF1	Our suppliers require the use of RFID as a precondition to do business with them
	SCF2	Our company actively pushes suppliers to implement/use RFID
	SCF3	Our customers require the use of RFID technology as a precondition to do business with them
External pressure		What do you think are the greatest enablers from outside your company for the adoption of RFID (five-point Likert scale: "strongly agree"/"strongly disagree")?
	EP1	RFID mandates
	EP2	Governmental regulations
	EP3	Recommendations of industry associations
	EP4	Competitors' decision to use RFID
	EP5	Adoption and positive experiences by other industries

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3. Ilias P. Vlachos. 2014. A hierarchical model of the impact of RFID practices on retail supply chain performance. *Expert Systems with Applications* **41**, 5-15. [CrossRef]
4. May Tajima. 2012. The Role of Technology Standardization in RFID Adoption. *International Journal of IT Standards and Standardization Research* **10**:10.4018/IJITSR.20120101, 48-67. [CrossRef]
5. Lincoln C. Wood, Torsten Reiners, Julia PahlManufacturing and Logistics Information Systems 5136-5144. [CrossRef]