Winter 12-4-2016

The Long-Term Impact Of RFID Adoption

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ABSTRACT

Most research problems on Radio frequency identification (RFID) focus on effects of RFID implementation on firms, factors affecting RFID adoption, and impact evaluation of RFID implementation. And literature about RFID adoption concentrates on short-term effects or impact evaluation. However, short-term analysis will not identify the impact of RFID adoption adequately. We use monthly data of 86 companies which adopted RFID projects around the world at some point from January 1997 to December 2011 and perform four years calendar portfolio analysis (CPA) and Tobin's Q comparison analysis to gain comprehensive insights into the mechanism of RFID on firm performance. Further, we investigate five contextual factors that moderate the impact of RFID adoption including adoption time, country, industry, and financial health condition of adoption firms. We find that RFID may not demonstrate its value instantly, but it has indeed enhanced firms' future growth potential in the long run.

Keywords: RFID adoption, event study, calendar portfolio analysis, Tobin's Q.

INTRODUCTION

As of 2006, it has witnessed a mushroom development of the Radio Frequency Identification (RFID), which is expected to take over the barcode technology at a great rate. However, some existing challenges, such as the huge cost, the integration problem and performance uncertainties, make investors hesitate to undertake this innovative technology project. As a result, there is a need for rigorous empirical assessment of the effects of RFID investments on firm performance. At the same time, investigation of this nature is crucial as it provides researchers and practitioners with concrete evidence on whether RFID investments should be considered as a strategy for the creation of firm competitive advantage. Nevertheless, the literature has not yet adequately addressed that issue. Both conceptual and empirical research that assesses the effect of RFID adoption on firm performance remains underdeveloped. Therefore, it is of critical importance to understand not only whether RFID can create value but also how, when and why it could impact firm performance.

The RFID system is viewed as a type of IT-based supply chain management systems (SCMS) because it can provide unprecedented visibility to the supply chain [37]. This visibility has the potential to improve supply chain efficiency and firms operational performance through enhancing inventory efficiency, increasing inventory accuracy, optimizing logistics, and coordinating the flow of materials [10][73]. The use of RFID technology is an extension of IT technology, which can also expand IT technology to the physical world. RFID systems are key components of Internet of things (IoT) at the present stage, which is the network of connected physical objects, and stresses the item traceability and addressability, not mere objects identification [4]. Due to network connectivity or the function of RFID technology, connected objects can collect and exchange data. Therefore, the application of RFID can realize real-time monitoring of almost every link in the supply chain ranging from purchasing, production, sales and after-sale service, which is believed to be able to reduce cost, increase revenue, or increase customer satisfaction because of efficiency improvement [72][75]. During the application process, RFID systems can gather data for subsequent analysis to advocate for or against management decisions. Tajima [60] argued that appropriate use of RFID could create and sustain a competitive advantage. In fact, with the application of RFID, Vital Entertainment Group, which provides video production services and equipment rental and sales to customers throughout the United States, improved efficiency, increased inventory accuracy by more than 50 percent and decreased labor costs [8]. Following the RFID solution's installation at all three distribution centers (DC) of Patrizia Pepe, an Italian fashion brand of Tessilform S.p.A., the DCs could process approximately 330 products hourly compared to 140 products previously [64]. Hellström [25] analyzed two firms' data and found that RFID investment resulted in nearly 0% loss of roll containers in IKEA, and, a 20% annual loss was avoided in Arla Foods.

However, there is no consistent empirical evidence on the trade-off between RFID benefits and costs among those a few empirical studies. Jeong and Lu [28] had used the event study method to estimate the short-term impact of RFID on market value of firms, and found a positive impact. But another similar research conducted by Bose et al. [9] observed opposite results in short time. Both theoretical and methodological explanations could be used to account for the contradictory results. From the theoretical viewpoint, RFID has the potential to improve firm performance and customer value, but as the RFID technology matures, the entry barriers is lowered, the market competition is intensified and the market efficiency that enables a firm to maintain monopoly power is eliminated. From the methodological viewpoint, the samples used, measurements used, or the failure to control the other event effects are the primary reasons for the inconsistent results. Furthermore, RFID implementation takes years of effort, experimentation, and commitment, research on the short-term impact may not fully reflect possible financial influence of RFID adoption. And IT, like RFID, contributes to performance dimensions such as strategic flexibility and intangible value. RFID's value cannot be fully realized in a short time and short-term analysis will not identify these benefits of RFID [6]. Thus, a long-term observation is needed to investigate RFID's impact.

A critique in the management literature to event studies using long-term windows is that other events will naturally occur as the window expands into the future and will confound the effects of the event under study [44]. In response to those issues, calendar portfolio analysis is used in this study to discover RFID's long term impact on firms' market value. This method is market-based and risk-adjusted for general market movement, inflation, firms' market risk and so on. Single indicator alone has its prerequisite and its insufficiency, in this paper we use different metrics. It is argued that efficiency performance measures (such as Tobin's Q, Return on Equity, productivity) are different from effectiveness performance measures (such as market value-added and IT-enabled strategic options) [39]. Rate-of-return measures, such as Return of Assets (ROA), Return on Equity (ROE), and Return on Sales (ROS), are base on historical accounting measures. These ratios based upon accounting measures typically only reflect the past information of the firm, not forward looking and they are not risk-adjusted. Additionally, accounting measures of firm performance are sensitive to the time lags necessary for realizing the potential of capital investment. This could be particularly problematic in the situation of RFID investment, due to the RFID implementation complexity and uncertainty. While Tobin's Q is a forward-looking performance measure, which not only reflects the value of physical assets but the value of its intangible assets [40][51][54]. Therefore, we adopt the CPA and Tobin's Q comparison analysis to gain comprehensive insights into the mechanism of RFID on firm performance.

Our paper contributes to the research in the following ways. Firstly, by adopting metrics including the market based performance measure (AR) and efficiency performance measure (Tobin's Q), we examine the impact of RFID adoption on company's performance from different perspectives. Our results indicate that RFID investments do create value to firms but this benefit is more invisible and stands for shareholder value, which is quite different from bondholder value indicators such as AR. Thus we provide a reasonable explanation to the inconsistent results reported in literature. Secondly, since the adoption of RFID requires significant amount of time and effort, therefore short-term observation in the length of a few months may not be sufficient. We measure the influence of RFID adoption over a period from the first year to the fourth year after adoption and therefore our results are more reliable compared to short-term analysis. Moreover, from the long-term analysis, we provide empirical evidence to the question of how long can a company benefit from RFID adoption.

The remainder of this paper is structured as follows: First, we briefly summarize previous literature on RFID implementation effects, factors affecting RFID adoption and impact evaluation of RFID implementation. Then, we present our hypothesis in detail. And we describe our data and methodology involved in the next. Finally, we discuss our results and make the conclusion.

LITERATURE REVIEW

Effects of RFID Implementation on Firms

The resource-based view (RBV) argues that firms possess resources, which are defined as assets or capabilities used to detect or respond to market opportunities, fluctuation or threats [14][52][67]. As to information system (IS) resources, they rarely make a direct contribution to sustained competitive advantage (SCA); they are necessary for SCA, but not sufficient [15]. From the RBV perspective, firms develop IS capability from the deployment of IS resources to production operations and business processes over an extended period of time, which makes the capability embed in the firm and idiosyncratic to the firm. Thus it is difficult for firms that have much in common to imitate due to path dependencies [12][14][17][21]. When integrated with business process, can RFID bring benefits for adopting firms [25]. Visich et al., [66] generalized three-stage impact of RFID on supply chain. This three-stage impact is corresponding to preliminary, intermediate, and mature stages of RFID implementation .

At the preliminary stage, RFID project is not yet started, and firms is prepared for RFID implementation. Firms may conduct a pilot project to experience potential benefits of RFID implementation and to see whether or not there is a match between business process and the application of RFID. This stage reflects the customization of RFID [25]. Once firms decide to implement the technology, they must invest corresponding manpower, material and financial resources. At the intermediate stage, RFID is implemented at a certain entity in the firm and the impact of RFID is associated with automational effects on operational processes for value creation [13]. This stage reveals that RFID can be considered as a part of the "universal infrastructure [30]" or firm resources (ideally, all facilities in the firm are RFID-enabled [3]). At the mature stage, RFID technology is embedded in the organization's operational and managerial work and is used to its fullest potentials [12], i.e. informational effects on managerial processes, and help the adoption firms obtain sustained competitive advantage. A report by the McKinsey Global Institute [43] presented that data were also firm resources. With application of RFID technology, firms can obtain a large amount of RFID data with abundant explicit or implicit information that are real-time and time-dependent [1], which is not possible with the use of bar codes—the predecessor technology of RFID technology [60]. If the derived data are appropriately analyzed for business purpose with certain data analysis technology, the application becomes more customer-oriented and it may generate economic gains for the firm further [107], which can guarantee the firms sensitivity towards market response and external relationships [67].

Factors Affecting RFID Adoption

Despite the advantages of RFID implementation, the reality of RFID adoption is far behind early anticipation that RFID will be widely applied [74]. Therefore, it is necessary to make a comprehensive analysis of the various factors that affect RFID adoption decision. Based on technology-organization-environment (TOE) framework [48][62][70], the factors influencing RFID adoption can

be grouped into technological (T), organizational (O) and environmental (E) context [7][12][32][34][36][65][70][77]. Furthermore, TOE factors not only have impacts on RFID adoption, but also affect value creation of RFID [10][68]. Once the factors that significantly influence the adoption of RFID have been validated, in next phase it would be of great value to explore the value difference across adopters and non-adopters—namely the value or impact evaluation of RFID implementation.

Impact Evaluation of RFID Implementation

Different performance measures represent RFID implementation influence on different perspectives of the firm. In general, there are nonfinancial measures and financial measures. Possible nonfinancial measures are inventory days [41], inventory accuracy [18], throughput [27], and productivity [58]. These measures are limited to manufacture firms. Because non-manufacture firms are also in our sample, these measures cannot be applied in our study. As to financial measures, there are accounting based measures and market based measures.

Accounting Based Measures

Accounting based measures, e.g., profit margins [10] and sales growth [41], do reflect some association between a firm deployment of its RFID resources and RFID value. Among all accounting based measures, ROA and return on sales (ROS) are the most widely used accounting based measures for IT value [19][26]. However, ROA is a lag indicator that reports the outcome of past actions and is backward-looking [55]. Due to the fact that IT adoption usually doesn't generate direct and tangible benefit, using ROA may produce conflict results [69]. Furthermore, RFID implementation require large costs, such as hardware costs, software costs, system integration costs, installation services costs, personnel costs and business process reengineering costs [53]. The cost of RFID may still larger than the technology itself [76]. Hence, ROA or other accounting based measures may not completely evaluate the impact of RFID adoption on firm performance. Moreover, almost all studies that evaluate the impact of IT implementation on firms focus on performance measures measured over a period of time, not measured at a point in time. The conclusions made by these studies are severely affected by their sample period, and these ex post studies suffer from benchmark choice problems and interpretation problems at the same time. These problems are severe for studies that use accounting measures of performance [35].

Market Based Measures

Market based measures such as stock response, i.e. AR, are believed to have advantages such as reflecting stockholders value directly and also investors' evaluation of the impact of managerial decisions. Due to its failure to control for clustering time problem and the differences in the involved firm's environment, it is unsuitable to examine long term impact. For long term impact, cumulative abnormal returns (CAR) or calendar portfolio analysis is mostly used. In continuous time, the CAR represents the abnormal return on a portfolio that is rebalanced every period to give equal weight in each security [57]. Considering the diversity of our samples, CAR will not be an option in our study. To measure long-term abnormal return appropriately, we use calendar-time portfolio analysis (CPA), which is method from the finance literature. The main advantage of the calendar-time portfolio analysis method is that it automatically accounts for cross-sectional correlation of returns [46].

To avoid the drawbacks of ex post metrics, such as ROA, we focus on a performance measure evaluated at a point in time-Tobin's Q [6]. The Tobin's Q is commonly known to be a good market based measure of firm value which is forward-looking, risk-adjusted, and less susceptible to changes in accounting practices [47]. The advantage of Tobin's Q is that it incorporates the capitalized value of benefits from RFID implementation, and can measure the contribution of the firm's intangible assets derived from RFID to market value. Tobin's Q can measure market power from both existing assets and future growth potential of the firm. It is more consistent with the forward-looking nature of the capital markets. In this regard, using Tobin's Q to measure firm performance allows us to capture both observable and unobservable aspects of the relationship between stakeholder welfare. It does a better reflection of RFID's true contribution to firm value.

Then, in order to get comprehensive insights about the RFID adoption impact on adopting firms, we adopt the CPA and Tobin's Q methods to calculate AR and Tobin's Q at the same time.

HYPOTHESIS

The success of IT projects is contingent on whether firms can accrue enough resources and capabilities to create the business value. During the implementation process, IT investments interact with other organizational resources and the external environment to help the firm to respond more proactively and in a timely manner to the external and inherent changes.

For technologies bring significant changes to the operation of firms like RFID, it could be quite time consuming since more resources need to be allocated. Some even caution that the benefits of RFID investments will never materialize because of the consumption of the huge resources. Empirical evidence shows that the major effects from the implementation of RFID are automational effects on operational processes followed by informational effects on managerial processes [66]. Furthermore, the implementation of complicated systematic project like RFID will increase firm expense and asset item, and decrease cash flow in the financial statements. As a result, a firm that implements RFID project may appear financially unattractive to investors. Referring to Tobin's Q, it is quite different from other indicators and stands for the shareholder value. Motivated by their

diverging interests, shareholders favor riskier investments and focus more on future expected returns. Indirect benefits such as customer satisfaction improvement, shortened customer response times may not be truly reflected in stock market evaluation but could be reflected in shareholder value indicator like Tobin's Q. Hence, we may hypothesize the following:

H1a: Firms adopting RFID investments generally will experience significant and negative abnormal market return over a long term.

H1b: The adoption of RFID will have positive influence on Tobin's Q of Firms over a long term.

The timing of adoption reflects the IT strategy of firms. However, no consensus has ever been made regarding the relationship between entry order and profitability. On one hand, first mover advantage view-holders claim that early adopters can obtain a lot of potential benefits such as technological leadership, favorable market position, better access to scarce resources, and strengths in the learning curve, which can make early adopters obtain superior performance and a competitive advantage at the same time [50]. On the other hand, others argue that entry order is not the sole determinant of competitive edge but must be contingent on certain markets and the actions of the first mover and the later entrants [38]. The year 2006 is selected as the boundary year because RFID Journal.com claims that "as we enter2006, RFID can be said to have crossed the chasm". Firms are divided into two groups: RFID adoption before 2006 and RFID adoption after 2006. If first mover advantage exists, we expect to see that companies adopt RFID before 2006 will suffer less negative influence on their abnormal market return, and have greater growth and development potential than later adopters. Early adopters may benefit more compared with later adopters. Hence, we hypothesize the following:

H2a: Firms adopt RFID after 2006 will have higher and negative market abnormal return than those adopt RFID before 2006 over a long term.

H2b: RFID adoption will have will have more positive influence on Tobin's Q for firms adopt RFID before 2006 than those adopt RFID after 2006.

Research has asserted that country plays an important role in determining IT investment's impact. But the conclusion from existing literature is controversial. Dewan and Kraemer [20] together with Pohjola [49] had found a strong relationship between IT and productivity in developed countries, but not in developing countries. However, Meng and Lee [45] discovered that the abnormal return IT investment announcements brought in China was significantly positive. The reasons for mixed results reported in literature are multiple. For one thing, the national environment like cultural, economic, legal and business markets is crucial for firms to develop sustained competitive advantages [71]. For another, though non-US countries may face numerous problems such as standards, costs, business environments and untested markets, the huge market size together with a rapid increase in logistic demand could also bring them fresh opportunities. In US, RFID becomes a competitive necessity to avoid the competitive decline rather than the competitive edge. In non-US countries, the adoption of RFID is much less popular and therefore adopters may capture the competitive advantage more easily. Hence, we conjecture that non-US listed companies have more opportunities to achieve longstanding competitive advantage than firms in US, however US companies may benefit from lower cost for implementation therefore will have better performance in terms of abnormal market return.

H3a: Non-US listed RFID adopters will have higher and significant negative abnormal market returns compared with US listed adopters over a long term.

H3b: RFID adoption will have higher and positive influence on Tobin's Q for Non-US firms than US firms.

Type of industry is believed to be an essential moderator of IT investment. Different industries have different technological resources, capital resources and complementary assets as well as different level of IT capability. We follow Bose et al. [9] and classify our samples into manufacturing and nonmanufacturing samples. On one hand, the manufacturing industry relies heavily on RFID owing to the external supplier and customer's pressure. Greater effort is needed for manufacturing firms than non-manufacturing firms to integrate RFID technology with their customers and to improve the visibility of material flow [23]. While Non-manufactures don't focus on manufacturing parts thus they don't have to invest much into RFID. Non-manufacture RFID adopters can greatly enhance the efficiency of firms and improve the quality of operation or services, which makes them stand out in their industry. On the other hand, manufacturing firms usually don't have IT infrastructure foundation and high IT management capability as good as those of nonmanufacturing firms have. More effort is needed to address the resource problem and the transformation cost could be really high. This higher cost would even compress their lower profit margin compared with non-manufacturers. Hence, we may anticipate that manufacturing firms will suffer more compared with nonmanufacturing firms.

H4a: Manufactures who adopted RFID will have lower and significant negative abnormal market return compared with non-manufacture adopters.

H4b: RFID adoption will have higher and positive influence on Tobin's Q for non-manufacturers than manufacturers.

The financial resources dimension refers to the monetary resources, which are available to cover the costs associated with the purchase, implementation, and maintenance of technological innovations. Additionally the extra resources can be used to acquire the necessary managerial and technical talent to facilitate the implementation of an innovation [11]. A greater abundance of financial resources should provide an organization with more opportunities and resources to evaluate RFID using means such as experiment to decide the appropriateness of RFID [32]. To be short, financial health of firms is an indicator whether firms have enough IT related budget to cover associated IT costs of recruiting specialized personnel and building any needed infrastructure which may turn into drivers for future growth. This is especially the case in the long term, because more cash is needed to ensure the transformation process of RFID. However, allocating more money in building IT infrastructure may imply that less money can be invested in the core business of firms especially for financially unhealthy firms. Based on the above studies, we hypothesize that the market will react more negatively toward financially unhealthy firms over a long term. Thus, we propose the following hypothesis:

H5a: Financially healthy RFID adopters will have significant and higher negative abnormal return compared with financially unhealthy RFID adopters.

H5b: RFID adoption will have higher and positive influence on Tobin's Q for financially healthy RFID adopters than financially unhealthy RFID adopters.

DATA AND METHODOLOGY

Data Collection

Our data are derived from several secondary sources, including Standard & Poor's COMPUSTAT database, Lexis-Nexis, Bvd-Orisis database, and Dr. Kenneth French's website (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/index.html). RFID announcements are collected from Lexis-Nexis database. We refer to Dr. French's website to calculate the stock market based performance measure used in our analysis. In addition, we rely on COMPUSTAT for calculating abnormal return, Tobin's Q, and the controls used in our analysis. Altogether our datasets comprises approximately 119 RFID announcements by 86 firms over the period from January 1th, 1997 to December 31th, 2011. The firms in the final sample meet the following criteria. We collect data using a systematic screening mechanism is conducted following Bose et al. [9].We gather performance data for five successive years upon and after the adoption of the RFID technology (i.e., t to $t + 3$, where t is the year of introduction).

Next, we use two different metrics to capture firm financial performance, namely, abnormal return (AR) and Tobin's Q. We outline our measurement approach for capturing these measures as follows.

Calendar Portfolio Analysis

The calendar portfolio analysis is conducted in two steps: the first step involves computing an average return for the cross-section of investors or firms, and the second step then measures the risk-adjusted performance by estimating a multifactor (e.g., the Fama-French three factor) time-series regression model. The CPA procedure is illustrated in next.

The first step is computed as follows. Firstly, we calculate the monthly stock flucutation:

$$MAR_{it} = (R_{it} - R_{i(t-1)}) / R_{it} \quad (1)$$

Where, R_{it} is the closing price for ith firm in month t. The stock price is retrieved from Google finance and Yahoo finance.Then, in each calendar month t, calculate a mean abnormal return R_{pt} across firms in the portfolio:

$$R_{pt} = 1/ (\sum^{N}_{i} D_{it}) * (\sum^{N}_{i} MAR_{it} * D_{it}) \quad (2)$$

R_{pt} is the portfolio return for month t, MAR_{it} is the monthly abnormal return for ith firm in the portforlio, N is the number of stocks in month t, D_{it} is a dummy variable ,when stock i exsit in month t,then 1 else 0.

Next, we adopt the Fama-French three-factor time-series regression model. For each portfolio in month t, we form an equally weighted portfolio for each subset consisting of all announcements. Under the assumption that individual abnormal returns are normally distributed with mean zero, we pool them together and get a pooled R_{pt} . The observing time windows we have chosen are 12 months, 24 months, and 36 months. Next, we undertake FFM method to observe the long term excess abnormal returns. In line with Sorescu et al. [55], we measure the returns on these portfolios using a three-factor Fama French model [22]. This implies regressing monthly stock returns on market, size, and book-to-market factors. In model form, this gives us:

$$R_{pt} - R_{ft} = \alpha_p + \beta_p (R_{mt} - R_{ft}) + \gamma_p SMB_{pt} + \delta_p HML_{pt} + \varepsilon_{pt} \quad (3)$$

Where R_{pt} is the rate of return of portfolio announcement on month t, R_{ft} is the rate of return on a U.S. Treasury bond f during the same period; R_{mt} is the rate of return of market index m on month t, SMB_{pt} was the correction for the difference in the rate of return between small and big firms in a value-weighted portfolio of stocks; and HML_{pt} is for the difference between the high and low book-to-market ratio stocks in a value-weighted portfolio of stocks. α_p is the model intercept. And β_p, γ_p and δ_p are parameter loadings of the three factors.

Several scholars have employed the FFM model to study the impact of branding [42], new product announcements [55] and marketing alliances [59] on market value. Since the samples in our paper are both US listed and non-US listed, hence, we adopt the merged model proposed by Bose et al. [9] in which an international *HML* is added to the FFM-three factor model, thus the model could explain the returns generated from global value and global growth portfolios. The monthly *IHML* data are downloaded from Prof. French's website. The merged Fama French model (FFM) is shown below .

$$R_{pt} - R_{ft} = \alpha_p + \beta_p (R_{mt} - R_{ft}) + D_p (\gamma_p SMB_{pt} + \delta_p HML_{pt}) + (1 - D_p) \epsilon_i IHML_{pt} + \varepsilon_{pt} \quad (4)$$

Where, $IHML_{pt}$ is the international book-to-market ratio correction factor for month t, D_p is a dummy variable that takes the value 1 when the announcement is listed in a US stock exchange and 0 otherwise.The estimate of y-intercept α_p provides a test of the null hypothesis that the mean monthly abnormal return on the calendar-time portfolio is zero. β_p is the slope that measures the sensitivity of R_{mt}, and ϵ_i is the corresponding slope. And ε_{pt} is the error term. The error term in this regression may be heteroskedastic, thus we use the weighted least squares estimation, where the weighting factor is based on square root of the number of securities in the portfolio in each calendar month. We used this model to establish expectations of the stock returns of firm i in year t. The monthly R_{ft}, SMB_{pt}, HML_{pt}, and $IHML_{pt}$ are downloaded from Prof. French's website. To examine the moderating effects, we define the market-to-book value correction factor (*IHML*) and firm size correction factor (*SMB*) as control variables and each moderating factor is put into the equation each time.

Tobin's Q Comparison Analysis

Tobin's Q is defined as the ratio of market value to the replacement cost of the firm. In principle, the numerator in Tobin's Q can be decomposed into the sum of the firm's capitalized income streams. Previous research has invented a number of ways to calculate Tobin's Q. Some suggest that the market value of the firm can be composed into the value of physical assets and the value of its intangible assets [40][51][63]. King and Lenox [33] argued that calculation of Tobin's Q was measured by dividing the sum of the firm's market capitalization, the book value of its long-term debt, and its net current liabilities by the book value of its total assets. We take the method of Chung and Pruitt [16], Bharadwaj et al. [7], Lindenberg and Ross's [40] using financial and accounting information available from the Compustat database. If the liquidating value is not available, we adopted another substitute method [24].

Next, a matched-pair test is conducted to examine whether the RFID adopting firms outperformed non RFID adopters. We match sample and control pairs based on specific matching criteria to minimize the confounding effects caused by some special factors in a particular industry or by the overall state of the economy at a specific time period. Matching on these variables rules out other alternative explanations for any difference found in financial performance between the two groups.Typically, the matching procedure is based on the industry (in terms of four industry Standard Industrial Classification code) and firm size (in terms of total assets) to control the industry and size effect. Following Stratopoulos and Dehning's [56], in our research, we adopt a similar method. The matched control group acts as a benchmark to measure differential performance. The control group is consisted of a list of non-RFID adopters. They are matched on Standard Industrial Classification (SIC) code and total assets to control for industry effect and size effect.

Aggregation of the differences between the RFID adopting group and the matched control group constitutes the test metrics. These differences are computed as follows:

$$(Tobin's\ Q\ Differential)_i = Tobin's\ Q_{RFID\ adopters} - Tobin's\ Q_{matched\ control} \quad (5)$$

Where $i = t + 1$, $t + 2$, and $t + 3$. If the Tobin's Q differential is positive and significant, it means that the RFID implementation does contribute to the future total firm value.

Control variable

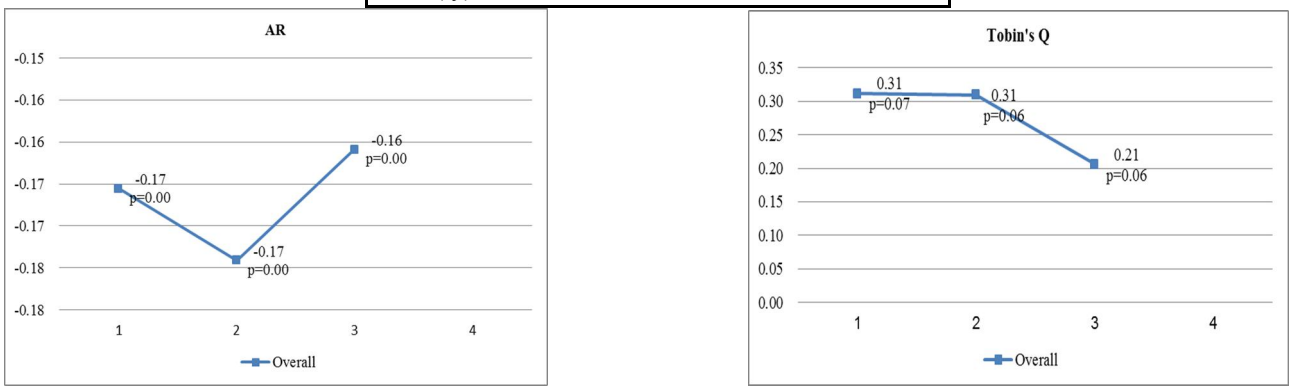
In addition to examining the overall effect of RFID adoption, the sample was divided into subsamples according to the value of contingent factors: timing, country, industry, and financial health. For timing, we divide the companies into two groups: announcements issued before 2006 and after 2006. The dummy variable *M* takes 1 when it is an announcement made after 2006. For country, we divide our sample as US firms and non-US firms. For industry, we divide our samples as manufacturing firms and non-manufacturing firms. For financial health, EM score is positively correlated with the firms' financial health [2]. According to [9], EM score higher than 8.63 is defined as healthy financial firms and lower than 8.63 unhealthy financial firms.

RESULTS

The overall results for the whole sample using two different performance indicators are presented in Table 1. As to the abnormal return, we can clearly observe a consistent significant negative relationship from *t + 1* to *t + 3*. In contrast, RFID adoption has significant positive influence on Tobin's Q from *t + 1* to *t + 3*. An decline in the absolute value of Tobin's Q is also observed.

Table 1: Overall effect of RFID adoption

	t + 1	*t + 2*	*t + 3*
AR	-0.17	-0.17	-0.16
P-value	(0.00)	(0.00)	(0.00)
(*df*)	496	778	1012
Tobin's Q	0.31	0.31	0.21
P-value	(0.07)	(0.06)	(0.06)
(*df*)	56	57	55



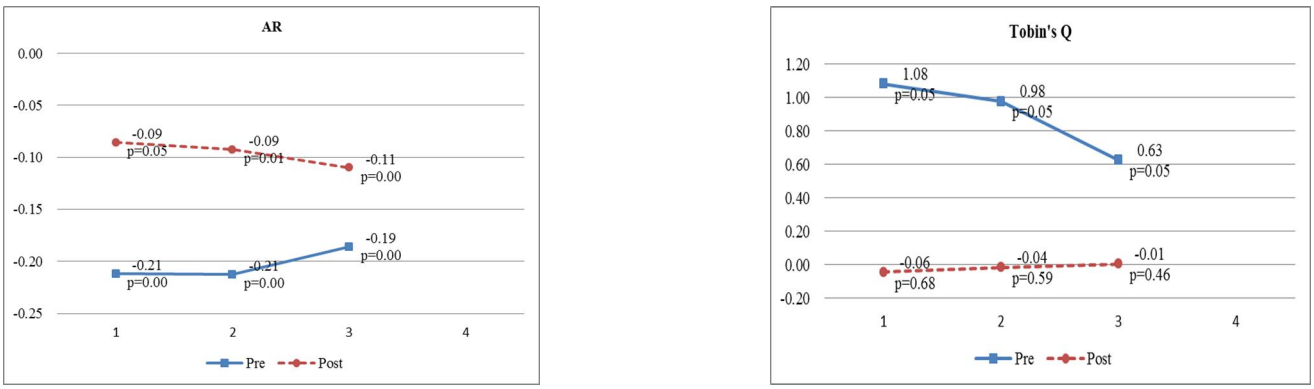
(a) (b)

Figure 1: Overall influence of RFID adoption

The results are quite mixed in relation to the adoption time. As show in Table 2, in general RFID adoption has negative influence on abnormal market return. However the effects on pre-2006 adopters are stronger than post-2006 adopters. It could also be observed that the effect size on pre-2006 adopters decreases from *t + 1* to *t + 3* while the effect size of post-2006 adopters increases over that period. The influence of RFID adoption on Tobin's Q is different for pre- and post-2006 adopter. It seems that early adopters Tobin's Q receive positive influence from adoption of RFID while later adopters received non-significant influences. However, the effect size of influence on Tobin's Q decreases from *t + 1* to *t + 3*.

Table 2: Impact of adoption timing

	t + 1		*t + 2*		*t + 3*	
Timing	Pre	Post	Pre	Post	Pre	Post
AR	-0.21	-0.09	-0.21	-0.09	-0.19	-0.11
P-value	(0.00)	(0.05)	(0.00)	(0.01)	(0.00)	(0.00)
(*df*)	216	262	348	445	451	593
Tobin's Q	1.08	-0.04	0.98	-0.02	0.63	0.01
P-value	(0.05)	0.75	(0.05)	0.72	(0.05)	0.54
(*df*)	17	38	18	38	17	37



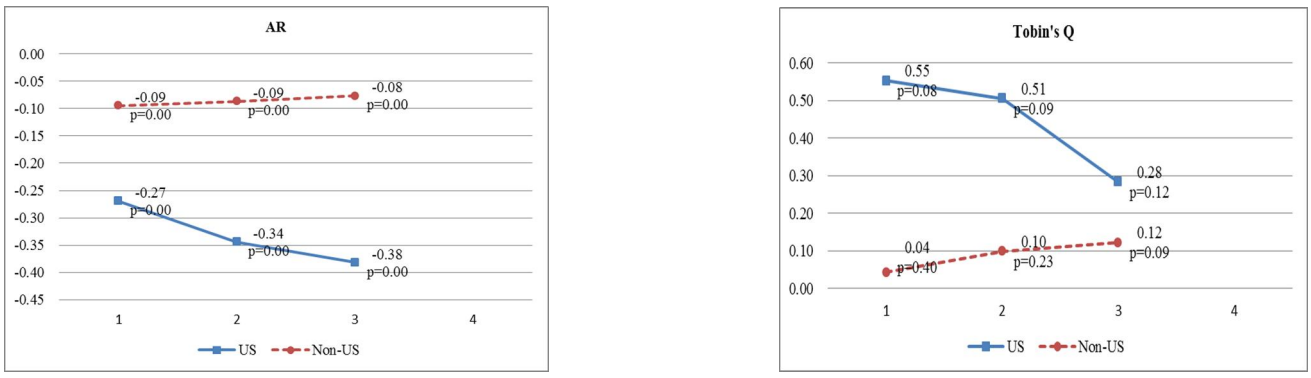
(a) (b)

Figure 2: Impact of adoption timing

As is shown in table 3, our results revealed that in US companies suffer a higher and significant negative abnormal market return than Non-US companies over the period during *t + 1* to *t + 3*. The effect size increased from *t + 1* to *t + 3* for US companies but decreased for Non-US companies. For Tobin's Q, it seems that for the first two years, the influence of adoption is not significant for US companies except for the first year. In contrast, for Non-US companies, although the influence is not significant at the beginning, the effect sizes gradually increases while the p-value gradually decreases.

Table 3: Impact of the country of firms

	t + 1		*t + 2*		*t + 3*	
Country	US	Non-US	US	Non-US	US	Non-US
AR	-0.27	-0.09	-0.34	-0.09	-0.38	-0.08
P-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
(*df*)	135	359	165	611	189	821
Tobin's Q	0.55	0.04	0.51	0.10	0.28	0.12
	(0.08)	0.37	(0.09)	0.21	0.12	0.11
(*df*)	29	26	29	27	28	26



(a) (b)

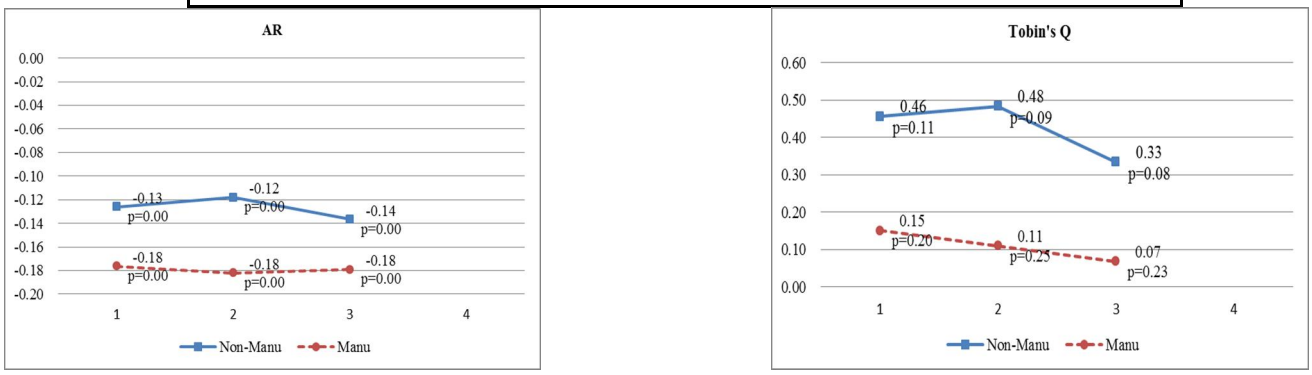
Figure 3: Impact of the country of firms

From Table 4, it is observed both non-manufacturers and manufacturers suffer significant negative influence on their abnormal market return from RFID adoption. The effect size is larger for manufacturers than that for non-manufacturers. For Tobin's Q, RFID adoption seems to have positive influence for both non-manufacturers and manufacturers. The size of effect on non-manufacturers is larger than that on manufacturers in general. However the influence is not significant for manufacturers. In contrast, the influence of RFID adoption begins to appear for non-manufacturers since *t + 2*.

Table 4: Impact of the industry of firms

	t + 1		*t + 2*		*t + 3*	
Industry	Non-Manu	Manu	Non-Manu	Manu	Non-Manu	Manu

AR	-0.13	-0.18	-0.12	-0.18	-0.14	-0.18
P-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
(*df*)	330	237	512	405	685	509
Tobin's Q	0.46	0.15	0.48	0.11	0.33	0.07
P-value	0.11	0.20	(0.09)	0.23	(0.08)	0.25
(*df*)	29	26	30	26	28	26



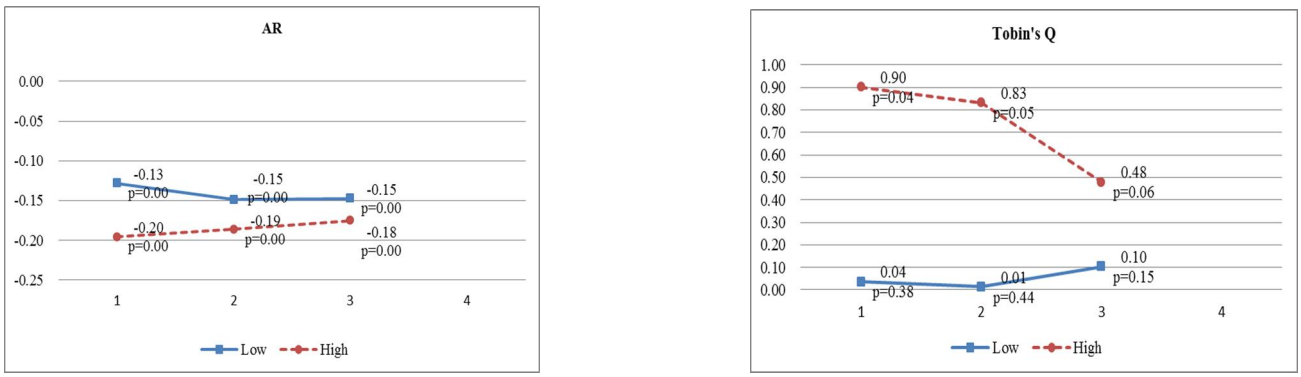
(a) (b)

Figure 4: Impact of industry of firms

As is revealed in Table 5, abnormal market return is more negative to firms with good financial health (high EM scores) compared with financial unhealthy firms (low EM scores) during the period from *t + 1* to *t + 3*. On the other hand, RFID adoption has significant and positive influence on Tobin's Q for firms with high EM scores but the effect size decreases from *t + 1* to *t + 3*. But for low EM score companies, there is no significant influence on Tobin's Q.

Table 5: Impact of financial health of firms

	t + 1		*t + 2*		*t + 3*	
EM	Low	High	Low	High	Low	High
AR	-0.13	-0.20	-0.15	-0.19	-0.15	-0.18
P-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
(*df*)	332	213	569	334	759	382
Tobin's Q	0.04	0.90	0.01	0.83	0.10	0.48
P-value	0.38	(0.04)	0.44	(0.05)	0.15	(0.06)
(*df*)	25	22	26	22	25	21



(a) (b)

Figure 5: Impact of financial health

DISCUSSION

Generally, it is revealed that RFID adoption has a significant negative impact on firms in terms of abnormal return. However, whether there is an influence on Tobin's Q depends on factors such as the timing of adoption, country, industry, and level of

financial health. The reasons behind our results could be multiple.

Firstly, RFID investment does not translate into performance improvement directly. Prior research has showed that the average payback period of RFID adoption is 4-5 years [25]. Therefore the spending or cost of RFID implementation will appear in firms' financial report over a long period and the amount is usually huge. By extending into a long-term observation period, it is helpful for us to understand the impact of RFID more accurately compared with short term studies because the implementation of RFID is a long term project. We discover an interesting pattern regarding to the length of influence of RFID on firms' growth potential, the evidence of which is from our analysis with contingent factors. Subgroup analysis showed that the influence of RFID on Tobin's Q sometimes appear only after $t + 3$ and the influence may decrease from $t + 1$ to $t + 3$. This finding is consistent with Kim and Sohn [31] whose research discovered that the average payback period is 4-5 years.

Secondly, the influence of RFID adoption may not be observed correctly because of the choice of performance measurement and contingent factors. By considering contingent factors, our results provide evidence on how RFID adoption strategy may influence firms' financial performance. The results considering the country effect suggest that in mature market such as US, RFID is a type of competitive necessity which is essential for survive but may not bring competitive advantage. Our results on adoption timing suggest that first mover advantage is still important for RFID implementation. The results on industry again suggest that IT investment does not lead to financial gain directly. Therefore, managerial speaking, our results provides the following suggestions to practitioners. First, it is necessary to examine the overall adoption rate of RFID in market. If the adoption rate is low, RFID adoption may make you lead otherwise RFID's effect is just keep you survive. Second, for managers of manufacturers, extra caution is needed if they want to adopt RFID because those firms may face additional risk due to heavy operational cost and challenges in integrating IT and business. Third, for short term stock market investors, they should avoid investing in firms who adopted RFID during the last three years while for long term value investors, those firms were worth of investment especially for those whose Tobin's Q received a positive influence from the adoption.

This study has its own limitation. First, the sample size could be larger is the data are complete. Second, instead of dividing the firms into US firms and non-US firms, it would be more interesting to fix effect of individual countries given that enough samples could be collected for each country. Finally, it would be more interesting if longer period is studied. If that is possible, we may discover whether manufacturers can finally gain benefit from RFID adoption, which indicates the time profit from usage of RFID exceeds the cost for RFID implementation.

CONCLUSION

Previous studies on the effects of RFID adoption have relied largely on anecdotal evidence, non-financial metrics or accounting based measures that ignore intangible value. In this paper, we present an empirical study of the impact of RFID adoption on firm value across a broad sample of 86 firms over the period from 1997 to 2011. Using different measures: abnormal market return and Tobin's Q, we observe the influence of RFID adoption on those measures during the period of $t + 1$ to $t + 3$ (where t is the year of adoption). Our study offers a comprehensive insight of RFID adoption form it market reaction, accounting operational performance and its future revenue-generation potential. In general, significant negative abnormal return for RFID adoption firms and significant positive influence on Tobin's Q are observed. Subsample analysis with contingent factors discover results consistent with those of the whole sample.

Our research has several contributions. First, our results suggest within the window of three years of adoption, RFID will bring beneficial influence to future growth potential but not ROA and market value. Second, the influence may last for two years but no more. Our results also discover the effect of adoption timing which may suggest first move advantage for RFID adoption. In addition, country, industry, and financial health of firms all may assert influence on the impact of RFID adoption, suggesting that RFID adoption is a complex project and managers should take all these factors into consideration.

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