Effects of RFID Technology on Profitability and Efficiency in Retail Supply Chains

Completed Research Paper

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ABSTRACT

Many companies do not consider adopting radio frequency identification, or RFID, technology because of the uncertainty of return on investment and the lack of business cases demonstrating its profitability or efficiency. This study investigates whether companies that have adopted RFID technology have better financial performance ratios in the U.S. retail industry. Companies using RFID technology have significantly higher operating income margins, lower inventory ratios, and lower per-employee costs. A regression analysis shows that inventory efficiency and cost efficiency do impact profit margins. The analysis also reveals that maintaining a low-level inventory ratio creates higher profit margins, but more research is still needed to demonstrate that higher profits result when companies adopt RFID technology.

KEYWORDS

RFID, Retail Industry, Supply Chain, Profitability, Efficiency

INTRODUCTION

Radio frequency identification, or RFID, technology allows businesses to share accurate information about inventory data and the supply chain network's product flow between suppliers and retailers. RFID technology allows automatic scanning, which can reduce scanning error rates, as well as the man-power required to scan the products. The technology can also reduce stockouts, which can lead to improved customer satisfaction and reduced revenue loss. Overall, RFID technology should improve profitability for the companies that have adopted it.

RFID technology is a global phenomenon that began in the U.S. retail industry. It first came into the spotlight when Wal-Mart, announced its plan to use the technology during a pilot test in October 2003 (Hunt et al., 2007). Wal-Mart was the first to issue a sweeping RFID technology mandate, which required its top 100 suppliers to put RFID tags on their pallets and cases beginning in January 2005 (RFID Journal, 2003). The mandate was soon expanded to 300 suppliers (Hunt et al, 2007).

Target, one of Wal-Mart's biggest competitors, soon issued its own RFID technology mandate for its top suppliers: They were required, beginning in 2005, to apply RFID tags to any pallets and cases sent to Target's distribution centers and it would expand to all suppliers in spring, 2007 (RFID Journal, 2004). After that, other major retail companies such as Kroger, Home Depot, Albertson, BestBuy, CVS, and Walgreens announced their similar mandates for their businesses to adopt RFID technology (Supply Insight Inc., 2006). Major global retailers, such as Tesco, Metro AG, Carrefour, and Ahold, followed suit with RFID mandates of their own (Zhu et al., 2012). In addition, the U.S. Department of Defense published an RFID mandate, effective March 1, 2007, to its 43,000 suppliers (Malone, 2005), and the Food and Drug Administration published its guidelines about RFID technology adoption for the drug-distribution system (Whiting, 2004).

When Wal-Mart announced in 2007 that it would charge Sam's Club suppliers a $2 penalty for each pallet without a RFID tag shipped to distribution centers beginning January 2008 (Weier, 2008), this was a serious message to 60,000 Wal-Mart and Sam's Club suppliers. Without RFID technology, suppliers were not going to deal with Wal-Mart in the near future.

Despite all these mandates, no evidence proves that the RFID technology offers companies a profit increase, probably because of its relatively short history of implementation and the U.S. financial crisis of 2007 – 2008. Industry leaders continue to express concerns about RFID technology's return on investment. This paper investigates how RFID technology impacts companies' profitability through improved inventory and operation efficiency.

This study begins with a brief literature review, followed by a detailed listing of the research approach, including the data collection procedure, research hypotheses, and research methods. After the discussion about outputs comes a conclusion section.

Literature Review

RFID technology is formally defined as "the use of wireless systems to identify, capture, and transmit information from tagged objects to enterprise systems" (Visich et al., 2009; Bhatacharya et al., 2010). Whitaker et al. (2007) made a regression analysis with two separate surveys conducted by *InformationWeek*, a leading IT magazine. They found that there was a positive association between information technology application deployment and RFID adoption. Companies with enterprise resource planning and supply chain management systems were likely to adopt RFID technology and better able to capture, store, and process data generated by RFID technology.

Hardgrave et al. (2008; 2011) studied the accuracy of inventory records with RFID tags. According to their reports, the retailers' average stockout rate was 8%, and 4% of annual sales were expected to be reduced because of those stockouts. The study measured stockout rates with tagged items and untagged items over five categories. Except for one category, furniture, RFID tagging was more effective in reducing stockout rates. The researchers estimated a 0.7% potential sales increase because of that reduction.

Freeman et al (2011) claimed that Wal-Mart is a technology leader as well as business leader in the retail sector because Wal-Mart is the world's biggest private sector data warehouse and operating data enabled supply chain coordinator that enables collaborative planning, forecasting, and replenishment (CPRF) and vendor managed inventory (VMI). Wal-Mart shares its data with its suppliers to keep its inventory cost low. Just-in-time as a method of improving competitiveness and reducing costs has proven to be very effective. With the advent of RFID allowing the creation of real-time databases, a real time representation of stock can be located and identified with RFID communication technology being placed in crucial spots in retail stores. Minimizing inventory is proving to be a means to developing a sustained competitive advantage in the arena of cost reduction. Cost containment through effective inventory management are reducing storage footprint, inventory taxes and insurance costs which are the driving factors propelling corporations seeking efficiency and profitability (Emiliani, et al, 2007). With an integration of RFID technology with JIT logistic systems, retail companies maintain reduced inventory and they enable operational efficiency for trucking, cross-docking, and distribution centers with real-time decision making (Qu et al., 2012).

Visich et al. (2009) and Bhattacharya et al. (2010) analyzed existing academic papers about companies adopting RFID technology. Visich et al. (2009) found that RFID technology could reduce stockouts, improve inventory accuracy, increase sales, and speed up receipt of goods in retail stores. Bhattacharya et al. (2010) used content analysis to find benefits for retailers using RFID technology: better management of inventory, improved security, increased operational efficiency, increased visibility, and reduced cost. Soon and Gutierrez (2008) argued that retailers had the power to force their supply chain networks to use RFID technology because the retailers had significant benefits over the manufacturers because of reduced inventory, lower labor costs, and stockout reduction.

Jeong and Lu (2008) examined the impact that investment announcements for RFID technology had on the market value of the firms using them, and the research demonstrated there was a positive abnormal return on those investment announcements. Lee and Lee (2010) developed a RFID-investment evaluation model and analyzed the impact of RFID technologies on the cost savings. Chang (2011) examined manufacturing companies that adopted RFID technology. He chose 62 paired data sets, each of which had a manufacturing company with RFID technology and a competing manufacturing company without RFID technology. He found that manufacturing companies with higher level of inventory ratios and a low level of sales efficiency are likely to adopt RFID technology and RFID technology offered significant benefits for firms through improved inventory ratios and sales efficiency, which translated into higher profit for the firms.

The most popular research method in empirical RFID technology studies is to conduct a survey for key members such as information-technology managers or operation managers (Osyk et al., 2012; Park et al., 2010; Li et al., 2010; Zelbst et al, 2010). Osyk et al. (2012) surveyed the warehousing industry and found that the companies were less optimistic about RFID implementation, and return on investment was the number one concern. Zelbst et al. (2010) surveyed 122 manufacturing companies and found that utilizing RFID technology directly impacts manufacturers' operational performance. Li et al. (2010) surveyed 49 members of Association of Operations Management Rhode Island Chapter and discovered that financial concerns and the lack of business examples were the major reasons they were not considering implementation of RFID technology. Park et al. (2010) compared survey results from the U.S. and Korea, which showed that there was no significant difference in the perception of importance of RFID technology, the benefit and risk of RFID, and RFID's impact on business performance between the two countries.

Skepticism remains that the RFID technology is an upgraded barcode system with a huge cost and little benefit even though RFID industry experts and academic researchers argue that the RFID technology is a disruptive technology to transform supply chains into more efficient systems (Collins et al., 2010). Most empirical analyses of RFID studies focus on supply chain efficiency using the RFID technology. Even if there are lots of RFID case studies for supply chain efficiency, it is not easy to find how much the RFID technology improves cost-savings and profit-boosting. There is not a firm connection between supply chain efficiency and RFID adopted companies' profitability.

In this paper, the author focuses on the U.S. retail industry and categorizes members of the retail industry into two groups, RFID technology adopted retail companies (RFID companies) and non-adopted retail companies (non-RFID companies). These two groups are compared on the basis of financial performance, inventory management efficiency, and per employee efficiency. In addition, the author tries to find a relationship between those efficiencies and profitability in the U.S. retail industry.

DATA COLLECTION

As mentioned earlier, after the first RFID mandate of Wal-Mart in 2003, Wal-Mart announced a compliance penalty for $2 per pallet for suppliers who failed to tag products using RFID technology, which were effective from January 2008 (Weier, 2008). According to the Gartner's Supply Chain Study, in 2008, RFID adoption reached a threshold to spread it over to other industries as well as the retail industry (RFID Journal, 2008). As an industry leader, Wal-Mart defined the year 2008 as demarcation between pilot period and RFID implementation period.

This study used the *Compustat* database to obtain annual financial statements for U.S. retail companies, including balance sheets and income statements. In addition, the data for the number of full-time employees was added, which were not a part of financial statements. NAICS, the North America Industry Classification System, is the U.S. industry classification standard used in the federal statistics. The companies in the U.S. retail industry have a NAICS code beginning with 44 and 45. Between 2004 and 2011, there are 267 U.S. companies in the *Compustat* database that have an industry sector in retail. Among them, 140 companies were selected based on two criteria:

- Each had eight years of financial data, from 2004 through 2011, listed in the *Compustat* database.
- Each was listed in a traditional U.S. stock market, including NYSE, NASDAQ, or AMEX.

The reason for having eight consecutive years of data is to exclude short-lived companies in the stock trade market. The reason for having only U.S. stock market data points is that this study focuses on only the U.S. retail industry.

No official documents show when companies adopted the RFID technology for its supply chain operation. Some businesses announced their RFID implementation in their annual reports to the public or issued a press release about their use of RFID technology. Some developers of RFID technology produced RFID case studies based on their customers' performance. The authors used a web search with Google.com to find RFID technology news with 140 retail company names and their stock symbols with key words of 'RFID', 'supply chain,' 'adoption,' or 'auto ID'. There have been multiple sources of RFID related news in most output of search. In those cases, the RFID journal, a number one trade magazine in RFID, was chosen as a representative of those multiple news. Authors excluded companies whose start date of RFID technology is before 2003 and classified non-RFID companies whose start date of RFID technology after the year 2008. Altogether, of the 140 companies selected for the study, only 26 have a record of using RFID technology in their business before 2008.

This study uses four data sets with two dimensions: time periods – periods 1 or 2, and RFID technology – present or not present. The first number in each data set's bracket is the time period, where 1 refers to 2008 through 2011 and 2 references 2004 to 2007. The second number in the bracket reveals whether the company used RFID technology, where 1 means RFID was present and 0 shows the technology was not. The total number of observations in the data set is 1,120, which is made up of 140 companies over 8 years. Data Set [1,1], Data Set [1,0], Data Set [2,1], and Data Set [2,0] are the resulting sets. Data Set [1,1], because it represents companies' more recent incorporation of RFID technology, is the main data set the study compares to the other respective data sets. Table 1 represents these four data sets.

	RFID Present Before 2008 (1)	**RFID Not Present Before 2008 (2)**
Period 1 (2008 – 2011) (1)	Data Set [1,1]	Data Set [1,2]
Period 2 (2004-2007) (2)	Data Set [2,1]	Data Set [2,2]

Table 1. Two Dimensional Data Sets

Financial ratios are good tools to compare two individual companies or two groups of companies in the same industry. Days-in-inventory has been used in various studies of RFID adoption effect. Chang (2011) used Inventory to sales ratio, sales efficiency, i.e. sales per unit of labor, and profit margin to evaluate RFID adoption effect on manufacturing companies. Mark (2012) used inventory turnover to compare inventory efficiency of retailers. Using the above data sets, the following five ratios, were calculated. The profit margin, or PM, measures net profit as a percentage of revenue. Inventory management ratios for the data sets are days-in-inventory, or DII, and inventory-to-sales ratio, or ISR. DII measures the average number of days a company holds inventory before selling it, and ISR is equal to inventory divided by sales. The last group of ratios relates to per-employee efficiency to determine the effects of RFID technology on efficiency. Per-employee revenue, or PER, and per-employee cost, or PEC, are, respectively, sales revenues and cost divided by the number of full-time employees.

RESEARCH HYPOTHESES

Among the four sub data sets, the main focus of this study is Data Set [1,1] because it represents the companies most recently relying upon RFID technology. This study tested, first, whether the mean difference between Data Set [1,1] and Data Set [1,0] is equal to 0, and second, whether the mean difference between Data Set [1,1] and Data Set [2,1] is equal to 0. In addition, linear relationships are estimated between various ratios for inventory efficiency and per-employee efficiency, and profitability. Research hypotheses included:

H_1 *In Period 1(2008-2011), retail companies with RFID technology before 2008 show stronger signs of performance in profitability, inventory management efficiency, and per-employee efficiency when compared to non-RFID retail companies.*

H_2 *In Period 2(2004-2007), retail companies with RFID technology before 2008 show stronger signs of performance in profitability, inventory management efficiency, and per-employee efficiency when compared to non-RFID retail companies.*

H_3 *A significant linear relationship exists between efficiencies of inventory management and costs for retail companies and their profitability.*

RESULTS

Testing H1

For hypothesis H_1, an independent samples t-test compares mean scores for Data Set [1,1] and Data Set [1,0] with two different independent samples. To compare them, Levene's test is needed to check whether two samples have homogeneous variance (Carver & Nash, 2006). Among the 5 financial ratios, no ratio has homogeneous variance; therefore, the ratios are tested without the assumption of equal variance. In period 1 (2008-2011),the DII, ISR and PEC of companies using RFID technology before 2008 are significantly lower than those of non-RFID companies in period 1 and have a 1% significance level. There is no significant higher in PM and PER for those RFID companies. Therefore, the H_1 is partially supported. In period 1 (2008-2011), companies with RFID technology before 2008 have a stronger indication of performance in inventory management efficiency and per employee cost but the RFID adoption does not guarantee higher profit margin and better per employee revenue. Table 2 summarizes the results of comparing two period 1 data sets.

	PM	DII	ISR	PER	PEC
Mean difference	-0.013	-24.830	-0.034	-59.547	-43.030
t-statistic	-1.116	-4.905	-4.60	-2.65	-2.342
Degree of freedom	334.267	371.903	309.81	243.131	251.865
p-value	0.867	0.000	0.000	0.996	0.010
α	5%	1%	1%	5%	1%

Table 2. Independent Samples T-Tests for Companies with and Without RFID Technology, 2008-2011

Testing H2

H_2, is also tested by the independent samples t-test. Data Set [2,1] and Data Set [2,0] are two independent samples. As we did in testing H_1, Levene's test is conducted. Among the 5 financial ratios, no ratio has homogeneous variance; therefore, the ratios are tested without the assumption of equal variance. The results of testing H_2 are the same as those of testing H_1. In period 2 (2004-2007),the DII, ISR and PEC of companies using RFID technology before 2008 are significantly lower than those of non-RFID companies in period 2 and have a 1% significance level. There is no significant higher value in PM and PER for those RFID companies. Before 2008, the RFID companies in the U.S. retail industry have maintained a lower inventory level and better per employee cost efficiency. Therefore, the H_2 is also partially supported. In period 2 (2004-2007), companies with RFID technology before 2008 have a stronger indication of performance in inventory management efficiency and per employee cost but the RFID adoption does not guarantee higher profit margin and better per employee revenue. Table 3 summarizes the results.

	PM	DII	ISR	PER	PEC
Mean difference	-0.010	-22.915	-0.033	-56.689	-45.674
t-statistic	-0.808	-4.762	-4.616	-3.019	-2.809
Degree of freedom	177.359	331.275	304.085	304.522	325.019
p-value	0.790	0.000	0.000	0.999	0.003
α	5%	1%	1%	5%	1%

Table 3. Independent Samples T-Tests for Companies with and Without RFID Technology, 2004-2007

Testing H3

Base Model for Regression analysis

A linear regression analysis is used to determine the validity of H_3. This study used both cross-sectional and time-series panel data. Because data entries are missing for the number of full-time workers in 18 instances, the total number of observations for testing H_3 is 1,102. Estimating the panel data regression model by ordinary least square might provide a biased solution caused by unobserved heterogeneity (Dougherty, 2006). To overcome this possible problem, two approaches were offered: fixed effect and random effect. According to Green (2012), while the fixed effect assumes that individual heterogeneity is correlated with independent variables, the random effect assumes that the individual heterogeneity is uncorrelated with the independent variables. Jerry A. Hausman developed a test for determining which model is appropriate.

Retailers with RFID technology can influence their PMs through three approaches: reduced inventory can decrease cost, reduced labor can decrease cost, and reduced stockout can increase revenue (Soon & Gutierrez, 2008). The outputs from testing H_1 & H_2 indicate that companies with RFID before 2008 have better inventory efficiency, in terms of DII and ISR, and better cost efficiency, PEC, but they do have lower sales efficiency, or PER. These four ratios use independent variables to predict PM as a dependent variable. However, because of the high correlation between DII and ISR (0.938), and between PEC and PER (0.980), ISR and PEC represent the most reliable inventory efficiency and cost efficiency independent variables. To test this, the following base regression model was estimated:

$$PM_{it} = \beta_0 + \beta_1 ISR_{it} + \beta_2 PEC_{it} + \varepsilon_{it}$$

For i = 1 ~ 140 companies and t = 2004 ~ 2011

This pooled regression model is built under the classical assumption of ordinary least squares to ignore the time and individual dimensions of the panel data. One of the assumptions of this model is homoskedasticity, or equal statistical variance. The Breusch-Pagan Test was used to test the homoskedasticity assumption by running a regression with the squared residuals as a single dependent variable. Because the *p-value*, 0.0382, was less than 0.05, the null hypothesis of homoskedasticity was rejected with a 5% significance level. Therefore, this data qualifies as heteroskedastic. The significant relationship is present in the model at a 0.1% significance level, but its R^2 is relatively low at 0.3841. The significance of coefficients, ISR and PEC, are present at 0.1%. Variance Inflation Factor, or VIF, is a measure of multicollinearity, which is caused by highly correlated independent variables. The VIF values of two variables were each 1.091386, so the variables do not have multicollinearity.

However, the Durbin-Watson statistic, DW d, is quite low at 0.3361. DW d must be compared to two critical d values: d_L and d_H. With two independent variables and 100 observations, the 1% one-tailed critical values are $d_L = 1.50$ and $d_H = 1.58$. If the

d is less than d_L, the null hypothesis, or no evidence of positive correlation, is rejected. If the d is greater than d_H, the null hypothesis cannot be rejected. Because $d < d_L$, this model should have an autocorrelation problem. To overcome that in panel data, the authors must choose one of the above approaches.

To do the Hausman Test, the individual dummy variables should be introduced in the pooled regression model listed above. The null hypothesis for the Hausman Test is no differences result between the fixed-effect model and the random-effect model. Because of the near 0 *p-value*, 6.193e-15, from the Hausman Test, the null hypothesis was rejected. Therefore, the fixed-effect model was more appropriate. Table 4 summarizes the test results from the base model.

	Test Value	Critical Value	Result
Durbin-Watson	d =.3361 *p-value* < 2.2e-16	$D_L(n=100, \alpha=.01, k=2)$ =1.50	Autocorrelation
Breusch-Pagan Test	*Chi-square* = 6.5298 *df* = 2 *p-value*=0.0382	α=.05	Heteroskedasticity
Hausman Test	*Chi-square* = 65.4306, *df* = 2, *p-value* = 6.193e-15	α=.01	Fixed Effect
VIF	1.091386	10	No Multicollinearity

Table 4. Test Statistics and Output

Fixed-Effect Model for Regression Analysis

Baltagi (2005) explained a procedure to estimate the fixed-effect regression model. The model adds some dummy variables in each step.

Model 1: Pooled regression model with no dummies.

Model 2: Adding individual intercept dummies to model 1.

Model 3: Adding time intercept dummies to model 2.

Model 4: Adding ISR's individual slope dummies to model 2.

Model 5: Adding PEC's individual slope dummies to model 4.

Model 6: Adding time slope dummies as well as time individual dummies to model 5.

Table 5 presents the six fixed effect regression models:

Model No.	Regression Model
(1)	$PM_{it} = \beta_0 + \beta_1 ISR_{it} + \beta_2 PEC_{it} + \varepsilon_{it}$
(2)	$PM_{it} = \beta_0 + \beta_{0i} D_i + \beta_1 ISR_{it} + \beta_2 PEC_{it} + \varepsilon_{it}$
(3)	$PM_{it} = \beta_0 + \beta_{0i} D_i + \beta_{0t} T_t + \beta_1 ISR_{it} + \beta_2 PEC_{it} + \varepsilon_{it}$
(4)	$PM_{it} = \beta_0 + \beta_{0i} D_i + \beta_1 ISR_{it} + \beta_2 PEC_{it} + \beta_{1i} ISR_i * D_i + \varepsilon_{it}$
(5)	$PM_{it} = \beta_0 + \beta_{0i} D_i + \beta_1 ISR_{it} + \beta_2 PEC_{it} + \beta_{1i} ISR_i * D_i + \beta_{2i} PEC_i * D_i + \varepsilon_{it}$
(6)	$PM_{it} = \beta_0 + \beta_{0i} D_i + \beta_{0t} T_t + \beta_1 ISR_{it} + \beta_2 PEC_{it} + \beta_{1i} ISR_i * D_i + \beta_{2i} PEC_i * D_i + \beta_{1t} ISR_t * T_t + \beta_{2t} PEC_t * T_t + \varepsilon_{it}$

Table 5. Fixed-Effect Regression Models

Table 5 presents the output of the above 6 fixed-effect models. The *p-values* of (2) through (5) from the Breusch-Pagan Tests are near 0, so the 6 models qualify as heteroskedastic. The problem with heteroskedasticity is that the t-statistics of coefficients cannot be relied upon because the estimated standard errors are biased. The heteroskedasticity-consistent, or HC, standard errors were proposed by Halbert White to fit models with heteroskedastic residuals and correct standard errors (Green, 2012). The output from the HC standard errors has the same coefficient with different *t-values* and *p-values* of the coefficients, which are listed in Table 6.

Model No.	BP Test p-value	Durbin -Watson	R^2	F-Stat (p-value)	Degree of freedom	Intercept (p-value)	ISR (p-value)	PEC (p-value)
(1)	0.0382	0.3361	0.3841	342.7	2, 1099	0.3639	0.1972	-0.0003
				(0.000)		(0.0000)	(0.0000)	(0.0000)
(2)	2.2e-16	1.3314	0.9567	150.4	141, 960	0.4120	-0.1715	-0.0001
				(0.000)		(0.0000)	(0.0038)	(0.0002)
(3)	2.2e-16	1.3265	0.9570	143.5	148, 953	0.4114	-0.1670	-0.0001
				(0.000)		(0.0000)	(0.0050)	(0.0003)
(4)	2.2e-16	1.6377	0.9694	93.0	280,821	0.4843	-0.7065	-0.0001
				(0.000)		(0.0000)	(0.0002)	(0.0000)
(5)	2.2e-16	1.9727	0.9864	118.2	419, 682	0.5113	-0.7673	-0.0004
				(0.000)		(0.0000)	(0.0003)	(0.5969)
(6)	2.8e-11	1.9965	0.9873	116.9	439, 662	0.4415	-0.4232	-0.0001
				(0.000)		(0.0000)	(0.0520)	(0.8993)

Table 6. Comparison of Results Corrected by HC Standard Error

(1), (2), and (3) had autocorrelation problems because their *d* values were lower than d_L, and (4), (5), and (6) did not have autocorrelation problems because their *d* values were greater than d_H. Considering *p-values* of coefficients in (4), (5), and (6), (4) is the most robust. Its intercept is 0.4843, and -0.7065 and -0.0001 are the coefficient of variables, ISR and PEC, meaning that, first, the values of ISR have more influence to the PM than those of PEC, and, second, the lesser values of ISR and PEC are, the higher the PM.

The regression results indicate that maintaining a lower level of inventory can have a positive effect on PMs, and lower per-employee costs do not show a significant effect on increasing profitability. Since the data used in the regression analysis are a combined data set with RFID and non-RFID companies, this study concludes that the RFID technology does not increase profitability for companies using RFID technology. When comparing between RFID data and Non-RFID data, if both data sets use the same approach in either fixed effect or random effect, the direct comparison is ideal. However, the random effect model is acceptable for the RFID company data set and the fixed effect model is good for the non-RFID company data set. Therefore, indirect comparison with fixed effect model is used between entire retail industry and non-RFID companies. Table 7 shows both results from whole retail data set and non-RFID data set. The results from the both data sets are very similar. Therefore, the profit increase through inventory management efficiency and cost efficiency from the RFID technology adoption is not significant. Therefore, H_3 is supported but adoption the RFID technology does not guarantee to enforce a stronger relationship between ISR, PEC and PM.

Data	*Intercept*	*ISR*	*PEC*	*R^2*
Whole retail data	0.4843	-0.7065	-0.0001	.9694
Non-RFID data	0.4842	-0.7061	-0.0001	.9699

Table 7. Comparison of Results with Whole Retail Data and Non-RFID Data

CONCLUSION

Since Wal-Mart announced its plan to use it, RFID technology has been expanding. Even if Wal-Mart and other U.S. major retail companies adopted RFID technology, many U.S. companies have been hesitant to adopt the RFID technology because of the uncertainty of return on investment and the lack of business cases demonstrating its profitability or efficiency.

This study explores the role of RFID technology in the U.S. retail industry. Comparing RFID companies' ratios to the non-RFID companies', RFID retailers have better performance in inventory management efficiency of DII and ISR and labor cost efficiency of PEC in both period 1 (2008-2011) and period 2 (2004-2007). Therefore, we cannot conclude that RFID retailers' superiority in the ratios is due to adoption of RFID technology. In both periods, it cannot conclude that PM and PER of RFID companies are better than non-RFID companies. It may possibly be because of the Great Recession of 2007-2008. Through 2009, there were negative growth rates in U.S. gross domestic product, and U.S. retail sales total were lower than that in 2007.

Companies with RFID technology are big businesses in the U.S. retail industry. Among 140 U.S. retail companies, 26 RFID retail companies' market shares equal 77.87% of the 140 U.S. retail companies' market shares over the 8 years. Based on the 2011 U.S. sales, 19 RFID companies are in the top 25. Therefore, companies with RFID technology rank highly in the retail industry hierarchy, but small retail companies are not willing to adopt the RFID technology. Even with only 19%, or 26 of 140, companies having RFID technology in the retail industry earlier than 2008, the effect on industry could be larger because of the market power of those 19%.

The regression analyses suggest that there is no clear evidence that RFID technology boosted profit for the companies that adopted it. If this study expands over the year 2011 and includes manufacturing industry, it will be expected to understand clearly the effects of RFID technology adoption in the whole supply chain network. As it took 20 years for barcode systems to be ubiquitous (Hardgrave et al., 2008), even if RFID systems has been adopted faster than barcode systems, it might need more time to find a clear evidence of RFID effect on retail companies' profitability.

REFERENCES

1. Baltagi, B. H., (2005). "Econometric Analysis of Panel Data 3rd e." New York, NY: Wiley.
2. Bhattacharya, M, Chu, C. and Mullen, T. (2007). RFID Implementation Retail Industry: Current Status, Issues, and Challenges, Decision Science Institute Conference, Phoenix, AZ, 2007.
3. Bhattacharya, M, Chu, C. and Mullen, T. (2010). An Exploratory study of RFID adoption in Retail sector, Operation Management Research, Vol 3, pp80-89.
4. Carver, R. H. & Nash, J. G. (2006). "Doing Data Analysis with SPSS Version 14," Belmont CA: Thomson.
5. Chang, Y.B. (2011). Does RFID improve firms' financial performance? An empirical analysis, Information Technology and Management, vol 12, No. 3, pp 273-285.
6. Collins, J.D. , Worthington, W.J., Reyes, P.M., and Romero, M. (2010), Knowledge Management, Supply Chain technologies, and firm performance, Management Research Review, Vol. 33, No. 10, pp 947-60.
7. Dougherty, C. (2006). "Introduction to Econometric 3rd e.," New York: Oxford University Press
8. Emiliani, B., Stec, D., Grasso, L., Stodder, J. (2007). "Better thinking, better results: case study and analysis of an enterprise-wide lean transformation 2nd e.", Kensington, Conn: Center for Lean Business Management.
9. Freeman, R. B., Nakamura, A. O, Nakamura, L. I., Prud'homme, M, and Pyman, A. (2011). "Wal-Mart Innovation and Productivity: A Viewpoint," *Canadian Journal of Economics*, Vol. 44, No. 2, pp 486-508.
10. Green, W.H. (2012). "Econometric Analysis 7th e.," Upper Saddle River, NJ: Prentice Hall.
11. Griffith, R. and Harmgart, H. (2004). Retail Productivity, The Institute for fiscal Studies Working Paper Series, Retrieved from http://www.ifs.org.uk/publications/3326
12. Hardgrave, B.C., Langford, S., Waller, M., and Miller, R. (2008). Measuring the Impact of RFID on Out of Stock at Wal-Mart, MIS Quarterly Executive, Vol. 7, No. 4, pp. 181-192.
13. Hardgrave, B.C., Goyal, S., and Aloysius, J. (2011). Improving Inventory Management in the Retail Store: The Effectiveness of RFID Tagging across Product Categories, Information Technology Research Institute Working Paper, Retrieved from http://itri.uark.edu/91.asp?code=completed&article=ITRI-WP155-0910

14. Hunt, D., Puglia, A. and Puglia, M. (2007). WAL-MART RFID INITIATIVE, Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/9780470112250.app1/pdf
15. Jeong, B.K., and Lu, Y. (2008). The Impact of Radio Frequency Identification (RFID) Investment Announcements on the Market Value of the Firm. Journal of Theoretical and Applied Electronic Commerce Research, Vol. 3, No. 1, pp. 41-54.
16. Lee, I. and Lee B.C. (2010). An Investment evaluation of Supply Chain RFID Technologies: A Normative Modeling Approach, International Journal of Production Economics, Vol. 125, pp. 313-323.
17. Li, S. and Visich ,J.K. (2006). Radio Frequency Identification: Supply Chain Impact and Implementation Challenges, International Journal of Integrated Supply Management, Vol. 2, No. 4, pp. 407-423.
18. Li, S., Godon, D. and Visich J.K. (2010). An exploratory study of RFID implementation in the supply chain, Management Research Review ,Vol. 33, No. 10, pp 1005-1015.
19. Lipsey, R.G, and Carlaw, K. (2001). What Does Total Factor Productivity Measure?, Retrieved from http://www.csls.ca/ipm/1/lipsey-e.pdf
20. Malone, R. (2005). RFID Mandates: Gorillas in the Mist, Retrieved from http://www.inboundlogistics.com/cms/article/rfid-mandates-gorillas-in-the-mist/
21. Mark, K. 2012. "Half a Century of Supply Chain Management at Wal-Mart," Harvard Business School Press, 9B12D010.
22. Osyk, B. A., Vijayaraman, B.S., Srinivasan, M., and Dey, A. (2012). RFID adoption and implementation in warehousing, Management Research Review, Vol. 35, No. 10, pp 904-926.
23. Park, K.S., Koh, C.E., and Nam, K. (2010). Perceptions of RFID Technology: A Cross-National Study, Industrial Management & Data Systems, Vol. 110, No. 5, pp. 682-700.
24. Qu, T,. Luo, H., Cao, N., Fang, J., Zhong, R. Y., Pang, A.L.Y., Qiu, X, and Huang, G. Q. (2012). "RFID-Enabled Just-In-Time Logistics Management System for "SHIP" – Supply Hub in Industrial Park, *Proceeding of 42nd International conference on Computer and Industrial Engineering,* Cape Town, South Africa.
25. RFID Journal. (2003), Wal-Mart Expands RFID Mandate, Retrieved from http://www.rfidjournal.com/article/view/539.
26. RFID Journal. (2004), Target Issues RFID Mandate, Retrieved from http://www.rfidjournal.com/article/view/802
27. RFID Journal. (2008). AMR Research: RFID Adoption's Tipping Point is Here, Retrieved from http://www.rfidjournal.com/articles/view?6936
28. Soon, C. & Gutierrez, J.A. (2008). Effects of the RFID Mandate on Supply Chain Management, Journal of Theoretical and Applied Electronic Commerce Research, 3 (1), 81-91.
29. Sullivan, L. (2005). "Wal-Mart RFID Trial Shows 16% Reduction In Product Stock-Outs." *InformationWeek*, October 14. Available at: http://informationweek.com/story/showArticle.jhtml?articleID=172301246
30. Supply Insight Inc., (2006), Retail Mandate for RFID, http://www.supplyinsight.com/Retail_RFID_Mandates.htm.
31. U.S. Census Bureau. (2012). U.S. Census Bureau News, Retrieved from http://www.census.gov/mtis/www/data/pdf/mtis_current.pdf
32. Visich, J.K., Li, S., Khumawala, B.M., and Reyes, P.M. (2009). Empirical Evidence of RFID Impacts on Supply Chain Performance, International Journal of Operations and Production Management, Vol. 29 No. 12, pp. 1290-1315.
33. Weier, M.H. (2008). Wal-Mart Gets Tough On RFID, InformationWeek.com, http://www.informationweek.com/wal-mart-gets-tough-on-rfid/205900561
34. Whiting, R. (2004). FDA Pushes to Drug Industry to Adopt RFID, Retrieved from http://www.informationweek.com/fda-pushes-drug-industry-to-adopt-rfid/17800155?queryText=FDA
35. Whitaker, J., Mithas, S., Krishnan, M.S., (2007). A field study of RFID deployment and return expectations. Production and Operations Management, Vol. 16, No. 5, pp. 599–612.
36. Zelbst, P.J., Green, K.W. and Sower, V.E. (2010). Impact of RFID technology utilization on operational performance, Management Research Review, Vol. 33, No. 10, pp.994-1004.
37. Zhu, X., Mukhopadjyay, S. K., & Kurata, H. (2012). A review of RFID technology and its managerial applications in different industries, Journal of Engineering and Technology Management, Vol 29, pp. 152-167.