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A hierarchical model of the impact of RFID practices on retail supply chain performance

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Abstract
The primary purpose of this study was to evaluate the impact of RFID practices on supply chain performance. We examined eight variables of RFID applications grouped in two categories: location (supplier's warehouse, retailer's central warehouse, retailer's local warehouse, retailer's owned stores) and utilisation (standards, transportation, pallet level, specialised software). Given the inherent difficulty in assessing supply chain performance and the widespread use of different performance models, such as the SCOR and balanced scorecard, we developed a list of performance indicators. Factor analysis produced 7 supply chain performance factors: supplier, inventory, distribution, ordering, plan, sales, and forecasting. Empirical data were collected via an online survey administered to 300 retail companies. Of the 300 surveys, 130 usable questionnaires were returned, for a 43.3% response rate. To the best of our knowledge, this is the first study to provide an analytical model that places supply chain performance indicators as dependent variables in a hierarchical regression equation with RFID variables as independent variables. Results found that the implementation of RFID practices significantly affect the supply chain performance in the following areas: supplier, inventory, distribution, plan, sales, and forecasting. RFID can improve the performance of distribution systems, including products dispatched and inventory in transit by 33.8% and stock availability by 45.6%. This study contributes to both the RFID and the supply chain performance literatures. Limitations and suggestions for further research are also discussed.

Highlights
- RFID practices have a positive impact on stock availability (45.4%), waste (42.2%), sales increase (40.1%), and overall supply performance (36.3%).
- RFID adoption can provide a source of sustainable competitive advantage, which will attract more companies in the near future.
- KPIs need to address planning, forecasting, source, replenishment, ordering, distribution and delivery, store operations, and sales and returns

Keywords: RFID, Supply Chain Performance, Key Performance Indicators, Retailing, Technology Adoption
Abbreviations: RFID: Radio Frequency Identification, KPI: Key Performance Indicators, SCOR: Supply-chain Operations Reference-*model*

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1. Introduction

Amid the global economic crisis, managers must capitalise on the significant ways the rapidly evolving forms of information and technology are transforming today's businesses. For example, advanced technologies such as radio frequency identification (RFID) have been increasingly used in industrial, medical and consumer segments to optimise wireless communications and have the potential to solve managerial problems regarding the development and implementation of operational plans and systems.

Contactless communication has been a great catalyst for increased supply chain performance. For example, in 2003, Wal-Mart, the world leading retailer, mandated that all of its major suppliers adopt RFID, thus eliminating manual counting and bar-coding (Kim and Garrison, 2010). Though the benefits of RFID technologies are quite well known, empirical research indicates that they have limited applications in the retail supply chain. Therefore, there is a gap in our understanding as to how retail managers perceive the impact of RFID on supply chain performance. For example, Visich, et al. (2009) noted that RFID has not reached a transformational level even though the common norm is that these new technologies have a great impact on operational improvements as increased competition and advances in information technologies demand considerable structural changes in retail supply chains (Fearne and Hughes, 2000). However, the implementation of RFID in value chains may require a re-engineering of operations, a factor that would act as a significant obstacle against the adoption of RFID.

The aim of this study was to examine how the implementation of RFID during various stages of the retail supply chain impacts the performance of the supply chain. To measure the supply chain performance, several performance models were reviewed and a combination of performance indicators was adopted.

2. Literature Review

First, RFID technology is described, and its main characteristics are outlined. The advantages and benefits of RFID in supply chain management are then discussed and followed by a review of RFID in retail supply chains. This section concludes with a review of different supply chain performance models with an emphasis on the SCOR model.

2.1. RFID Technology

RFID is an identification method used to transmit information from a tag to a reader device. RFID is an automatic object identification technology that identifies objects within a given radio frequency range through radio waves without human intervention or data entry (Muller-Seitz et al., 2009). An RFID system consists of tags, readers, and middleware. A tag is usually a microchip with an antenna. The tag keeps and transmits data to a reader, which is an electronic device used to wirelessly communicate information from the tag to a back-end database (Tajima, 2007). The RFID middleware filters data from readers to avoid information overloading, ensures data accuracy, and feeds enterprise resource planning (ERPs) systems with data to control and manage their business systems and operations. Therefore, RFID overcomes the shortfalls of individual manual tracking systems in storing, tracking, wirelessly identifying and communicating information without the need for the object to be within the line-of-sight (Lee and Lee, 2010). Compared to bar-coding, RFID offers (i) reading advantages, as no physical or visual contact is necessary for tags and readers to communicate; (ii) identification advantages, as RFID can be applied at the item level to identify each product, thus offering item traceability and supply chain transparency; and (iii) physical advantages, as tags are safer than barcodes and they last longer, typically 10 years, under extreme environmental conditions such as humidity, heat, vibration, shock, and other conditions frequently associated with warehouse and transportation operations.

Various market research reports predict the growth in the manufacturing of RFID tags and their increased market acceptance. RNCOS (2012) predicted that the global RFID market will grow at a CAGR of approximately 18% between 2011 and 2014 and reach approximately US$ 19.3 billion. ABI Research (2011) estimated that nearly 750 million RFID tags were consumed by apparel and fashion retailers in 2011. This rapid development of RFID has created momentum regarding its advantages. Particularly, RFID is considered to improve the management of supply chain processes as it can enhance demand forecasting, production planning, inventory management, and retail operations (Ustundag and Tanyas, 2009, Lin et al., 2011). However, most studies report anecdotal evidence such as food safety management (Lao et al., 2012), reverse logistics (Lee and Chan, 2009; Trappey et al., 2010), intelligent traffic management expert systems (Wen, 2010), adaptive product tracking (Ko et al., 2011), resource allocation for garment manufacturing (Lee et al., 2013), and supply chain management combined with lean production (Chen et al. 2012) with respect to RFID applications.

2.2. Advantages of RFID in supply chain management

There is consensus that RFID offers abilities in managing supply chains such as unique identification of products, intelligent communication and real-time information (Zeimpekis et al. 2007; Zhang et al., 2012). These abilities affect all areas of the supply chain such as warehouse management, transportation management, production scheduling, order management, inventory management and asset management (Bourlakis et al., 2011). Specific supply chain operations, such as tracking, shipping, checkout and counting, become more reliable and faster with RFID technology as the technology provides accurate and timely data for managing the information flows, which, in turn, leads to improved material flow and inventory management (Dai and Tseng, 2012). Moreover, RFID systems offer a wealth of supply chain-related data and information that are used for improving the planning and control of supply chain operations (Ngai et al. 2010).

Sarac et al. (2012) conducted a literature review of 142 articles from 1958 to 2009 that examined the impact of RFID technologies on supply chain management and found that RFID addresses three types of supply chain problems: inventory inaccuracy, bullwhip effect and suboptimal replenishment. Despite the evolution in information technology and the ability to automate inventory management, companies often report a mismatch between recorded and actual inventory levels (Dai and Tseng, 2012). DeHoratius and Raman (2008) reported that 65% of the inventory records in retail stores were inaccurate, thus resulting in higher inventory costs, lost sales, and reduced profits. RFID can improve inventory accuracy by eliminating transaction costs and providing real-time information for inventory management and control (Xu et al. 2012; Dai and Tseng, 2012). The bullwhip effect is an observed phenomenon occurs when the demand variability is amplified in the supply chain as demand orders move up the supply chain (Forrester, 1958). The causes of the bullwhip effect can be the demand forecast, order batching, price fluctuations, gaming principle, lead time, market sensitivity, resource allocations, poor information sharing, and lack of supply chain visibility and transparency (see Geary and et al., 2006 for a review of bullwhip effect studies). Therefore, RFID can reduce the bullwhip effect by improving inventory visibility and reducing safety stock levels (Zhou, 2011). Replenishment is critical in safeguarding customer service with the minimum inventory holding costs. The wealth and timeliness of real-time data of RFID provide companies an asset for developing advanced and intelligent replenishment policies that manual or barcode-based systems do not provide. For example, Condea et al. (2012) argued that RFID-based policies have the potential to improve cost efficiency and service levels.

2.3. RFID Applications in Retail Supply Chains

Despite its advantages, there is a limited understanding of the business value of RFID technology in retail supply chains (De Marco et al. 2012). Kok et al. (2008) argued that RFID can be used widely by retailers to identify the precise whereabouts and quantity of merchandise at various supply chain echelons without spending significant time on detailed audits to measure inventory availability across various supply chain locations. RFID can be used for tracking merchandise and inventory (Wamba et al., 2008) on assets such as pallets, cases, or bins as real time data collection is made possible unlike barcodes, which require line-of-sight to read information (Tajima, 2007). RFID adoption may impact labour at the supply chain levels by increasing labour productivity as enhanced asset visibility reduces stock losses and thus relieves the labour workload required for manual inventorying and stock keeping (Tsai et al. 2010). Senauer and Seltzer (2010) indicated that RFID at the store level helps in reducing out of stock merchandise through improved inventory control, while Gaukler (2010) noted that such an inclusion of RFID improves product availability, thereby improving overall profitability and store performance. With the increasing volume of products being sold at the store, the ability to generate accurate demand forecast increases. Furthermore, the implementation of RFID is also found to affect the accuracy of retailers' demand forecast, which further improves the accuracy of stock orders to the replenishment level.

RFID can also be used to intelligently exchange information with customers at the store level, i.e., it describes intelligent racks at store shelves, which can be used to track movement of merchandise in and out of the designated shelf / rack (Muller-Seitz et al., 2009). Such an enablement with integrated electronic displays can also improve the in-store customer experience (Hinkka, 2012). Additionally, RFID can be used by the store managers to understand customer buying behaviours and shopping patterns (Bertolini et al. 2012). Kholod et al. (2009) reported that data captured regarding the length of the customer in-store shopping path has an effect on actual sales volume at the store.

RFID can be applied in various locations across the retail supply chain including warehouses, transportation (either retail and/or supply), distribution centres, and retail stores (Yin et al., 2009). The benefits of using RFID in warehouse management derive from the advantages in inventory management by reducing optimum stock levels and eliminating inventory inaccuracies. Wilding and Delgado (2004) analysed RFID implementations in warehouses or distribution centres in Marks and Spencer, Scottish Courage and Wal-Mart and assessed its impact on improving supply chain performance in areas such as fulfilling lead times, managing inventory availability, reducing shrinkage, etc. following the RFID implementation. Ganesan et al. (2009) identified the need to collect cross-channel customer information through the adoption of RFID and to combine the insight about customer behaviours with suppliers' capabilities to bring about innovation in the supply chain. Sari (2010) explains that suppliers can use real time sales data from stores to reduce overall inventory costs, thereby confirming that RFID is considered to be more of a collaborative supply chain strategy rather a strategy for traditional supply chains. An example of operational process improvements is the complete elimination of shelf inspection at Wal-Mart stores (Seideman, 2003). Bendavid et al. (2009) noted that adopting RFID to create automatic self-service stores generates considerable benefits by reducing human resource effort to perform non-value added activities. Similarly, implementing RFID at a warehouse enables the team to move towards optimised delivery models and away from traditional batch delivery models.

Though RFID improves information quality and accuracy, thus encouraging collaboration with supply chain partners, there are many factors that could undermine its implementations. RFID inhibitors may include the context of warehouse processes and location dimensions, erroneous tagging and reading of tag information (Cheung and Choi, 2011), a lack of organisational readiness and support, and high costs associated with support systems and technologies (Thiesse, et al. 2011). Li et al. (2010) noted that firms were limited by their lack of understanding on how such an RFID implementation would be beneficial across their supply chain measuring points. Visich et al. (2009) argued that the major shortcoming with RFID implementation is the ineffective use of information obtained from various measurement points, which results in a lack of effective implementation, continuous monitoring and measuring of critical information.

2.4. Supply Chain Performance

Improving supply chain performance has become one of the critical issues in sustaining competitive advantages for companies (Cai et al., 2009; Estampe et al., 2010). Performance measurement has evolved during the last three decades from using accounting and budgeting systems as tools to measure business performance to incorporating non-financial measures such as competitors, suppliers, and customers (Chae, 2009). For example, Slack et al. (2001) proposed five performance objectives: quality, speed, dependability, flexibility, and cost. The scope of research on performance measurement has broadened during the last decade, and a number of performance models have been developed to measure, control, evaluate and benchmark according to firm strategic objectives and against industry standards (Gale et al. 2009; Chan and Qi, 2003). Two widely used performance measurement models with supply chain applications are the supply chain operations reference (SCOR) and the balanced score card (BSC). Bigliardi and Bottani (2010) applied the BSC model for measuring performance of food company supply chains using both financial and nonfinancial metrics. Thakkar et al. (2009) developed a performance framework for small and medium enterprise (SMEs) that allowed them to more thoroughly examine their supply chain issues and thus plan strategic improvements by combining BSC and SCOR models. The SCOR model emphasises the operational process and includes customer interactions, physical transactions, and market interactions. The SCOR arranges chain performance measurements in levels of hierarchical structure. Level 1 consists of five supply chain processes: plan, source, make, deliver, and return. Since its introduction in 1996, the SCOR model has been increasingly adopted by companies to improve their supply chains (Huang et al. 2005).

Chan and Qi (2003) recommended a new framework wherein a process-view of the supply chain is adopted and each chain activity is analysed within this context. Banomyong and Supatn (2011) developed a supply chain performance assessment tool (SCPAT) for SMEs and proposed three areas for performance evaluation: cost, time and reliability. Wong and Wong (2007) used a multifactor performance measurement model that considered multiple inputs and output factors and addressed the day-to-day need to measure supply chain performance using new customer centric metrics such as the number of times orders were filled on time and the order delivery rate in addition to financial metrics. Given a wide variety of models and key performance indicators (KPIs) available for measuring supply chain performance, Chae (2009) suggested organisations focus on critical areas to group and align crucial KPIs according to industry standards as so doing would also limit performance measurement to the chosen KPIs consistent with industry requirements. Nevertheless, Cai et al. (2009) argued that most decision makers use measurement metrics for appraising supply chain performance by identifying critical KPIs for monitoring and optimising supply chain performance.

Therefore, for the purpose of the present study, eight areas were chosen to assess supply chain performance: (1) **Plan** - This level 1 SCOR concept addresses demand/supply planning processes, access supply resources, aggregate demand, plan inventory, any priority distribution. (2) **Forecast** - Demand forecasting is a priority in logistics and supply chain management. (3) **Source** - Another SCOR dimension that addresses the procurement of actual goods to match estimated demand. It includes activities such as receiving, inspecting, and storing. (4) **Replenishment** - Replenishment costs can be a considerable proportion of the total supply chain costs. Further, replenishment time is directly related to customer satisfaction. (5) **Ordering** – This is a performance indication that relates to supplier-relationship effectiveness (6) **Deliver** - This area consists of processes that provide finished goods to satisfy planned or actual demand and refers to order management, transportation and distribution. (7) **Make** - Make refers to the processes of production, packaging, holding and releasing products. (8) **Sales and Return** – This area deals with the management of the return flow of materials from consumers and includes activities such as authorising, verifying, disposing, replacing. It also addresses credit management.

3. Methodology

3.1. Research design

To develop a robust model that links RFID practices and supply chain performance, we drew our sample from large retail companies across the globe. In-depth interviews were conducted with key decision makers prior to designing a pretest. Having obtained positive responses, the questionnaire was sent to 300 retail companies via an online methodology. A pre-survey letter explaining the nature of the survey, its goals and ethical issues was also sent to participants to increase recipient's trust in and understanding of the significance of the survey. The questionnaire was sent to retail business managers. Screening questions filtered those who possessed adequate knowledge of RFID applications. We received 130 usable questionnaires. The total response rate was 43.3%, which is considered high percentage as electronic surveys generally receive much lower response rates than traditional paper surveys (Menachemi, 2011).

Respondents were from all over the world, and Table 1 presents the distribution of the sample, which includes the Americas at 26%, Europe at 30%; and Asia at 30%.

Non-response bias was also assessed. A large number of non-responders may cause bias in the risk estimation due to confounding factors associated with the tendency to not respond. Many reasons can contribute to non-participation among respondents, yet not all of these reasons may contribute to response bias. Questions that address a sensitive subject (e.g., financial performance) may increase the potential for response bias. Therefore, this study avoided collecting sensitive data and information to avoid non-response bias. Further, anonymous surveys, such as this one, may partially assist in minimising non-responses (Marquis, Marquis, & Polich, 1986). Additionally, in global studies, certain regions or populations among respondents may be too busy to participate, thus resulting in the underrepresentation of a particular group in the collected data. In this study, there was adequate coverage from all regions. Last, respondents may not trust the value of the study. For this reason, a cover letter explaining the value to all contacted respondents was sent. All of these issues were considered when designing the survey to minimise the systematic non-response bias. After data collection, to ensure that the respondents were comparable to non-respondents, analyses of variances were conducted between these groups. The non-response bias was assessed by comparing demographic variables (region, company size) among non-respondents, early respondents and late respondents (Armstrong and Overton, 1977). No significant differences were found.

------------------Insert Table 1 approximately here ------------------------

3.2. Measures

RFID application was measured using eight variables. The first four variables measured the application of RFID in a specific location across the supply chain (F1: supplier's warehouse; F2: retailer's central warehouse; F3: retailer's local warehouse; F4: retailer's owned store). The other four variables measured the utilisation of RFID enablers (F5: standards, F6: transportation, F7: pallet level, F8: specialised software).

The variables were measured on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Although location variables (F1, F2, F3, F4) could be measured as dichotomous yes/no variables, we chose to measure them using a Likert scale as RFID implementations can differ across the globe and companies can use it with some rather than with all suppliers.

Supply chain performance variables were derived from the SCOR model. We measured each one of the eight SCOR categories (plan, forecasting, source, replenishment, ordering, distribution and delivery, store operations, sales and returns) with three or four measures. In total, twenty-nine performance measures were used. To reduce the number of performance variables and increase the validity of hierarchical regression analysis, we ran a confirmatory factor analysis on performance variables (Table 2). A principal component analysis with varimax rotation was conducted to assess the underlying structure for the twenty-nine supply chain performance measures. The scales were measured on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Seven factors were extracted: supplier, inventory, distribution, ordering, plan, sales, and forecasting (Table 2). After rotation, supplier accounted for 12.260% of the variance, inventory for 12.207%, distribution for 11.984%, ordering for 11.029%, plan for 9.428%, sales for 8.092% and forecasting for 7.707%. The Kaiser-Meyer-Olkin measure was .805, with values greater of .6 indicating sampling adequacy. The Bartlett's test of sphericity squared value was 2342.317 and significant at 0.1%, thus indicating there were not significant relationships among variables. We examined anti-image, which shows correlations among variables that are not due to the common factors, and most or all values off the diagonal were small, thus indicating that variables were relatively free of unexplained correlations. We used the Anderson-Rubin Method, which ensures orthogonality of the estimated factors, to produce factor scores.

Table 2 contains the items, the scale composite reliability (Cronbach α), and factor loadings for the rotated factors. The first factor, which included items measuring the supplier performance, was labelled supplier (five items, α= 0.841). The second factor, labelled inventory, included items that measured the firm's inventory practices (four items, α= 0.821). The third factor, labelled distribution, included four items (α=0.812) that measured the firm's performance on its distribution systems. The fourth factor, labelled ordering, included five items (α=0.846) that measured the effectiveness of the firm's ordering policies and processes. The fifth factor, labelled plan, included four items (α=0.817) that measured firm performance in planning ahead i.e., category planning. The sixth factor, labelled sales, included four items (α=0.692) that measured sales performance. The seventh factor, labelled forecasting, included three items (α=0.791) that measured forecast effectiveness. All factors had high scale composite reliability (Cronbach's alpha), thus indicating a reliable factor structure.

------------------Insert Table 2 approximately here------------------------

Although the supply chain performance measures are appropriate, they have some limitations, which should be discussed. The first is that they are self-reported responses from retail managers, who may have a stake in seeing positive relationships between their decisions about RFID and achievement of the firm's objectives. However, as the responses from the sample contain ample variance, it suggests that the responses do not reflect an extremely strong positive bias (see Table 3, variables 1 through 9). If the respondents had greatly inflated their responses, there would have been more consistently positive results than those that were evidenced. Second, as in all self-reported studies, the possibility of common method variance should be addressed. When both the outcome measure (i.e., supply chain performance) and the eight predictor variables are self-reported on the same survey instrument, both measures share common method variance. Accordingly, there are a number of techniques that can be used to minimise common method variance (Podsakoff et al., 2003).

We used the Harmon's factor test to examine whether common methods variance in the predictor and outcome variables inflates the empirical relationships among the variables. Craighead et al. (2011) conducted a meta-analysis of 320 survey studies and found that two-thirds of the relevant articles published between 2001 and 2009 did not formally address common methods variance, and for those that did address it, they mainly used Harmon's test. Harmon's test consists of a factor analysis of all relevant variables. If a large degree of common method variance is present, one factor will emerge. Such an analysis was conducted on the supply chain performance and RFID practice variables of this sample. Nine factors emerged, with the first factor (which, in cases of common method variance, would account for a majority of the variance) only accounting for 26.77% of the variance. Thus, common method variance is unlikely to bias this sample.

Third, management perceptions about concepts such as effectiveness and performance may actually be more valid indicators than objective data such as profitability, market share and sales as these measures are directly related to a vast number of variables, such as trends in the economy, industry factors, and other environmental factors. Therefore, self-reported measures may, in some cases, represent more accurate descriptions than do more objective measures (Day, 2003; Podsakoff and Organ, 1986). In the present study, the only people with the breadth and depth of knowledge to adequately report on these concepts are the supply managers.

4. Results

4.1. Univariate analysis

Table 3 presents the Pearson correlation analysis. The control variable (sales) showed low correlation with the performance variables as well as with every single RFID variable. On the contrary, almost all supply chain performance variables were associated, to some extent, with RFID practices.

Having automated the supplier's warehouse with RFID (F1) showed significant association with two performance variables: inventory (r=.-.232, p<.05) and forecasting (r=.397, p<.01). Having automated the retailer's local warehouse with RFID showed significant association with two performance variables: supplier (r=.-.200, p<.05) and forecasting (r=.252, p<.01). Having automated standards with RFID showed a significant association with one performance variable: supplier (r=.-.181, p<.05). Having automated transportation with RFID showed significant association with two performance variables: sales (r=.-.190, p<.05) and forecasting (r=.364, p<.01). Having automated pallet levels showed significant association with one performance variable: forecasting (r=.-.183, p<.05).

------------------Insert Table 3 approximately here------------------------

4.2. Hierarchical regression

To explore the relationships between RFID practices and supply chain performance, a hierarchical regression analysis was used. We ran seven multiple regressions, one for each supply chain performance. We then entered variables in three steps and created the models. In

Step 1, we entered only the control variable (firm size) in the regression equation creating the control model. Based on the resource-based view, RFID practices are competitive advantage if they are difficult to emulate. Similarly, large firms may have resource advantages over smaller firms. Therefore, we included firm size as a control variable measured by the number of employees. In Step 2, which is labelled as the independent model, we added the eight RFID practices into the regression equations. Finally, in Step 3, we entered the 28 interactions of the eight factors into the regression equations, thus creating the interaction model. Tolerance tests showed no significant collinearity among variables.

Hierarchical regression results of RFID practices on the seven supply chain performance measures are reported in detail in a series of tables. Table 4 reports the supplier and inventory variables, Table 5 presents the distribution and ordering variables, Table 6 presents the plan and sales variables, and Table 7 presents the forecasting variable.

------------------Insert Table 4 approximately here------------------------

------------------ Insert Table 5 approximately here------------------------

------------------ Insert Table 6 approximately here------------------------

------------------ Insert Table 7 approximately here------------------------

The beta weights presented in Table 4 suggest that supplier warehouse ($\beta=0.09$, $p<.1$) and pallet level ($\beta=0.12$, $p<.1$) are the most influential in predicting the supplier performance variable. Supplier warehouse ($\beta=0.11$, $p<.01$), Retailer central warehouse ($\beta=0.12$, $p<.1$), transportation ($\beta=0.09$, $p<.1$), and pallet level ($\beta=0.11$, $p<.1$) significantly impact inventory performance. Particularly, with respect to the supplier performance variable, the change in adjusted R square value (ΔR) was .140, $p<.1$ ($F=3.167$, $p<.1$), while the change in the inventory R square value was 0.186, p<.01 (F=2.820, p<.01), respectively. Regarding the supplier, the change in Step 3 was also significant, with a value of 0.305, p<.1 (F=2.288, p<.1). According to the above results, RFID practices, especially when applying RFID in the supplier warehouse at the pallet level, contribute to supplier performance by reducing supplier delivery lead-time to stores and lead-time to order stock from the supplier as well as negatively impacting the timely fulfilling of customer orders (Table 2). The implementation of RFID in supplier and retailer warehouses as well as in transportation at the pallet level generates benefits in inventory management with respect to improved store inventory, reduced safety stock levels, and reduced lead-time from retail warehouse to retail store. Retailer central warehouse has the highest beta coefficient (β=0.12), thus indicating that inventory reduction is largely influenced by the automation of the retailer's central warehouse.

With respect to the ordering performance variable, the independent and the interaction models produced no significant changes in adjusted R square values. This can be attributed to the fact that the ordering factor had a significant Cronbach α of .821, yet the measures that affected the ordering factor refer to issues such as pick accuracy and on-time dispatch sales percentage of order. Accordingly, the construct validity appears not to reflect the Cronbach reliability. In contrast, the independent model of the distribution performance variable produced significant results. In particular, the change in adjusted R square was 0.134 p<.1 (F=1.866, p<.1). Distribution performance also had meaningful results in the interaction model, with the change in adjusted R square being 0.338 p<.1 (F=1.937 p<.1). Results indicate that the performance of the distribution system, including products dispatched and inventory in transit, is improved by 33.8%, which is considerable, though it requires the combination of RFID practices.

The interaction model with plan as the dependant variable showed the highest R square change among all supply chain performance variables, with a value of .456 p<.1 (F=2.526, p<.001). This indicates that when RFID is widely applied across the supply chain, there is a 45.6%

improvement in stock availability. Significant beta values included the variables for retailer central warehouse (β= 0.86 $p<.1$) and pallet level (β= 0.5 $p<.01$) as well as the interaction between retailer local warehouse and Retailer owned stores (β= 0.12 $p<.001$). Sales also had a high R square change in the interaction model, with a value of 0.391 $p<.01$ ($F=2.023$, $p<.01$). Furthermore, the hierarchical regression produced significant results for the forecasting variable in the independent model (ΔR = 0.233 $p<.001$; $F=7.708$, $p<.001$). Forecasting and supplier were the only variables where the control variable (size) demonstrated a significant change in adjusted R square, with values of 0.157 $p<.001$ ($F=21.74$, $p<.001$) and 0.068 $p<.01$ ($F=8.523$, $p<.01$), respectively.

5. Discussion & Conclusions

The primary purpose of this study was to evaluate the impact of RFID practices on retail supply chain performance. To our knowledge, this is the first study to provide an analytical model that uses supply chain performance indicators as dependent variables in a hierarchical regression equation with RFID variables as independent variables on a global scale. Hierarchical regression models permit the examination of a set of variables in a step-wise way by producing three models (control, independent, interaction) that separately estimate the contribution of the variables and their interactions.

We examined the following eight variables for RFID applications: supplier warehouse, retailer central warehouse, retailer local warehouse, retailer owned stores, standards, transportation, pallet level, and specialised software. Given the inherent difficulty in assessing supply chain performance and the widespread use of different performance models, such as the SCOR and Balanced Scorecard, we initially compiled a list of eight key performance indicators, each one measured by three or four measures and thereby resulting in twenty-nine measures. To reduce the number of performance variables, we ran a factor analysis that produced a reliable solution of seven factors. The supply chain performance factors included supplier, inventory, distribution, ordering, plan, sales, and forecasting.

This study contributes to both the RFID and supply chain performance literatures in a number of ways. The hierarchical models indicate that there is no single RFID variable that contributes significantly to supply chain performance. However, when the eight RFID variables are entered together into the independent regression model, they produce significant and statistically powerful results for the following supply chain performance factors: supplier, inventory, distribution, ordering, plan, sales, and forecasting. The only factor not significantly impacted was ordering.

Specifically, implementing RFID at the supplier warehouse and pallet level increases supplier performance. The extension of the RFID implementation to the retailer's central warehouse significantly impacts the inventory performance.

Through the implementation of RFID, retailers and their suppliers have access to more accurate and more detailed knowledge of inventory, demand and supply history. When all RFID practices are combined, the performance of the distribution system, including products dispatched and inventory in transit, is improved by 33.8% and stock availability is improved by 45.6%. Although an increase of 45% should be considered a huge improvement in supply chain performance, lower percentages should not be negated or considered negligible. By providing more clarity of information about KPIs across the supply chain, managers can make more accurate and more timely decisions, which, in turn, allow for further lead time reductions.

One limitation of the findings is the use of self-report questionnaires to collect data on all measures as it limits our ability to draw conclusions about the causal nature of the relationships. Self-report surveys may suffer from common method bias because the actual phenomenon under investigation becomes difficult to differentiate from measurement artefacts.

Harman's single-factor test, a widely known approach for assessing common method variance in single-method research designs, found no common method bias, yet this test also has limitations in controlling for bias, especially in multiple equation systems in which relationships among criteria variables are hypothesised (Podsakoff et al., 2003; Craighead et al., 2011). Further, due to the nature of study, it was not realistic to approach non-respondents to determine the reasons for their non-participation. Despite these limitations, this study provides evidence regarding the effects of RFID on supply chain performance and suggests that RFID must be widely applied across the supply chain to increase performance even at high levels, such as 45%.

However, this wide application of RFID requires technical infrastructure that includes the standardisation of data exchanges and the implementation of proper software applications. As RFID technology is in its early phases of adoption. Supply chain members are only beginning to adopt the technology and evaluate the benefits that this technology can provide in improving operations, reducing costs, and improving customer satisfaction. As is the case with any new technology adoption, managers must consider the relative advantages of this technology and how it fits into their organisational culture. However, as an inter-organisational technology, RFID can bring mutual benefits to more supply chain partners, and accordingly, the key performance indicators must include a wider spectrum of supply chain activities.

As the development and implementation of RFID technology has been one of the most widely discussed topics, the findings of this research may be benefit business managers in manufacturing, third party logistics providers, retailers as well as small- and medium-size suppliers. The first major managerial implication is that, given the RFID impact on supply chain performance indicators, its adoption can provide a source of sustainable competitive advantage. Accordingly, these potential performance improvements will attract more companies in the near future and increase the competitiveness that results from RFID implementations. With the help of this study, supply chain managers can better understand how RFID adoption impacts various supply chain areas. The detailed analysis (change in R square, F-power, and beta-values) provides insights on how different RFID combinations would impact supply chain performance, and further RFID technology may show the direction of future collaborative relationships among supply chain members. RFID requires a common understanding of various technological parameters, such as tags, software and data standardisation. Thus, as more and more companies introduce RFID into their supply chain practices, the more the collaborative practices would depend on specific RFID implementation. Retailers with a leading position in chain integration may play a pivotal role in the evolution of supply chain practices as they relate to and encompass advanced technologies, including RFID.

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Table 1 Sample Distribution

Region	**Sample**
Americas	26%
Europe	30%
Asia (India, China and other Asian counties)	30%
Pacific (Australia and New Zealand)	8%
Middle East (UAE, Saudi Arabia and Gulf)	6%

Table 2 Factor Analysis – Supply Chain Performance Factors

	Factor loadings						
	Supplier	Inventory	Distribution	Ordering	Plan	Sales	Forecasting
Overall supplier performance	**.773**						
Supplier delivery lead time at stores	**.766**						
Lead time to order stock from Supplier	**.742**						
On time fulfilment of customer orders	**.564**						
Average cycle stock levels at a category level	**.539**		.495				
Store inventory performance, in terms of sufficient stock cover		**.819**					
Average safety stock levels at a category level		**.768**					
Retailer warehouse timelines for delivery / distribution to stores		**.746**					
Inventory availability – days of stock cover		**.585**					.477
Average tnventory dispatched per day per store			**.758**				
Average buffer stock levels at a category level			**.734**				
Financial / OTB planning			**.637**				
Inventory in transit			**.614**				
DC pick accuracy, i.e., accuracy of pick operation as run by the warehouse colleague				**.754**			
Sell through % (units sold divided by units received into the store for a given time				**.673**			
Retailer warehouse service levels in terms of on time dispatch to stores				**.629**			
Forecast accuracy of number of purchase ordesr to be raised			.473	**.583**			
Lead time to replenish stock from the supplier DC into the retailers DC or stores				**.553**			
Percentage of shrinkage / waste at stores at a category level					**.735**		
Category planning					**.717**		
Store inventory performance, in terms of sufficient stock cover					**.555**		
Supplier stock availability	.502				**.546**		
Average level of stock as returns in transit from warehouse to supplier						**.876**	
Average level of stock as returns in transit from stores to warehouse or directly to						**.803**	
Percent of increase in sales across channels such as Web, normal Brick and motor stores,						**.610**	
Average inventory received per day per store		.495				**.566**	
Actual purchase accuracy i.e. Accuracy of Purchase orders raised by buyers to suppliers							**.793**
Forecast of effective DC space utilisation rates							**.663**
Forecast accuracy of average stock levels	.486						**.491**
Eigen value	9.551	3.324	2.449	2.214	1.436	1.096	1.015
Initial percent of variance explained	32.936	11.460	8.443	7.636	4.953	3.779	3.500
Rotation sum of squared loadings (total)	3.556	3.540	3.475	3.198	2.734	2.347	2.235
Percent of variance explained	12.260	12.207	11.984	11.029	9.428	8.092	7.707
Cronbach α (sample N)	.841	.821	.812	.846	.817	.692	.791

Table 3 Means, Standard Deviations and Correlation Matrix

Variables	Mean	Std. Deviation	1	2	3	4	5	6	7	8	9
Control Variable											
1. Employees	1,989	1,238	1	.069	-.001	-.090	.024	-.061	-.090	.025	.067
RFID variables											
2. F1	5.297	2.412	.069	1	.252**	.160	.418**	.168	.165	.140	.371**
3. F2	5.492	2.435	-.001	.252**	1	.536**	.564**	.615**	.296**	.372**	.390**
4. F3	4.356	2.537	-.090	.160	.536**	1	.466**	.433**	.355**	.387**	.315**
5. F4	5.492	2.195	.024	.418**	.564**	.466**	1	.657**	.466**	.411**	.431**
6. F5	5.068	2.290	-.061	.168	.615**	.433**	.657**	1	.390**	.447**	.282**
7. F6	6.314	2.466	-.090	.165	.296**	.355**	.466**	.390**	1	.356**	.451**
8. F7	5.593	2.005	.025	.140	.372**	.387**	.411**	.447**	.356**	1	.280**
9. F8	7.042	1.993	.067	.371**	.390**	.315**	.431**	.282**	.451**	.280**	1
Performance Variables											
10. Supplier	1	0	-.262**	-.155	.098	.200*	.099	.181*	.167	-.071	.125
11. Inventory	1	0	.059	.232*	-.177	-.063	.020	-.097	-.166	.102	-.058
12. Distribution	1	0	-.002	-.061	.094	-.047	-.093	-.143	-.088	-.170	.113
13. Ordering	1	0	-.080	-.138	-.023	-.086	-.135	.102	-.142	.044	-.093
14. Plan	1	0	-.067	-.172	.075	-.008	-.006	.039	-.020	-.078	.071
15. Sales	1	0	.085	-.031	-.058	-.021	.002	-.014	.190*	.151	.005
16. Forecasting	1	0	.397**	.197*	-.080	-.252**	.017	-.173	-.364**	-.183*	.017

* Correlation is significant at the 0.01 level (2-tailed).* Correlation is significant at the 0.05 level (2-tailed)

Table 4 Hierarchical regression results of RFID practices on Supply Chain Performance- Supplier & Inventory

	Supplier			Inventory		
Variables	**Step 1**	**Step 2**	**Step 3**	**Step 1**	**Step 2**	**Step 3**
Control variable						
Firm Size	-0.0 -2.9**	0.13 0.34	0.14 0.19	4.78 0.63	-0.07 -0.19	0.00 0.00
RFID Practices						
F1		-0.09 -2.39*	-0.27 -1.64		0.11 2.84**	-0.15 -0.85
F2		-0.02 -0.51	0.79 2.15*		-0.12 -2.38*	0.13 0.33
F3		0.06 1.61	0.22 0.76		0.00 0.23	-0.44 -1.38
F4		0.01 0.23	0.41 0.99		0.05 0.94	1.21 2.66**
F5		0.08 1.43	-0.11 -0.40		-0.02 -0.42	-0.15 -0.47
F6		0.02 0.62	-0.49 -1.81*		-0.09 -2.11*	-0.73 -2.49*
F7		-0.12 -2.40*	-0.56 -2.79**		0.11 2.26*	0.15 0.72
F8		0.08 1.59	0.16 0.70		-0.02 -0.54	-0.02 -0.08
Interactions						
F12			0.05 1.97*			-0.00 -0.19
F13			-0.01 -0.92			0.00 0.21
F14			-0.04 -1.04			-0.04 -0.96
F15			0.01 0.41			0.01 0.35
F16			-0.00 -0.02			-0.00 -0.03
F17			-0.01 -0.71			-0.01 -0.40
F18			0.01 0.81			0.06 2.40*
F23			-0.03 -1.59			0.01 0.41
F24			0.04 0.79			-0.02 -0.38
F25			-0.01 -0.42			0.02 0.57
F26			0.03 1.14			0.02 0.66
F27			-0.10 -2.51*			0.09 2.19*
F28			-0.10 -2.35*			-0.13 -2.96**
F34			-0.04 -1.21			0.06 1.62

F35			0.04 1.22			-0.00 -0.01
F36			-0.01 -0.52			-0.01 -0.45
F37			0.07 2.27*			-0.02 -0.72
F38			-0.01 -0.55			0.02 0.84
F45			-0.03 -0.74			-0.01 -0.26
F46			-0.02 -0.46			0.04 0.90
F47			-0.00 -0.13			-0.14 -2.94**
F48			0.03 0.76			-0.05 -1.03
F56			-0.01 -0.43			-0.05 -1.46
F57			0.02 0.96			-0.05 -1.51
F58			0.00 0.07			0.08 1.61
F67			0.06 2.04*			0.07 1.98*
F68			0.01 0.57			0.01 0.52
F78			0.03 0.73			0.03 0.72
F Value	8.523**	3.167*	2.288*	0.408	2.820**	1.600
Adjusted R^2	0.060	0.142	0.289	-0.00	0.122	0.159
ΔR^2	0.068**	0.140*	0.305*	0.003	0.186**	0.234

Standardised regression coefficients are reported. Within cells, the first row figures are the beta coefficients, and the second row are the t-test values, significant at *$p < 0.10$, **p <0.01, ***p <0.001.

Table 5 Hierarchical regression results of RFID practices on Supply Chain Performance – Distribution & Ordering

	Distribution			Ordering		
Variables	**Step 1**	**Step 2**	**Step 3**	**Step 1**	**Step 2**	**Step 3**
Control variable						
Firm Size	-1.5 -0.0	0.18 0.45	-1.21 -1.54	-6.5 -0.8	0.37 0.92	0.33 0.38
RFID Practices						
F1		-0.05 -1.17	-0.48 -2.76**		-0.0 -0.5	-0.1 -0.8
F2		0.12 2.46*	-0.56 -1.46		-0.0 -0.2	0.15 0.37
F3		-0.02 -0.56	0.23 0.75		-0.0 -0.7	-0.1 -0.3
F4		-0.01 -0.20	-0.06 -0.15		-0.1 -1.7*	-0.7 -1.6*
F5		-0.10 -1.69*	0.00 0.02		0.14 2.46*	0.65 1.93*
F6		-0.03 -0.69	0.27 0.96		-0.0 -1.4	-0.2 -0.7
F7		-0.08 -1.54	0.34 1.63		0.05 0.94	0.18 0.81
F8		0.10 1.93*	0.66 2.69**		0.01 0.29	0.21 0.81
Interactions						
F12			0.01 0.42			0.04 1.25
F13			0.03 1.82*			0.01 0.52
F14			-0.03 -0.90			0.00 0.22
F15			0.06 1.35			-0.0 -0.6
F16			-0.03 -1.26			0.03 1.26
F17			0.04 1.56			-0.0 -0.5
F18			0.00 0.25			-0.0 -1.2
F23			-0.03 -1.23			0.01 0.67
F24			0.03 0.58			-0.0 -1.2
F25			0.01 0.23			-0.0 -0.5
F26			-0.00 -0.20			0.05 1.40
F27			0.02 0.60			-0.0 -1.1

F28			0.06 1.38			0.00 0.05
F34			-0.04 -1.16			-0.0 -0.0
F35			0.09 2.57*			0.01 0.44
F36			-0.05 -2.21*			-0.0 -2.0*
F37			0.02 0.69			-0.0 -0.8
F38			-0.03 -1.06			0.06 1.69*
F45			-0.06 -1.43			0.02 0.51
F46			0.10 2.19*			-0.0 -0.0
F47			0.02 0.42			0.09 1.86*
F48			-0.02 -0.38			0.03 0.65
F56			-0.05 -1.52			-0.0 -0.7
F57			-0.04 -1.44			0.02 0.68
F58			0.01 0.27			-0.0 -0.6
F67			0.00 0.18			0.01 0.43
F68			-0.01 -0.54			0.00 0.14
F78			-0.12 -2.64**			-0.0 -1.1
F Value	0.000	1.866*	1.937*	0.756	1.573	1.349
Adjusted R^2	-0.00	0.062	0.228	-0.00	0.042	0.099
ΔR^2	3.604	0.134*	0.338*	0.006	0.109	0.268

Standardised regression coefficients are reported. Within cells, the first row figures are the beta coefficients, and the second row are the t-test values, significant at *p <0 .10, **p <0.01, ***p <0.001.

Table 6 Hierarchical regression results of RFID practices on Supply Chain Performance – Plan & Sales

	Plan			Sales		
Variables	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
Control variable						
Firm Size	-5.4 -0.7	0.19 0.47	0.45 0.61	6.88 0.92	-0.49 -1.18	-0.96 -1.23
RFID Practices						
F1		-0.10 -2.34*	-0.05 -0.33		-0.00 -0.20	0.16 0.98
F2		0.05 0.93	0.86 2.41*		-0.02 -0.51	-0.74 -1.96*
F3		-0.02 -0.49	-0.34 -1.20		-0.02 -0.51	0.20 0.66
F4		0.02 0.30	-0.42 -1.05		-0.01 -0.28	0.24 0.57
F5		0.01 0.19	-0.01 -0.04		-0.02 -0.49	-0.40 -1.31
F6		-0.02 -0.60	0.08 0.34		0.10 2.30*	0.58 2.10*
F7		-0.06 -1.11	-0.54 -2.79**		0.08 1.62	0.41 1.98*
F8		0.08 1.54	0.26 1.16		-0.03 -0.69	-0.28 -1.14
Interactions						
F12			-0.08 -3.02**			0.00 0.16
F13			-0.00 -0.44			-0.02 -1.00
F14			0.07 1.97*			-0.03 -1.00
F15			0.04 0.99			0.07 1.71*
F16			-0.03 -1.36			-0.08 -3.05**
F17			-0.00 -0.32			-0.01 -0.58
F18			0.02 0.94			0.05 2.16*
F23			0.03 1.66*			0.01 0.58
F24			-0.01 -0.20			0.01 0.24

F25			-0.02 -0.57			0.06 1.43
F26			-0.10 -3.31**			0.00 0.25
F27			0.02 0.53			0.05 1.23
F28			0.03 0.76			-0.00 -0.14
F34			0.12 3.53***			0.04 1.19
F35			-0.07 -2.10*			-0.05 -1.51
F36			0.04 1.61			-0.00 -0.06
F37			-0.03 -1.01			0.00 0.14
F38			-0.05 -1.61			-0.03 -1.03
F45			-0.05 -1.20			-0.06 -1.41
F46			0.02 0.53			0.00 0.18
F47			0.00 0.06			0.03 0.76
F48			-0.05 -0.99			-0.03 -0.59
F56			0.06 1.88*			-0.00 -0.25
F57			0.03 1.21			-0.02 -0.92
F58			-0.01 -0.31			0.05 1.05
F67			0.03 1.14			-0.06 -2.01*
F68			-0.02 -0.81			0.03 1.36
F78			0.01 0.42			-0.02 -0.46
F Value	0.525	1.069	2.526***	0.848	1.210	2.023**
Adjusted R^2	-0.00	0.005	0.325	-0.00	0.015	0.244
ΔR^2	0.004	0.077	0.456***	0.007	0.084	0.391**

Standardised regression coefficients are reported. Within cells, the first row figures are the beta coefficients, and the second row are the t-test values, significant at *p <0 .10, **p <0.01, ***p <0.001.

Table 7 Hierarchical regression results of RFID practices on Supply Chain Performance - Forecasting

	Forecasting		
Variables	Step 1	Step 2	Step 3
Control variable			
Firm Size	0.00 4.66***	-0.08 -0.24	0.40 0.57
RFID Practices			
F1		0.05 1.59	-0.02 -0.16
F2		0.00 0.07	0.72 2.11*
F3		-0.07 -2.00*	-0.52 -1.88*
F4		0.13 2.46*	0.01 0.04
F5		-0.05 -1.11	-0.51 -1.87*
F6		-0.16 -4.28***	-0.06 -0.25
F7		-0.04 -1.05	0.06 0.35
F8		0.05 1.25	0.02 0.09
Interactions			
F12			0.00 0.04
F13			-0.00 -0.25
F14			-0.00 -0.16
F15			0.00 0.21
F16			-0.00 -0.14
F17			0.03 1.19
F18			-0.00 -0.29
F23			0.00 0.02
F24			-0.00 -0.05
F25			-0.03 -0.76
F26			-0.04 -1.43
F27			-0.04 -1.05
F28			-0.00 -0.10
F34			0.00 0.03

F35			-0.03 -1.12
F36			0.03 1.34
F37			0.07 2.39*
F38			-0.00 -0.01
F45			0.06 1.66*
F46			-0.01 -0.42
F47			-0.04 -1.08
F48			0.02 0.47
F56			-0.01 -0.56
F57			0.02 0.79
F58			0.04 1.01
F67			0.03 1.10
F68			0.00 0.20
F78			-0.06 -1.58
F Value	21.74***	7.708***	3.038
Adjusted R^2	0.150	0.340	0.391
ΔR^2	0.157***	0.233***	0.193

Standardised regression coefficients are reported. Within cells, the first row figures are the beta coefficients, and second row are the t-test values, significant at *p <0 .10, **p <0.01, ***p <0.001.