Association for Information Systems
AIS Electronic Library (AISeL)

ECIS 2009 Proceedings

European Conference on Information Systems (ECIS)

2009

Adoption of cross-company RFID: An empirical analysis of perceived influence factors

Christoph Goebel
Humboldt-Universität zu Berlin

Christoph Tribowski
Humboldt-Universitat zu Berlin, christoph.tribowski@wiwi.hu-berlin.de

Oliver Gunther
Humboldt-University, Berlin, guenther@wiwi.hu-berlin.de

ADOPTION OF CROSS-COMPANY RFID: AN EMPIRICAL ANALYSIS OF PERCEIVED INFLUENCE FACTORS

Abstract

Although the use of RFID in the supply chain still lags behind expectations, its appeal to practitioners and researchers remains unabated. Apart from technical challenges, the profitability of an RFID deployment is a major concern for potential customers. A promising way to increase an RFID solution's profitability is to use RFID transponders in several companies along the supply chain and share the cost and implementation effort. This paper represents a first attempt to identify the factors affecting the perceived likelihood that cross-company RFID is adopted. Our empirical results indicate that profitability is a key influence factor in this context. Related important factors are the uncertainty of costs and returns and the possible imbalance of costs and returns among the supply chain participants. The influence of organizational factors, such as power, leadership and experience, is negligible in comparison.

Keywords: RFID, Inter-organizational Information Systems, Empirical Study.

1 INTRODUCTION

The potential of Radio Frequency Identification (RFID) for boosting supply chain efficiency has been stressed repeatedly by practitioners and researchers alike (Niederman et al. 2007). However, the actual adoption of the technology in supply chain monitoring applications has been unexpectedly low to date. In 2006 the biggest share of RFID transponders produced worldwide (556 million) went to applications such as 'smart' cards, keys, passports and tickets (IDTechEx 2007). Only 388 million transponders were sold for the purpose of identifying goods including drugs, tools, books, apparel and other consumer products (153 million) and logistical units like packages, cases and pallets (235 million). Industry experts expect the RFID market to take off as soon as item level tagging in logistics applications becomes economically feasible for selected industries (such as the apparel industry). The current market price of passive RFID transponders (about 7 Eurocents) is the pivot parameter of most profitability calculations. The efficiency gains achievable in the logistics operations of organizations such as labour cost savings and prevention of process errors has to outstrip RFID transponder and infrastructure costs. Otherwise, the vision of pervasive RFID tagging is unlikely to become a reality.

Given today's increasing division of labour, physical items usually enter and leave the control spheres of several organizations during their lifetimes. Enabling as many supply chain participants as possible to use the same RFID transponders attached to these physical items is a straightforward measure to increase the overall financial return on tag investment. The backend-infrastructure required for the processing of RFID data can also be shared by several organizations. The final vision is the Internet of Things: the worldwide interconnection of the all databases containing object-related data. Industry consortia like the Auto-ID labs and EPCglobal continue to work on the technical standards that are supposed to form the basis of the Internet of Things (Brock 2001).

Unfortunately, the introduction of cross-company IT systems has always been a difficult and time-consuming task. A well-known example of such systems from the supply chain domain is Electronic Data Interchange (EDI) which took decades to be successfully introduced. Among other things, asymmetric costs and benefits, different risk attitudes and capabilities across the supply chain participants can complicate the adoption and efficient usage of inter-organizational information systems (Scala and McGrath Jr. 1993).

In this paper we focus on the factors related to the adoption of inter-organizational RFID systems. We identify a number of candidates and empirically test the corresponding hypotheses using data from a recent survey. To the best of our knowledge, this is the first empirical work conducted on non-technical influence factors of cross-company RFID systems.

In Section 2 we provide an overview of related literature. Our hypotheses and a conceptual model are presented in Section 3. In Section 4 we describe the employed methodology and the results of an empirical study. Section 5 discusses managerial implications of our work. Section 6 concludes.

2 RELATED WORK

The academic literature on RFID and its use in supply chain management is already substantial. Recent literature reviews include Ngai et al. (2008). Most of the publications directly related to our research topic can be allocated to one of two groups: (i) conceptual and empirical research on RFID adoption on the company level, and (ii) analytical research on the distribution of RFID benefits between a prototypical manufacturer and retailer.

A number of papers belonging to the first group concentrate on collecting the views of practitioners concerning the benefits of RFID within their organizations with different emphases. Leimeister et al. (2007) investigated the perceived strategic importance of RFID among IT decision makers. They found that the perceived strategic importance is correlated with industry affiliation and company size. Seymour et al. (2007) have developed a framework of possible factors of RFID adoption based on several accepted theories on technology adoption and diffusion, e.g. Bakry's (2003) e-readiness model and Rogers' (2003) Innovation Diffusion Process. Sharma et al. (2007) propose a model for RFID adoption on the company level that is among other things grounded in the literature on inter-organizational systems; they adopt a number of factors form research on the adoption of Electronic Data Interchange (EDI), in particular Chwelos et al. (2001) and Teo et al. (2003). Madlberger (2008) investigated the influencing factors on the introduction of RFID in supply chain management applications and found that internal process improvements, inter-organizational benefits, technical advantages and the costs of RFID, but not the company size, have an influence on the introduction of RFID. Using data from a survey among 146 German companies Gille and Strüker (2008) measured how the type and sophistication of benefit and performance analyses conducted before and after RFID introduction impact the productivity gains achieved by RFID. They found that the frequent use of particular measurement methods is strongly correlated with to the improvement of target variables such as lead time and labour cost. In another paper, the same authors addressed specific aspects of small and medium sized companies (Strüker and Gille 2008). They found that RFID adoption is easer in smaller enterprises.

Some researchers have begun to investigate the distribution of benefits across prototypical supply chains; this automatically leads to the question how RFID transponder costs should be shared optimally in case benefits are distributed unequally. Gaukler et al. (2007) investigated this research question using an analytical model. They showed that sharing the tag costs results in overall profit maximisation if the manufacturer is the more powerful than the retailer. However, if the retailer is more powerful, there is a need for sharing tag costs in order to realize the maximum profit. Unfortunately, the analytical model is based on a highly stylized supply chain model and only captures information benefit and tag cost while ignoring the benefits resulting from labour and error cost savings.

This paper empirically investigates the factors that determine the adoption of cross-company RFID. The focus on the entire supply chain instead of single companies sets it apart from previous empirical business research on RFID. While using an empirical approach makes it easier to grasp real world conditions, our findings leave more room for interpretation than results obtained from analytical models.

3 HYPOTHESES AND CONCEPTUAL MODEL

Our conceptual model consists of one major dependent variable, namely the perceived likelihood of cross-company RFID adoption. The model is designed to reveal the influence of several factors on this dependent variable. These independent variables include the expected degree of RFID profitability across the supply chain, the uncertainty of RFID benefits, the uncertainty of RFID costs, the asymmetry of RFID profitability across the participants, the existence of a driving organization that takes the initiative in planning cross-company RFID deployment, the existence of a dominant supply chain participant who can force the introduction of cross-company RFID, and the existing RFID experience in the supply chain. In addition to this greater model we also investigate how expected degree of RFID profitability is impacted by two more independent variables, namely the depth and the breadth of the inter-organizational RFID implementation. We propose the following related hypotheses:

H1: *The expected profitability of cross-company RFID positively influences the perceived likelihood of adoption.*

By this hypothesis we imply that higher stakes provide an incentive for better coordination. In other words we hypothesize that if the supply chain participants expect a higher profit for the supply chain as a whole they will be more motivated to collaborate in order to realize (and possibly redistribute) this return. This factor profitability appears in many studies on technology adoption; however it is usually decomposed into benefits and costs (cf. Sharma et al. 2007). We focus on profitability since we are interested in the 'size of the pie' to be distributed among all the supply chain participants.

The current uncertainty involved in estimating the costs and benefits of RFID may cause risk-averse decision makers to not participate in or bail out of cross-company RFID projects. Transaction cost theory suggests that in situations where the outcome of a joint investment is highly uncertain and the assets are highly specific, the emerging negotiation, monitoring and legal costs can be significant (cf. e.g. Williamson 1979). Furthermore, the fear of opportunistic behaviour can result in a complete failure to coordinate on technology adoption. We therefore hypothesize that the uncertainty of RFID benefits as well as the uncertainty of the eventual cost of the RFID implementation have a negative effect on the perceived likelihood of adoption.

H2: *The uncertainty of the benefits provided by cross-company RFID negatively affects the perceived likelihood of adoption.*

H3: *The uncertainty of the costs of cross-company RFID negatively affects the perceived likelihood of adoption.*

With regard to the consumer products industry it has often been argued that RFID will provide higher benefits for retailers than for manufacturers (Byrnes 2003). Whereas the former can use it for various purposes on the shop floor, the latter may not be able to reap substantial benefits (Weber and Jensen 2007, p. 34). Without efficient and incentive-compatible methods to redistribute RFID costs, a concerted deployment of RFID along the supply chain will be hard to achieve. Although its importance has been repeatedly stressed, RFID cost redistribution remains an open issue (Bensel et al. 2008). The more asymmetrically profitability is distributed among the supply chain participants, the more incentives in different forms have to be provided by those participants who gain more. Due to the company-centred vantage point of the existing literature, this factor has no been considered in previous work. Against this background we formulate the following hypothesis:

H4: *The asymmetry of RFID profitability in the supply chain has a negative effect on the perceived likelihood of cross-company RFID adoption.*

One or several supply chain participants can play a crucial role in initiating and supporting the RFID introduction process. Regarding cross-company RFID there are two prominent examples for such leading organizations: Wal-Mart and Metro. Although their methods of fostering RFID introduction differ, they both stand out as main supporters of the technology in the respective supply chains. Wal-Mart took unilateral action in planning the deployment of RFID and issued mandates to their suppliers (Romanow and Lundstrom 2003). Metro actively involved suppliers and other companies by starting the future store initiative (Loebbecke 2005). In particular, they offered non-monetary compensation to their suppliers, including the timely communication of relevant sales data. If they exist, such companies usually take the lead in coordination and standardization activities. We hypothesize that the existence of such RFID 'leaders' has a positive impact on the perceived likelihood of adoption, irrespective of the means that they apply to foster the adoption process.

H5: *The existence of a RFID leader in the supply chain has a positive influence on the likelihood of cross-company RFID adoption.*

We would like to stress that a RFID leader does not necessarily have to be powerful in the sense that it can 'mandate' the supply chain wide adoption of RFID (irrespective of the mentioned examples). However, the existence of a powerful player in the supply chain can have an influence just as crucial as the existence of a RFID leader (cf. Sharma et al. 2007). From an economics point of view, power asymmetries can intensify incentive problems regarding the adoption of shared information technology. If a supply chain participant is economically dependent on another one, it will fear that this other organization will impose its will when the parties disagree on some issue during the implementation process. In joint projects, such as cross-company RFID introduction, this dependency can be reinforced by large upfront investments. In anticipation of such opportunistic behaviour, the weaker party may refuse to cooperate right from the start. Against this background one would expect adoption failure if there are power imbalances in the supply chain. In the empirical IS literature, however, the contrary hypothesis seems more common, namely that the (potential) influence of a powerful partner positively affects the intention of the weaker party to adopt inter-organizational information technology (cf. Sharma et al. 2007); however, we would like to emphasize that at least the empirical results of Chwelos et al. (2001), who have investigated EDI adoption, do not show a significant impact of the degree of dependency. We hypothesize that the existence of a powerful company in the supply chain (semantically similar to 'dependency' as defined by Chwelos et al. 2001) has a negative effect on the perceived likelihood of adoption.

H6: *The existence of a powerful player among the supply chain participants has a negative impact on the adoption of cross-company RFID.*

If the stakeholders involved in a cross-company RFID project have gained experience with the technology upfront, they should also have a more realistic view of the cost-benefit tradeoffs and technical challenges of its inter-organizational use. This in turn should make them more confident to avoid pitfalls in the planning and implementation phase. We therefore expect that decision makers estimate the probability of cross-company RFID adoption to be higher if there is more extant knowledge about the technology in the supply chain.

H7: *A higher degree of RFID experience in the supply chain positively affects the perceived likelihood of cross-company RFID adoption.*

The more details about the movement of goods through the supply chain can be obtained from RFID-enabled information systems, the higher the potential for supply chain process automation. Experts in the field have long argued that benefits are likely to increase when moving from pallet to case and case to item-level tagging (Michael and McCathie 2005). At the same time, the more processes are restructured and adjusted to each other in order to effectively use the additional data capturing capability provided by RFID, the higher the ROI of the transponders becomes. However, increasing the depth of an RFID implementation does not necessarily improve its profitability since it comes with higher implementation and integration costs. Just think of the additional transponders required to tag single products instead of cases or the effort involved in redesigning all supply chain processes instead of just one or two. Although this cost-benefit trade-off is non-trivial, we hypothesize that the depth of the inter-organizational RFID implementation has a positive impact on the expected profitability.

H8: *The depth of the inter-organizational RFID implementation has a positive effect on its expected profitability.*

Similar to the depth of a cross-company RFID implementation, its breadth should have a positive effect on the expected profitability. Breadth denotes the number of different organizations participating in the RFID application. If each additional supply chain organization that participates in the inter-organizational RFID application can benefit from the RFID transponders moving through the supply chain, the overall ROI of the transponders should increase with the number of participants. The following hypothesis reflects this reasoning.

H9: *The breadth of the inter-organizational RFID implementation has a positive effect on its expected profitability.*

Figure 1 shows the conceptual model and the corresponding hypotheses graphically.

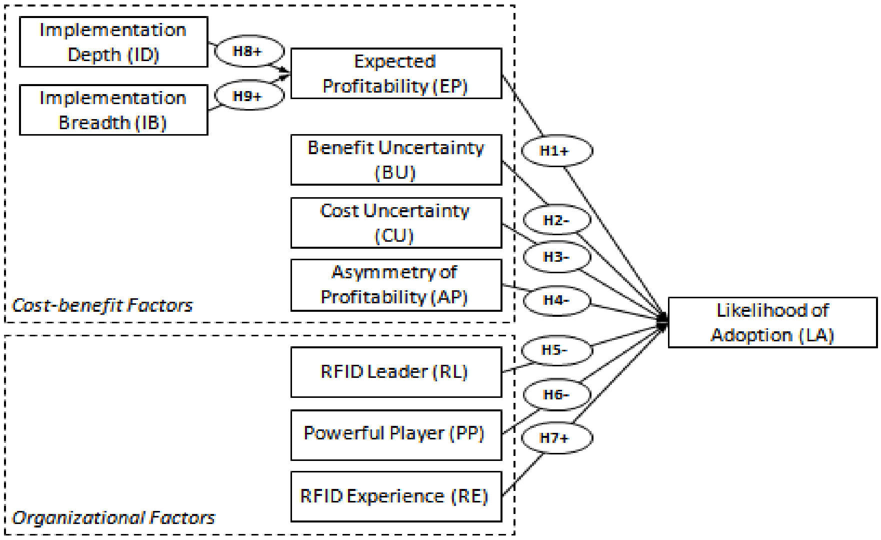

Figure 1. Conceptual model.

4 EMPIRICAL STUDY

4.1 Survey Design and Sampling

In order to test the hypotheses outlined in the previous section we developed scales that measure the different variables. In the forefront of the survey several industry experts and representatives were interviewed in a small workshop. The wording of the questionnaire was discussed in order to make sure that the all terms and formulations were clear and interpreted correctly and equally by the practitioners.

The developed questionnaire was appended to a more general survey on RFID in logistical applications. Its online completion was possible in German or English language. Sample collection took place from April 1st to September 2nd 2008. 947 personal invitations were emailed. Additionally, the survey was announced in a number of popular logistics and RFID publications and forums. After several weeks the invited persons were reminded of the survey by phone.

The data collection effort resulted in 153 answered questionnaires. 107 out of the 153 were responses to the personal invitations, the rest (46 responses) were filled out anonymously in response to the public announcements. Not considering the anonymous responses, the response rate was 11.3%.

Revenues in mln. €	% of companies	Employees	% of companies	Industry	% of companies	Supply chain role	% of companies
< 100	14.7%	< 500	29.4%	Electrical	16.2%	Supplier	10.3%
100-1,000	13.2%	500-5,000	22.1%	IT	14.7%	Manufacturer	41.2%
> 1,000	27.9%	5,000-50,000	27.9%	Retail	11.8%	Retailer	17.6%
n. a.	44.1%	> 50,000	20.6%	Logistics	8.8%	Logistics SP	8.8%
				Automotive	7.4%	IT SP	22.1%
				Consumer goods	5.9%		
				Engineering	5.9%		
				Others	29.4%		

Table 1. General sample characteristics.

In order to evaluate the representativeness of the sample, we analyzed its distribution with respect to four general company profile indicators: size of revenue, number of employees, industry affiliation, and the role that the respondent's company plays in the supply chain. Table 1 summarizes the general sample description. None of the indicators exhibits any unexpected concentration. The companies represented in the sample take on different roles in the supply chain: as the corresponding sample description data indicates, our data reflects the opinion of managers who represent suppliers, manufacturers, retailers, logistics service providers and IT service providers. This ensures that questions referring to the supply chain as a whole are answered from different vantage points and therefore increases the validity of our results.

In addition to the basic company profile, we provide descriptive statistics on RFID implementation progress indicators. These indicators include the number of respondent organizations that have implemented RFID pilots and running applications, the duration of RFID usage and the budget of a typical RFID project within the respective company. Table 2 summarizes the RFID-related statistics. They show that the sample is dominated by respondents who have gained substantial experience with the RFID technology.

Type of RFID use	% of companies	Duration of RFID use	% of companies	Typical RFID project budget in €	% of companies
None	23.5%	0	23.5%	0	23.5%
Pilot	26.5%	< 1 months	11.8%	< 100,000	25.0%
Running system	50.0%	1 - 6 months	14.7%	100,000 - 500,000	17.6%
		7 - 12 months	22.1%	500,000 - 1 mln.	20.6%
		1 - 2 years	11.8%	> 1 mln.	13.2%
		> 2 years	16.2%		

Table 2. RFID-related sample characteristics.

4.2 Descriptive Results

Table 3 provides descriptive statistics of the obtained survey data. A darker cell background indicates a higher concentration of the respective answer. As the results show, the majority of survey participants judge the profitability of cross-company RFID (EP) positively. Slightly more participants believe that cross-company RFID will be adopted (LA) in their supply chain; almost half of the respondents are undecided. Surprisingly, more participants indicated that they find it rather easy to estimate costs and benefits of cross-company RFID ex-ante.

Measured Variable	5 Point Scale (1 = very low, 5 = very high)					Mean	Std. Error
Implementation Depth (ID)	9%	13%	31%	35%	12%	3.279	0.016
Implementation Breadth (IB)	19%	19%	31%	1%	29%	3.029	0.022
Expected Profitability (EP)	3%	9%	22%	38%	28%	3.794	0.015
Benefit Uncertainty (BU)	6%	34%	35%	19%	6%	2.853	0.015
Cost Uncertainty (CU)	4%	29%	38%	24%	4%	2.941	0.014
Asymmetry of Profitability (AP)	16%	28%	28%	18%	10%	2.779	0.018
RFID Leader (RL)	3%	13%	26%	28%	29%	3.676	0.017
Powerful Player (PP)	9%	16%	22%	25%	28%	3.471	0.019
RFID Experience (RE)	22%	16%	38%	22%	1%	2.647	0.016
Likelihood of Adoption (LA)	4%	13%	46%	29%	7%	3.221	0.014

Table 3. Descriptive statistics (cell shading indicates concentrations).

4.3 Statistical Methodology and Results

The purpose of our statistical analysis is to test the hypotheses presented in section 3 using our data sample. In this section we outline and justify the applied statistical methodology.

The subset of the collected data used to test the hypotheses of our conceptual model consists of 10 times 68 values encoded on a range from 1 to 5. These values represent ordinal measurement points of the defined indicators. Our aim is to determine whether the independent variables in the model have a significant effect on the dependent variables and if so whether the effect is positive or negative. A suitable statistical methodology to estimate these effects is ordinal logistic regression. We apply this method to the general and the subordinate model with the dependent variables LA and EP respectively. In a first step, we conducted regressions of all independent variables onto the corresponding dependent variables. All statistical computations related to this paper were done using the Zelig library for the statistical software R (Imai et al. 2008). Table 4 summarizes the results of the monovariate ordinal logistic regressions.

Dep. Var.	Indep. Var.	Est. coef.	Std. error	t-value	Sig. level	Residual dev.	AIC
EP	ID	0.982	0.233	4.210	99.9%	166.91	176.91
EP	IB	0.142	0.154	0.923	-	186.17	196.17
LA	EP	0.679	0.247	2.748	99%	171.21	181.21
LA	BU	-0.410	0.241	-1.696	90%	175.98	185.98
LA	CU	-1.125	0.281	-4.008	99.9%	161.12	171.12
LA	RL	-0.090	0.203	-0.442	-	178.69	188.69
LA	AP	-0.670	0.219	-3.979	99.9%	161.24	171.24
LA	PP	-0.332	0.184	-1.809	90%	175.53	185.53
LA	RE	0.201	0.211	0.950	-	177.97	187.97

Table 4. Results of monovariate ordinal logistic regressions.

The statistical effect of the IB variable on the EP variable and the effect of both RL and RE on LA turned out to be insignificant at the 90% level.

Further, the results of the monovariate regressions reveal a significant positive effect of the ID on the EP variable. The variables EP, BU, CU, AP and PP all have a statistically significant effect on LA. While the impact of ID and EP is positive, the impact of BU, CU, AP and PP is negative. The effect of the variables BU and PP is only significant at the 90% level whereas the other variables' significance reaches higher levels.

In order to compare the relative explanatory power of the independent variables, we also employed multiple regression analysis.

When conducting multiple regression analysis so-called multicollinearity can cause problems (Mason et al. 1975): a high degree of correlation between the independent variables in a multivariate regression model can cause the regression coefficient estimates to vary erratically in response to small changes in the model or the data. In particular, the regression coefficients of all independent variables may change drastically depending on which variables are included or left out of the model. Thus, using the regression output without controlling for the adverse effects of multicollinearity on model estimation can lead to wrong interpretations.

In order to identify potential sources of multicollinearity in our data we calculated the correlation of the independent variables of the two multivariate regression models using Spearman's rank correlation coefficient. Table 5 summarizes the results of this analysis.

The correlation coefficients and the significance levels provided in Table 5 reveal a number of significant correlations between the independent variables used in the model. In particular, there are strong positive correlations between the variables DI and BI, BU and CU, AP and EP, PP and CA, as well as between PP and AP.

	ID	IB	EP	BU	CU	RL	AP	PP	RE
ID	1 ∞								
IB	0.5029 0.0000	1 ∞							
EP			1 ∞						
BU			-0.0875 0.4781	1 ∞					
CU			0.0590 0.6332	0.3057 0.0112	1 ∞				
RL			-0.1633 0.1833	0.2716 0.0250	0.0218 0.8600	1 ∞			
AP			-0.2839 0.0190	0.0875 0.4781	0.0066 0.9576	0.0344 0.7806	1 ∞		
PP			-0.1504 0.2209	0.1652 0.1781	-0.0248 0.8410	0.3531 0.0031	0.3853 0.0012	1 ∞	
RE			0.2445 0.0445	-0.1101 0.3713	-0.0540 0.6622	-0.1510 0.2191	-0.0650 0.5983	-0.1751 0.1533	1 ∞

Table 5. Results of correlation analysis (Spearman's rhos and p-values, cell shading indicates strong and significant correlation).

Multicollinearity can be removed in a number of ways. One is to simply remove independent variables one by one until there is no correlated predictor variables left in the model. This process has to be conducted carefully; variables should only be removed if they cause an intolerable degree of multicollinearity.

In a first step we removed the highly correlated variables BI, RL and RE. The results of the monovariate regressions indicate that the influence of these variables on the respective dependent variables is insignificant; therefore they do not represent important predictors anyway.

The remaining correlations between independent variables include the one between CU and BU, AP and EP, and between PP and AP. In order to test whether these correlations cause problems with respect to parameter estimation, models without one variable out of each correlated variable pair were estimated and the corresponding regression coefficients were compared with the estimates from the initial model. These computations revealed that whereas the correlation between the CU and BU variable causes problems when estimating their regression coefficients within the same model, the correlation between AP and EP was unproblematic with respect to parameter estimation.

The impact of the PP variable turned out to be insignificant in the multivariate model and did not contribute to the model fit measured by the Akaike Information Criterion (AIC); we therefore dropped it from the model which eliminated the correlation between PP and AP.

Dep. Var.	Indep. Var.	Est. coef.	Std. error	t-value	Sig. level	Residual dev.	AIC
EP	DI	0.982	0.233	4.210	99.9%	166.91	176.91
LA	EP	0.564	0.254	2.222	95%	156.50	170.50
	BU	-0.657	0.258	-2.543	95%		
	AP	-0.723	0.222	-3.259	99%		
LA	EP	0.502	0.251	2.001	95%	143.53	157.53
	CU	-1.196	0.289	-4.137	99.9%		
	AP	-0.697	0.222	-3.145	99%		

Table 6. Multivariate ordinal logistic regression results after controlling for multicollinearity.

In summary, only the correlation between the BU and the CU variable could not be eliminated without significantly decreasing the explanatory power of the model. In order to resolve this problem, we estimated two models each containing one of the two variables.

The regression results for the final multivariate models after controlling for multicollinearity are provided in Table 6.

As stated earlier, the results of the multivariate regressions allow for a comparison of the different independent variables regarding the strength of their impact on the dependent variables. The estimated regression coefficient (abbreviated by Est. coef. in Table 6) indicates the direction (positive or negative) and the strength of the impact (absolute value). The obtained significance levels are sufficiently high (95-99.9%) to assume the existence of the postulated relationships with some confidence.

The PP variable becomes insignificant when it is estimated in the multivariate model. This suggests that its explanatory power is dwarfed by the other independent variables contained in the model. The AP variable has a stronger effect on LA than EP both if BU or CU is included in the model. If BU is included in the model, its impact is stronger than EP's but weaker than AP's. If CU is included, its impact is about twice as high as EP's and AP's.

As the results of the regression analysis indicate, hypotheses H1, H2, H3, H4, and H8 are supported by our data. The support for hypotheses H3, H4 and H8 is particularly significant. The statistical support for hypotheses H5, H6, H7, and H9 is not significant. Possible implications of the statistical results are discussed in the following section.

5 DISCUSSION AND MANAGERIAL IMPLICATIONS

The support for H1 suggests that the respondents who expect a high financial return on the introduction of cross-company RFID in the supply chain are more confident with respect to its realization. It implies that higher stakes in the form of unrealized profit make coordination on collaborative RFID introduction more likely. This result appears intuitive. More intriguing is the strength of the statistical support for H1 compared to the effect that uncertainty (BU and CU) and asymmetry of profitability (AP) have on the perceived likelihood of adoption. Higher uncertainty of both benefits and costs reduces the likelihood of adoption more strongly than the expectation of higher overall profitability. The same applies to the impact of a more unequal distribution of profitability (AP): the negative impact of asymmetric profitability on the perceived likelihood of cross-company RFID introduction is stronger than the positive impact of expected profitability. These results suggest that the adoption of cross-company RFID can be seriously threatened by both the uncertainty of its profitability and the imbalance of the financial returns realized by the different participants – even in situations where the overall profitability of such applications is judged very positively.

Our results indicate that cost uncertainty has a much stronger effect on the likelihood of adoption than benefit uncertainty. In other words, uncertain costs make decision makers more pessimistic regarding the introduction of cross-company RFID than uncertain benefits. Given the current problems of accurately quantifying RFID benefits this result comes as a surprise. However, it could be explained by a possible bias towards cost-based assessment of RFID applications in general. An indication speaking for this theory is the finding of Gille and Strüker (2008) that the costs of RFID applications are currently quantified more frequently than their benefits because they can be quantified more easily.

The lack of statistical support for hypotheses H5, H6 and H7 indicates that compared to the examined cost-benefit factors, the considered organizational factors have a less crucial influence on the perceived likelihood of cross-company RFID adoption. Neither does the promotion of RFID by a leading organization seem to play a decisive role (H6), nor do our results indicate a substantial influence of dependencies due to the existence of powerful supply chain participants (H7). The degree of extant RFID experience in the supply chain does not seem to be relevant either (H8).

The lack of statistical significance of H7 corresponds with the results of Chwelos et al. (2001) who tested the influence of dependency on intent to adopt EDI. However, we believe that it is still interesting since it encourages further research on the usefulness of RFID mandates such as the one issued by Wal-Mart.

The strong statistical support for H8 suggests that the benefit gain achieved by increasing the depth of cross-company RFID implementations is steeper than the corresponding cost increase. H9 can neither be supported nor rejected based on our data: the breadth of an inter-organizational RFID application in terms of participating organizations does not seem to affect its expected profitability. The economic network effect implied by this hypothesis would justify more upfront funding of initiatives that develop and standardize scalable system architectures for the Internet of Things: if profitability increased with the number of participants, the emergence of large clusters of companies that are connected by a common RFID backend infrastructure would become more likely. We believe that more research on possible economic network effects related to the use of RFID is definitely warranted.

Summarizing our interpretations of the statistical results, the main adoption hurdle of cross-company RFID implementation is the unequal distribution of profitability and the difficulties involved in estimating costs and benefits on the supply chain level. The influence of the considered organizational factors was dwarfed by the considered economic factors. In the light of high expectations regarding the profitability of cross-company implementation of RFID (see Table 1), our results suggest that in order to advance here, managerial efforts should for now concentrate on the development of adequate cost sharing arrangements and tools that support more accurate ex-ante cost and benefit estimation.

6 CONCLUSIONS

Our research has lead to a number of insights regarding the factors that are perceived to influence the adoption of cross-company RFID. The impact of all considered cost-benefit factors – namely the expected overall profitability of RFID across the supply chain, the uncertainty of costs and benefits, and the asymmetry of profitability – was statistically significant. The influence of the considered organizational factors – in particular the existence of a powerful player, the existence of an RFID 'leader' and the extant RFID experience in the supply chain – could not be proven. Our results therefore indicate that the role of organizational factors may be overrated in the given context – at least in direct comparison to cost-benefit factors. However, the collection of more empirical data and the application of more sophisticated statistical methods are warranted in order to legitimately draw conclusions along those lines.

Technical challenges related to the use of RFID in supply chain operations, in particular the often criticised lack of technical standards for RFID hard- and software, have not been considered in our model although they could be an important determinant for RFID adoption. Follow-up research should therefore explicitly address technical issues and evaluate their impact on the adoption and success of cross-company RFID.

Based on our results we recommend that future non-technical RFID research should focus on effective and more reliable ways to estimate and measure RFID costs and benefits across the supply chain and to share RFID technology costs in an incentive-compatible way.

References

Bakry, S. H. (2003). Toward the Development of a Standard E-Readiness Assessment Policy. International Journal of Network Management, 13(2), pp. 129-137.

Bensel, P., Günther, O., Tribowski, C. and Vogeler, S. (2008). Cost-Benefit Sharing in Cross-Company RFID Applications: A Case Study Approach. International Conference on Information Systems, Paris, France.

Brock, D. L. (2001). The Electronic Product Code (EPC) – A Naming Schema for Physical Objects. Auto-ID Centre White Paper.
Byrnes, J. (2003), Who will Profit from Auto-ID? Harvard Business School Working Knowledge. http://hbswk.hbs.edu/archive/3651.html. Last visited: 11/15/2008.
Chwelos, P., Benbasat, I., and Dexter, A. S. (2001). Research Report: Empirical Test of an EDI Adoption Model. Information Systems Research, 12(3).
Gaukler, G. M., Seifert, R. W. and Hausman, W. H. (2007). Item-level RFID in the Retail Supply Chain. Production and Operations Management, 16 (1).
Gille, D. and Strüker, J. (2008). Into the Unknown: Measuring the Business Performance of RFID Applications. In Proceedings of the 16th European Conference on Information Systems, Galway, Ireland.
IDTechEx (2007). RFID Forecasts, Players and Opportunities 2007-2017. www.idtechex.com/forecasts. Last visited: 11/15/2008.
Imai, K., King, G. and Lau, O. (2008). Toward A Common Framework for Statistical Analysis and Development. Journal of Computational and Graphical Statistics, 17(4), pp. 1-22.
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, 4 (1), pp. 45-64.
Loebbecke, C. (2005). RFID Technology and Applications in the Retail Supply Chain: The Early Metro Group Pilot. In Proceedings of the 18th International Bled eConference, Bled, Slovenia.
Madlberger, M. (2008). Einsatz von RFID im Supply Chain Management: Eine empirische Analyse der Einflussfaktoren. In Proceedings of Multikonferenz Wirtschaftsinformatik, München, Germany.
Mason, R. L., Gunst, R. F. and Webster, J. T. (1975). Regression Analysis and Problems of Multicollinearity. Communications in Statistics – Simulation and Computation, 4(3), pp. 277-292.
Michael, K. and McCathie, L. (2005). The Pros and Cons of RFID in Supply Chain Management. In Proceedings of the International Conference on Mobile Business, Sydney, Australia, pp. 623-629.
Ngai, E., Moon, K. K., 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, 112 (2), pp. 510-520.
Niederman, F., Mathieu, R. G., Morley, R., and Kwon, I.-W. (2007). Examining RFID Applications in Supply Chain Management. Communications of the ACM, 50(7), pp. 92-101.
Rogers, E. M. (2003). Diffusion of Innovations. Free Press, New York, USA.
Romanow, K., Lundstrom, S. (2003). RFID in 2005: The What is More Important Than the When with Wal-Mart Edict. AMR Research Alert.
Scala, S. and McGrath Jr., R. (1993). Advantages and Disadvantages of Electronic Data Interchange – an Industry Perspective. Information & Management, 25(2), pp. 85-91.
Seymour, L., Lambert-Porter, E., and Willuweit, L. (2007). RFID Adoption into the Container Supply Chain: Proposing a Framework. In Proceedings of the 6th Annual ISOnEworld Conference, Las Vegas, USA.
Sharma, A., Citurs, A., and Konsynski, B. (2007). Strategic and Institutional Perspectives in the Adoption and Early Integration of Radio Frequency Identification (RFID). In Proceedings of the 40th Hawaii International Conference on System Sciences, Hawaii, USA.
Strüker, J. and Gille, D. (2008). The SME Way of Adopting RFID Technology: Empirical Findings from a German Cross-Sectoral Study. In Proceedings of the 16th European Conference on Information Systems, Galway, Ireland.
Teo, H. H., Wei, K. K., Benbasat, I. (2003). Predicting Intension to Adopt Interorganizational Linkages: An Institutional Perspective. MIS Quarterly, 27(1).
Weber V. and Jensen, O. (2007). RFID Implementation in Germany: Challenges and Benefits", OECD Report.
Williamson, E. (1979). Transaction Cost Economics: The Governance of Contractual Relations. Journal of Law and Economics 22(2), pp. 233-261.