MODERATED REGRESSION: EFFECTS OF IT INFRASTRUCTURE INTEGRATION AND SUPPLY CHAIN PROCESS INTEGRATION ON THE RELATIONSHIPS BETWEEN RFID CRITICAL SUCCESS FACTORS AND SYSTEM DEPLOYMENT OUTCOMES

Rebecca Angeles, Faculty of Business Administration, University of New Brunswick Fredericton, 7 Macauley Lane, Fredericton, New Brunswick E3B 5A3, Canada, 506-453-4962, rangeles@unb.ca

ABSTRACT

This study investigates how information technology (IT) infrastructure integration and supply chain process integration moderate the relationships between RFID critical success factors, and operational efficiency and market knowledge creation. The moderated regression procedure was applied and found to partially support the hypotheses. IT infrastructure integration was the more effective moderator.

INTRODUCTION

Recent studies have featured an interesting array of issues showing the range of the early implementation experiences with RFID. It seems to be a fitting time to regroup and look at the recent studies and see what their major findings have been. Studying critical success factors (CSFs) for RFID deployment will be a continuing exercise as research uncovers more issues and touchpoints that need to be attended to. This study attempts to do just that by focusing on 15 CSFs that are very likely to impact RFID initiative success or failure as firms pursue either operational efficiency or market knowledge creation or both. These RFID critical success factors are: (1) conduct a "proof of application" for RFID; (2) make a business case for RFID ; (3) conduct a "proof of concept" for RFID; (4) commit appropriate level of resources; (5) presence of an RFID champion; (6) identify the right technology partners to support the firm; (7) manage the integration of RFID-enabled applications with other enterprise applications; (8) reengineer the relevant business processes; (9) store, clean, filter, analyze, and share RFID data; (10) manage increased RFID data accumulation; (11) identify willing and ready trading partners to participate in RFID system; (12) find a way of sharing RFID system costs with trading partners; (13) doing a return-on-investment analysis on an iterative basis; (14) introduce necessary organizational changes for the RFID system; and (15) determine data hosting or outsourcing needs. Furthermore, this study focuses on the influence of two variables, information technology (IT) infrastructure integration and supply chain process integration on the relationships between each of the RFID CSFs and the two dependent variables, operational efficiency and market knowledge creation using moderated regression analysis.

LITERATURE REVIEW

Independent Variables: Critical Success Factors (CSFs) for RFID Implementation

The presence of an RFID champion who understands the possibilities of the technology usually helps the initial stages of getting the concept introduced in the firm [5] [7] [19] [23]. After a certain period of immersion in the knowledge of RFID, the time finally comes when the firm must decide whether or not to conduct a pilot study in order the test the information just gained. The request of a trading partner (customer or supplier) to participate in an intercompany pilot project may also instigate the experimentation process [4] [5] [7] [17] [18] [24]. There appears to be the right time to make a business case for RFID and to develop a limited "proof-of-concept" pilot study to demonstrate actual and palpable results to the firm [4] [7]. If the initial pilot study is successful, usually, the request usually follows for deploying more scalable pilots in areas that can quickly deliver demonstrable results [3] [23] [24]. At this point, project proponents need to commit the appropriate level of resources to support the pilots [7]. Subsequently, the firm needs to find the right technology partners to set up the RFID electronic environment [4] [7] [16] [19] [23]. If the project needs to go beyond the firm's four walls, the firm also needs to identify willing and ready trading partners (customers or suppliers) who could participate in the pilot [7] [9] [15] [16] [24]. In the course of conducting the extended trials, the firm also has to conduct a "proof of application" for the RFID technology [4] [5] [7] [13] [17] [18] [23] [24]. This means making sure that hardware and software products from multiple vendors can work together. The firm needs to find a way of engaging trading partners in the RFID initiative for a longer term. Related to this effort is finding a way of sharing the costs of the RFID network with trading partners [5] [7]. With corporate-wide RFID deployment, the firm needs to deal with a number of implementation issues: reengineer the relevant business processes [5] [7] [16]; manage the integration of RFID-enabled applications with other enterprise applications [2] [4] [7] 1[7] [19] [22] [24]; and manage necessary organizational changes [4] [7] [24].

There are also a number of data management concerns: manage increased data accumulation [7] [18] [24]; store, clean, filter, analyze, and share data [7]; use the same data base model among RFID participants [4] [5] [7]; and determine data hosting or outsourcing needs [4]. As the firm gains more experience with RFID, it should conduct iterative return on investment analyses as it gathers refined cost and benefit data [4] [7]. When the RFID system is used for production purposes, there is the need to train end users in the use of the system [4] [7] [24].

Dependent Variables: System Deployment Outcomes: Operational Efficiency versus Market Knowledge Creation

This study looks at two dependent variables --- gaining operational efficiency and creating partner-enabled market knowledge [12]. Operational efficiency is defined in this study as the extent to which a firm responds to its supply chain partner's daily needs efficiently. Partner-enabled market knowledge creation, in turn, refers to the firm's ability to increase their knowledge base over such things as competitive forces in the marketplace in conjunction with their supply chain trading partners.

Moderator Variable: IT Infrastructure Integration

IT infrastructure integration is defined as the degree to which a focal firm has established IT capabilities for the consistent and high-velocity transfer of supply chain-related information within and across its boundaries. Rai, Patnayakuni, and Seth [20] define IT infrastructure integration in terms of two subconstructs, data consistency and cross-functional SCM application systems integration. The extent to which data has been commonly defined and stored in consistent form in databases linked by supply chain business processes is referred to as data consistency [20]. Cross-functional supply chain management applications systems integration, on the other hand, is defined as the level of real-time communication of a hub firm's functional applications that are linked within an SCM context and their exchanges with applications like enterprise resource planning (ERP), customer relationship management (CRM), and supply chain management (SCM) applications, among others [12].

Moderator Variable: Supply Chain Process Integration

Supply chain process integration is defined following the construct used by Malhotra et al. [12]: the degree to which a hub firm has integrated the flow of information [10], physical materials [21], and financial information [11] with its value chain trading partners. Information flow integration refers to the degree to which a firm exchanges operational, tactical, and strategic information with its supply chain trading partners [12]. Physical flow integration is the level to which the hub firm uses global optimization with its value chain partners to manage the flow and stocking of physical materials and finished goods [12]. Financial flow integration is defined as the level to which a hub firm and its trading partners exchange financial resources in a manner driven by workflow events [12].

HYPOTHESES TO BE TESTED

This study purports to test the following hypotheses:
H1: The positive relationship between each of the RFID critical success factors and operational efficiency will be moderated by IT infrastructure integration --- i.e., the higher the level of IT infrastructure integration, the greater the positive relationship between each of the RFID critical success factors and operational efficiency.
H2: The positive relationship between each of the RFID critical success factors and market knowledge creation will be moderated by IT infrastructure integration --- i.e., the higher the level of IT infrastructure integration, the greater the positive relationship between each of the RFID critical success factors and market knowledge creation.
H3: The positive relationship between each of the RFID critical success factors and operational efficiency will be moderated by supply chain process integration --- i.e., the higher the level of supply chain process integration, the greater the positive relationship between each of the RFID critical success factors and operational efficiency.
H4: The positive relationship between each of the RFID critical success factors and market knowledge creation will be moderated by supply chain process integration --- i.e., the higher the level of supply chain process integration, the greater the positive relationship between each of the RFID critical success factors and market knowledge creation.

METHODOLOGY

Data for this research study were collected using a survey questionnaire administered online. Members of the Council of Supply Chain Management Professionals (CSCMP) were contacted and invited to participate in the study. A total of 198 firms responded to the study. The low response rate is due to the length and depth of the questionnaire that covered an extensive range of topics. This risk was built into the study since this project was considered primarily an exploratory effort at understanding the RFID implementation experience at this fairly early stage of the technology diffusion uptake in the marketplace.

FINDINGS

A description of the sample pool of firms shows that about 48.98 percent of the firms had less than 1,000 employees and 38.88 percent had more than 1,000 employees. This paper is reporting on a total of 126 firms that have not yet implemented RFID in their corporate premises. Majority of the total sample respondents also belong to the service sector (68.18 percent).

Regression Results

Initially, full multiple regression models with all 15 RFID critical success factors as independent variables and the two dependent variables, operational efficiency and market knowledge creation were ran. Both models with all 15 RFID critical success factors as independent variables in the models resulted in multicollinearity problems. Subsequent multiple regression models were tried and the number of independent variables in the models were reduced until the multicollinearity issue disappeared. The selected RFID critical success factors that "survived" these procedures are: 1) presence of an RFID champion; 2) find the right technology partners; 3) find willing trading partners; 4) integrate RFID applications with other enterprise business applications; 5) find data hosting and outsourcing application service providers; 6) conduct iterative ROI analysis; and 7) share RFID costs with trading partners.

Moderated Regression Procedure

Moderated regression analysis tests whether the relationship between two variables changes depending on the value of another variable (i.e., interaction effect) [1]. The moderator variable explains changes in the nature of independent variable to the dependent variable effect, and provides information concerning the conditions under which an effect or relationship is likely to be stronger. Regression analysis was conducted to test the hypotheses presented in this study. The moderated regression procedure requires testing first order effects, which in this study, will be referred to as "model 1." A model 1 simple regression tests the direct effects of a predictor variable on a dependent variable. As the independent variable, each of the RFID critical success factors was regressed against each of the dependent variables, operational efficiency and market knowledge creation. The variance in the dependent variable on account of the independent variable is noted using the R^2 value. Then, the regression procedure testing second order effects is conducted, which will be referred to as "model 2" in this study. A model 2 regression duplicates the model 1 regression equation and adds the product term which includes the hypothesized moderator variable. It is important to determine how large the change in R^2 should be in order to qualify as "practically significant" or one that should merit serious attention [1]. A statistically significant R^2 change of about 1 percent to 2 percent demonstrates an effect size worthy of consideration [6]. The results in this study include significant R^2 change values within the range with a maximum value of 4.2 percent and a minimum value of 0.6 percent, which indicate considerable significant moderating effects of IT infrastructure integration and supply chain process integration.

Moderated Regression Procedure Findings

In predicting operational efficiency, IT infrastructure integration appears to the more powerful moderator variable compared to supply chain process integration in accounting for the variance in the increase of operational efficiency over and above the variance explained by selected RFID critical success factors and IT infrastructure integration as separate independent variables in the model 1 equations.

IT Infrastructure Integration Capability as Moderator Variable with Operational Efficiency as a System Outcome

More substantial results are shown here in descending order of importance based on the percent R^2 change resulting from the introduction of a product term, ITIntegrateCat1, in the multiple regression equation. This is the nominal variable that represents the mean of data consistency and cross-functional process integration, the two components of IT infrastructure integration. Table 1 shows the results of running two regression models: model 1 showing the relationships between the predictor variables and operational efficiency, without the product term and model 2, the regression results with the inclusion of the product term. Table 1 shows the results with operational efficiency as the dependent variable and IT infrastructure integration capability as a moderator variable. IT infrastructure integration significantly moderates the relationship between the following predictor variables and operational efficiency in descending order of importance: 1) share RFID system costs with trading partners; 2) conduct iterative return on investment (ROI) analysis; 3) determine data hosting or outsourcing needs; 4) identify willing and ready trading partners ; 5) identify an RFID champion ; and 6) integrate RFID with other business applications. The table column labelled "% Variance Explained by Moderator with Product Term" indicates the contribution of the product term --- which is the product of the moderator variable, in this case, IT infrastructure integration and the specific predictor variable. And so, for instance, in the case of "share RFID costs with trading partners," the product term would be the product of "share RFID costs with trading partners" and IT infrastructure integration (i.e., ShareCosts3XIntegrate1). The next column label shows "F Value of Model 2 (degrees of freedom), which means that the F value of model 2 which includes the product term is shown along with the degrees of freedom for that regression model. The significance of the F change from model 1 to model 2 is indicated by the last column.

Table 1 Moderated Regression for Operational Efficiency with IT Infrastructure Integration as Moderator (N=126)

Independent Variables: Selected RFID Critical Success Factors					
Dependent Variable: Operational Efficiency					
Moderator Variable: ITIntegrateCat1 (Nominal variable for the mean of data consistency and cross-functional process integration --- IT infrastructure integration)					
RFID Critical Success Factors	**Model 1: R2 Without Product Term**	**Model 2: R2 With Product Term**	**% Variance Explained by Moderator with Product Term**	**F Value of Model 2 (degrees of freedom)**	**Significance of F Change**
Identify an RFID champion	.807	.822	1.5%	187.688 (3, 122)	p<.002
Find the right technology partners	.814	.823	0.9%	188.802 (3, 122)	p<.017
Find willing trading partners	.796	.817	2.1%	181.942 (3, 122)	p<.000
Integrate RFID with other business applications	.769	.780	1.1%	143.915 (3, 122)	p<.015
Find data hosting & outsourcing ASP	.752	.778	2.6%	147.249 (3, 122)	p<.000
Conduct ROI analysis	.710	.747	3.7%	120.349 (3, 122)	p< .000
Share RFID costs with TPs	.677	.719	4.2%	107.399 (3, 122)	p<.000

Let's take the case of "share RFID system costs with trading partners", the predictor variable whose relationship with operational efficiency is significantly moderated to the greatest extent by IT infrastructure integration. About 67.7 percent of the variance in operational efficiency is explained by "share RFID system costs with trading partners" and IT infrastructure integration as indicated by model

1 in Table 1. Model 2 is, then, introduced by including the product term (i.e., ShareCosts3XIntegrate1) which represents the interaction between "share RFID system costs with trading partners" and IT infrastructure integration. As shown on Table 1, the addition of the product term resulted in an R^2 change of .042, $F(3,122) = 107.399$, $p<.000$. This result supports the presence of a moderating effect. In other words, the moderating effect of IT infrastructure integration explains 4.2 percent of the variance in the increase of operational efficiency over and above the variance explained by "share RFID system costs with trading partners" and IT infrastructure integration as separate independent variables. The relationships between the remaining predictor variables (i.e. RFID critical success factors) and operational efficiency should be conducted similarly.

Supply Chain Process Integration as Moderator Variable with Operational Efficiency as a System Outcome

Table 2 shows the results with operational efficiency as the dependent variable and supply chain process integration capability as the moderator variable. Supply chain process integration significantly moderates the relationship between the following predictor variables and operational efficiency in descending order of importance: (1) share RFID system costs with trading partners; (2) conduct iterative return on investment (ROI) analysis; and (3) determine data hosting or outsourcing needs.

Table 2 Moderated Regression for Operational Efficiency with Supply Chain Process Integration as Moderator (N=126)

Independent Variables: Selected RFID Critical Success Factors					
Dependent Variable: Operational Efficiency					
Moderator Variable: SCMIntegrateCat1 (Nominal variable for the mean of physical, information, and financial flow integration --- Supply Chain Process Integration)					
RFID Critical Success Factors	**Model 1: R2 Without Product Term**	**Model 2: R2 With Product Term**	**% Variance Explained by Moderator with Product Term**	**F Value of Model 2 (degrees of freedom)**	**Significance of F Change**
Identify an RFID champion	.803	.807	0.4%	169.693 (3, 122)	p<.122 Not significant
Find the right technology partners	.816	.819	0.3%	183.643 (3, 122)	p<.213 Not significant
Find willing trading partners (TPs)	.769	.774	0.5%	139.166 (3, 122)	p<.106 Not significant
Integrate RFID with other business applications	.756	.758	0.2%	127.648 (3, 122)	p<.278 Not significant
Find data hosting & outsourcing ASPs	.758	.771	1.3%	137.304 (3, 122)	p<.008 or p<.01
Conduct ROI analysis	.686	.703	1.7%	96.108 (3, 122)	p<.010
Share RFID costs with TPs	.649	.670	2.1%	82.669 (3, 122)	p<.006 or p<.01

IT Integration Capability as Moderator Variable with Market Knowledge Creation as a System Outcome

Table 3 shows the results with market knowledge creation as the dependent variable and IT infrastructure integration as the moderator variable. IT infrastructure integration significantly moderates the relationship between the following predictor variables and market knowledge in descending order of importance: (1) share RFID system costs with trading partners; (2) identify willing and ready trading partners; (3) conduct iterative return on investment (ROI) analysis; (4) determine data hosting or outsourcing needs; (5) identify an RFID champion; (6) integrate RFID with other business applications; and (7) identify the right technology partners.

Table 3 Moderated Regression for Market Knowledge Creation with IT Infrastructure Integration as Moderator (N=126)

Independent Variables: Selected RFID Critical Success Factors					
Dependent Variable: Market Knowledge Creation					
Moderator Variable: ITIntegrateCat1 (Nominal variable for the mean of data consistency and cross-functional process integration --- IT infrastructure integration)					
RFID Critical Success Factors	**Model 1: R2 Without Product Term**	**Model 2: R2 With Product Term**	**% Variance Explained by Moderator with Product Term**	**F Value of Model 2 (degrees of freedom)**	**Significance of F Change**
Identify an RFID champion	.710	.731	2.1%	110.720 (3, 122)	p<.002 or p<.01
Find the right technology partners	.745	.758	1.3%	127.122 (3, 122)	p<.014 or p<.05
Find willing trading partners (TPs)	.720	.747	2.7%	120.380 (3, 122)	p<.000
Integrate RFID with other business applications	.747	.762	1.5%	130.244 (3, 122)	p<.006 or p<.01
Find data hosting & outsourcing ASP	.700	.725	2.5%	107.188 (3, 122)	p<.001 or p<.01
Conduct ROI analysis	.708	.734	2.6%	112.200 (3, 122)	p<.001 or p<.01
Share costs with TPs	.709	.750	4.1%	121.679 (3,122)	p<.000

Supply Chain Process Integration as Moderator Variable with Market Knowledge Creation as a System Outcome

Table 4 shows the results with market knowledge creation as the dependent variable and supply chain process integration as the moderator variable. Supply chain process integration significantly moderates the relationship between the following predictor variables and market knowledge in descending order of importance: (1) share RFID system costs with trading partners; (2) conduct iterative return on investment (ROI) analysis; and (3) determine data hosting or outsourcing needs.

Table 4 Moderated Regression for Market Knowledge Creation with Supply Chain Process Integration as Moderator (N=126)

Independent Variables: Selected RFID Critical Success Factors					
Dependent Variable: Market Knowledge Creation					
Moderator Variable: SCMIntegrateCat1 (Nominal variable for the mean of physical, information, and financial flow integration --- supply chain process integration)					
RFID Critical Success Factors	**Model 1: R2 Without Product Term**	**Model 2: R2 With Product Term**	**% Variance Explained by Moderator with Product Term**	**F Value of Model 2 (degrees of freedom)**	**Significance of F Change**
Identify an RFID champion	.720	.727	0.7%	108.037 (3, 122)	p<.095 or p<.10
Find the right technology partners	.759	.763	0.5%	130.882 (3, 122)	p<.162, Not signif.
Find willing trading partners (TPs)	.706	.712	0.6%	100.700 (3, 122)	p<.097 or p<.10
Integrate RFID with other business applications	.747	.753	0.6%	123.948 (3, 122)	p<.089 or p<.10
Find data hosting & outsourcing ASP	.716	.730	1.4%	110.121 (3, 122)	p<.014 or p<.05
Conduct ROI analysis	.700	.716	1.6%	102.458 (3, 122)	p<.011 or p<.05
Share RFID costs with TPs	.696	.723	2.7%	106.138 (3, 122)	p<.001 or p<.01

DISCUSSION OF FINDINGS

All four proposed hypotheses were partially supported in this study. Both variables, IT infrastructure integration and supply chain process integration, moderate the relationships between selected RFID critical success factors and the two dependent variables examined in this study, operational efficiency and market knowledge creation. Between the two moderator variables, however, IT infrastructure integration tempered a greater degree of the variance between selected RFID critical success factors (i.e., identify an RFID champion, find the right technology partners, find willing trading partners, integrate RFID with other business applications, find data hosting and outsourcing ASP, conduct ROI analysis, share RFID costs with trading partners, and the dependent variables, operational efficiency and market knowledge creation. IT infrastructure integration moderated the relationships between all these RFID critical success factors and the dependent variable, operational efficiency, with the exception of find the right technology partners.

Supply chain process integration, on the other hand, moderated the relationships between only three RFID critical success factors, find data hosting and outsourcing ASP, conduct ROI analysis, share RFID costs with trading partners, and the dependent variables, operational efficiency and market knowledge creation.

These findings affirm the importance of both the IT infrastructure integration and to a limited extent, supply chain process integration elements that undergird RFID system implementation. There are a number of ways to explain this key finding. First of all, when thinking about an RFID system implementation, setting up an IT architecture that ensures data consistency and a setup where related business applications are coordinated and linked in order to achieve cross-functional integration both internally and externally is fundamental and needs to be attended to first. The ability to achieve supply chain process integration which refers to the integration of information flow, physical flow, and financial flow can, then, follow after the basic RFID infrastructure has been put in place. Obtaining business intelligence with the support of data mining tools usually follows after considerable RFID information has been captured and stored. The ability to "mine" valuable insights from accumulated RFID information is a distinct capability in itself. This explanation is somehow confirmed by some of the findings of Visich, et al. [25], a group of researchers who sought to investigate the actual benefits derived from RFID initiatives on supply chain performance. Using Mooney et al.'s [14] framework for three linked effects on operational and management processes for value creation through information. These are automational effects (i.e., value derived from making processes more efficient), information effects (i.e., value obtained from gathering, storing, processing, and distributing information), and transformational effects (i.e., value derived from creating innovative business processes and business transformation). Visich et al. [25] analyzed 55 examples of firm experiences using RFID to obtain operational business value. They found 47 out of the 55 examples (85. 5 percent) exemplified automational effects, five (9 percent) reported informational effects, and three (5.5 percent) examples transformational effects. The results for informational effects, which are relevant to the supply chain process integration finding in this study, can be explained in three ways. First, the firms using RFID in the sample pool of 55 firms may be primarily seeking automational rather than informational or transformational benefits. Second, Visich et al. [25] found informational effects to be harder to quantify as opposed to automational effects. Thus, informational effects could very well be overlooked or underreported by managers and as a result, they may not perceive the contribution of informational effects in obtaining either operational efficiency or market knowledge creation. Third, Visich et al. [25] perceive informational effects to be a consequence of automational effects, where the information content generated by the operational processes increases, inevitably leading to the second order effect, the informational effects of IT on the operational processes. Another insight that may explain this study's result is one of the findings of Kapoor, Zhou, and Piramuthu [8]. They looked into the challenges associated with RFID implementations in supply chains and one they identified is the economic disincentive for supply chain trading partners to share item-level RFID information. The authors note that RFID information-sharing presents a conflict of interests between buyers and sellers. The authors found that trading partners in the upstream segment of the supply chain (i.e., involving suppliers) as opposed to the downstream segment (i.e., involving buyers) usually shoulder most of the costs of the RFID implementation while benefiting the least from the system and bearing more risks in sharing information with its multiple buyers. As a result, suppliers are reluctant to share RFID information, especially at the item-level.

CONCLUSION

Supply chain managers need to be proactive about enabling both IT infrastructure integration and supply chain process integration within their current IT environments to pave the way for a smooth transition to an effective RFID deployment. Also, future research efforts on this subject should investigate firms that have actually implemented RFID and measure the perceptions of the importance of IT infrastructure integration and supply chain process integration as mitigating factors in their RFID system initiatives.

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