The Financial Performance Effects of IT-Based Supply Chain Management Systems in Manufacturing Firms

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Abstract: This paper examines the financial benefits of adopting IT-based supply chain management (SCM) systems by 123 manufacturing firms over the period 1994 to 2000. By examining the change in financial performance pre and post adoption controlling for industry median changes in performance, we find that SCM systems increase gross margin, inventory turnover, market share, return on sales, and reduce selling, general, and administrative expenses. High-tech firms implementing SCM systems have similar benefits and even greater increases in gross margin, market share, and return on sales.

Key Words: Information Technology, Supply Chain Management, Firm Performance, Value Chain, Manufacturing

Introduction

Large scale empirical studies of the financial benefits from supply chain management (SCM) are as elusive as a consensus definition of SCM (Scannell et al., 2000). The best recent evidence of the value of SCM is Hendricks and Singhal (2003), who demonstrate that production or shipment delays attributed to SCM systems decrease firm value by an average of 10.28%. However, Hendricks and Singhal note that large sample empirical evidence directly linking SCM systems to financial firm performance metrics is quite limited with currently available evidence (e.g. Frohlich and Westbrook, 2001; Krause et al., 2000; Narasimhan and Das, 1999; Narasimhan and Jayaram, 1998; Shin et al., 2000; Tan and Kannan, 1999) based on either self-reported measures of performance or holistic measures of performance such as return on invested assets.

The intent of this study is to address this gap in the literature by first hypothesizing specific financial performance effects of IT-based SCM systems and then testing those effects using audited, externally reported financial performance measures. Using audited, externally reported financial performance measures adds an important degree of verifiability, an essential characteristic of a performance metric (Melnyk et al., 2004).

Recent evidence suggests that IT investments such as IT-based SCM systems pay off when the IT investment scenario is well targeted, well timed, and accompanied with complementary investments and actions (Barua and Mukhopadhyay, 2000). However, as with SCM studies, most of the research examining the effect of IT investments on firm performance has focused on broad, overarching firm performance measures, such as Tobin's q (Bharadwaj et al., 1999), equity market capitalization (Brynjolfsson and Yang, 1999) or stock price changes around the announcement of IT investments (Dos Santos et al., 1993; Dehning et al., 2003).

While these models have provided insights into the relationship between IT investments and firm performance, these insights remain at a fairly high level of analysis and, hence, should not be interpreted to apply at the level of specific work systems or work processes.

It is certainly possible to assess the impact of more specific investments in IT by considering the impacts of these investments with respect to more detailed, lower level financial accounts. Mukhopadhyay et al. (1995), for example, offer a rare glimpse at the specific changes in detailed financial performance measures by considering the effects of EDI on total inventory, obsolete inventory, and premium freight charges; and, Barua et al. (1995) identify relations between various IT and non-IT inputs and business processes, and relations between these business processes and overall firm performance finding (a) a positive impact of IT on business processes and (b) that certain business processes relate positively to overall firm performance. We follow a similar approach, guided by Porter's value chain (Porter, 1985).

Specifically, we develop theory that considers the impact of IT-based SCM systems on discrete components of the value chain and predict changes in specific financial performance measures associated with these components. IT-based SCM systems are of particular interest due to their increasing functionality enabling, through active process monitoring and automatic information routing, and SCM integration at a level not previously possible (Benjamin and Wigand, 1995; Gunasekaran et al., 2004). Using an industry adjusted sample, our empirical analyses explore the impact of IT-based SCM systems on financial performance measures such as raw materials, work-in-process, finished goods inventory, gross margin, and sales, general and administrative accounts.

Model Development

SCM has many definitions, all with a similar underlying theme: integrating the firm's internal processes with suppliers, distributors, and customers (Elmuti, 2002; Tan et al., 1999). Perhaps the most often cited definition comes from the Global Supply Chain Forum:

> Supply chain management is the integration of key business processes from end user through original supplier that provides products, services, and information that add value for customers and other stakeholders (Global Supply Chain Forum as reported in Lambert et al., 1998, p. 1).

Stated more simply, IT-based SCM systems coordinate and integrate the flow of materials, information, and finances from supplier to manufacturer to wholesaler to retailer to the end consumer. Here, IT serves as a key enabler of value chain integration through the capture, organization, and sharing of vital information regarding key business processes, both within and outside a firm's boundaries and contributes to firm profits by improving quality and cycle times and by reducing coordination costs and transaction risks (Nooteboom, 1992; Stroeken, 2000; Clemons and Row, 1992; Clemons et al., 1993; Mabert and Venkataramanan, 1998; Tan et al., 1998; Frohlich and Westbrook, 2001; Sanders and Premus, 2002; Vickery et al., 2003). Thus, we expect IT-based SCM systems to contribute significantly to both front-end and back-end improvements in financial performance.

The underlying causal relationships linking investments in IT-based SCM systems to improvements in specific financial performance metrics are based on the conceptual framework proposed by Dehning and Richardson (2002) in which IT investments are proposed to have both direct and indirect effects on firm performance. Here, intermediate process measures (e.g., metrics regarding improvement in inventory turnover, gross margin, and customer service) capture the direct effects of IT investments while recognizing that such investments also indirectly influence overall firm performance measures. For example, SCM systems can directly improve inventory management (by reduced inventory levels, holding costs, and spoilage) resulting in increased profitability and may also have indirect effects on firm performance through the lowering of coordination and SGA (sales, general and administrative) costs and indirectly improve overall firm performance through enhancing decision-making and forecasting.

That IT investments in SCM can be associated with improved firm performance has recently been demonstrated by Byrd and Davidson (2003) and Vickery et al. (2003) but only as measured by overall firm performance metrics such as return on equity (ROE), return on investment (ROI), return on sales (ROS), and market share as reported by survey respondents. We extend their work by examining improved business processes across the entire value chain using publicly reported, audited financial data.

As depicted in Figure 1, this depiction of a simplified value chain model has five key components. The study's hypotheses are now developed in the following order, following Figure 1: inbound processes, operations processes, outbound processes, support processes, and overall firm performance. We then conclude this section with the development of a hypothesis that accounts for the greater salience of SCM systems for firms in high-technology industries and a brief justification for the selection of financial performance measures.

Insert Figure 1 Approximately Here

Inbound Processes. The traditional value chain model (Porter, 1985) classifies procurement as a support activity rather than a value-adding process. Our analysis suggests that procurement, as an integral SCM functionality, is a value-adding process and therefore include procurement with inbound logistics as the inbound processes sector of the value chain.

As an illustration of procurement as a value-adding process, consider the role of procurement at Dell Computers (Harrington, 2002). Dell generates and makes available to its suppliers a new manufacturing schedule and expected demand for the next 52 weeks every two hours. This schedule reflects the latest customer orders, backlog numbers, stock status, and supplier commitments. Dell's SCM system directs suppliers to deliver the needed materials to a specific building and dock door for assembly on a particular manufacturing line at an appointed time. Due to these SC improvements, Dell has the highest inventory turnover ratio in the computer industry and ships more than 90% of its product -- all configured-to-order, not built-to-stock -- within five days of receiving the order. Such supply-chain related effects then possess indirect financial implications that ripple across the value chain.

Enhanced integration with suppliers can impact many dimensions of firm performance, including cost, quality, technology, delivery, flexibility, and profits (Gupta and Zhender, 1994; Blaxill and Hout, 1991; Krause et al., 2000). With inbound logistics, SCM system implementations add value through the availability of more current and more accurate information regarding orders that is then shared with suppliers enabling tight coordination of inbound logistics processes. As a consequence, inventory levels and associated costs are reduced while capacity utilizations are increased across the value chain. We therefore expect to observe increases in both raw material inventory turnover and gross profit margin for firm's adopting SCM systems:

> **H_1**: Firms that adopt SCM systems will have improved performance with inbound processes as reflected in increased raw material inventor turnover and gross profit margin.

Operation Processes. The operations sector incorporates activities such as manufacturing, assembly, and packaging. Once raw materials are received and inspected, they are entered into the manufacturing process and become work-in-process. Manufacturing flow management has been identified by The Global Supply Chain Forum as one of the seven key business processes in SCM (Lambert et al., 1998). As such, the manufacturing process affects numerous aspects of the product, including cost, quality, and performance; consequently, it must be constantly monitored and evaluated from a continuous improvement perspective (Mapes et al., 1997; Gunasekaran et al., 2004).

SCM systems can improve financial performance in operations by coordinating marketing forecasts, production schedules and inbound logistics through the availability of enhanced informational support for operations planning and control resulting in reduced levels of work-in-process and higher capacity utilization (Kleijnen and Smits, 2003; Gunasekaran et al., 2004). Accordingly, we predict increased work-in-process inventory turnover and asset turnover for SCM adopters:

> **H_2**: Firms that adopt SCM systems will have improved performance with operations processes as reflected in increased work-in-process inventory turnover and asset turnover.

Outbound Processes. Distribution, delivery, marketing, sales, and service processes are included here as outbound logistics processes. IT-based SCM systems enhance such processes in many ways, including (illustrating richly the needed integration across value chain activities): production schedules are used to plan advertising and promotion activities, market demand forecasts are used to insure that appropriate goods are on-hand to meet actual demand (and, hence, lowering finished goods inventories); and, accurate and current order and delivery information is used to provide appropriate capacity and expertise levels regarding customer support/service processes. As a consequence, we expect to observe higher finished goods inventory turnover and higher market share, with the higher market share driven by the reliable and responsive availability of those products/services most desired by customers (Vickery et al., 2003):

> **H_3**: Firms that adopt SCM systems will have improved performance with outbound processes as reflected in increased finished goods inventory turnover and market share.

Support Processes. Support activities in the value chain (technology development, human resource management, firm infrastructure) are also impacted by SCM systems. For example, improved marketing enables technology development activities to be better aligned with future market directions, enhanced production planning and monitoring reduces the need for extensive quality assurance, produces more accurate scheduling, and reduces variance in labor (therefore facilitates human resources management and reducing staffing complexities); and, enhancements in the collection, integration and sharing of information across the value chain reduces information processing costs across the value chain, the largest component of total logistics costs (Stewart, 1995; Gunaskaran et al., 2004). It is thus expected that the adoption of SCM systems will produce cost savings in administrative accounts across the value chain, which will be most readily observed in lower discretionary expenses such as those referred to selling, general and administrative (SGA) expenses (Kalwani and Narayandas, 1995):

> **H_4**: Firms that adopt SCM systems will have improved performance with support processes as reflected in decreased SGA expenses.

Overall Performance. Finally, if intermediate processes are improved, then the overall performance of the firm should improve as well. Using self-reported survey data, Tan et al. (1999) found that several SCM functions are significantly related to overall firm performance measures such as growth in market share, sales, and assets. Two overall metrics often used as such holistic measures of firm performance are ROA and ROS (Byrd and Davidson, 2003; Tan et al., 1999; Vickery et al., 2003). Additionally, it is clear that one of the primary benefits of SCM systems are inventory (level and cost) reductions associated with inbound, operations and outbound processes (Berry et al., 1994; Kalwani and Narayandas, 1995; Rungtusanatham et al., 2003; Watts and Hahn, 1993; Krause, 1997). We thus predict, along with increases in ROA and ROS, that increased total inventory turnover will be observed in firms adopting SCM systems.

> **H_5**: Firms that adopt SCM systems will have improved overall performance as reflected in increased total inventory turnover, ROA, and ROS.

SCM in High-Tech Industries. Firms in high-tech industries face an ultra-strong competitive pressures, e.g., short product/service life cycles and requirements for large investments in R&D (Qian and Li, 2003), which is reflected in a SC sense through the increased strategic importance of (domestic and global) supplier relationships and strategic alliances (Berry et al., 1994; Kobrin, 1991) in enabling these firms to (Harrington, 1999, p.50):

- Introduce new products frequently and rapidly.
- Source and sell globally.
- Accelerate pipeline flows, minimize inventory and reduce costs across the supply chain.
- Offer personalized one-to-one solutions to customers (i.e. build-to-order).

Due to the strategic necessity of such factors, we predict that the adoption of IT-based SCM systems will 'pay off' more for high-tech firms than for firms in non high-tech industries. This importance of SCM in high-tech companies is exemplified by the following quote from Rob Swanson, director of the Supply-Chain Performance Benchmarking Study for Pittiglio, Rabin, Todd, and McGrath of Weston, MA:

> In high-tech industries where product life cycles run in months rather than years, companies that aggressively integrate their supply chain can respond more quickly to customer demands, gaining significant time and cost advantages over their competition. A demand not met quickly can result in lost sales, lost customers, and obsolete inventories (Egan, 1995, p. 52).

In support of such a position, Hendricks and Singhal (2003) found that firms with high growth prospects had a larger loss of market value due to SC glitches than firms with low growth prospects. This implies that firms in industries with high growth prospects such as high-tech firms might benefit more from SCM systems, an implication supported by Fisher (1997) who contends that products in high-tech industries require responsive supply chains due to the unpredictable demand inherent in innovative products as well as the costs of obsolescence or shortages for early sales leaders. This arguments leads to a sixth and final hypothesis:

> **H_6**: Firms in high-tech industries that adopt SCM systems will enjoy greater financial performance improvements from their adoption of SCM systems than will firms in non high-tech industries.

Measuring Firm Performance. In selecting the performance measures to use in this study, we relied extensively on previous research in SCM performance measurement (Spekman et al., 1994; Fisher, 1997; Mainardi et al., 1999; Elmuti, 2000; Hult et al., 2000; Wisner and Tan, 2000; Chan et al., 2003; Hendricks and Singhal, 2003). In summary, with previous research as a guide, the measures we chose to assess the impact of IT-based SCM systems on firm performance are shown in Figure 2.

Insert Figure 2 Approximately Here

Research Methodology

In order to identify manufacturing firms that had implemented IT-based SCM systems, a search was performed on the Lexis/Nexis and Factiva newswire services. The search terms "implement or choose or select or purchase or install or chosen" within 25 words of the words "supply chain" were used to identify potential firms. Each press release was then read to identify firms that were actually implementing IT-based SCM systems.[1] Only firms with manufacturing

[1] Vendors of IT-based SCM systems include Aspen Technology, Baan, i2 Technologies, and Manugistics.

SIC codes (2011 - 3999)[2] and data on Compustat were retained, resulting in a final dataset of 123 manufacturing firms. The distribution of firms by year and 2-digit SIC code can be found in Table 1. Most of the SCM adoptions in the sample occurred in 1997-2000 (105 firms or 85.4%), with 1998 having the most at 35 (28.5%). The sample firms are fairly well distributed among 2-digit SIC industry. The highest concentration is in industrial and commercial machinery and equipment (21 firms, 17.1%), with no other industry having more than 16% of the total sample.

Insert Table 1 Approximately Here

The 3-digit SIC code classifications used by Francis and Schipper (1999) were used to identify high-tech firms. In total 36 out of the 123 manufacturing firms (29.2%) are classified as high-tech firms. A breakdown of the distribution of high-tech firms by 3-digit SIC code is provided in Table 2. The high-tech industry classification with the largest concentration of firms is computer and office equipment, with 14 firms (38.9%), and second is electronic components and semiconductors with 9 firms (25.0%). No other high-tech industry classification has more than 15% of all high-tech firms.

Insert Table 2 Approximately Here

Compustat data was used in deriving all performance measures. Once the performance measures were calculated, each variable was windsorized at ±3 standard deviations to control for any potential outliers. A few companies were missing the data necessary to calculate some of the performance measures. For these firms the missing values were replaced by the mean value

[2] Manufacturing SIC codes as defined by the U.S. Small Business Administration, http://www.sba.gov/regulations/siccodes/siccodes.html.

of each missing performance measure except inventory measures.[3] Due to reporting requirements and how Compustat collects data, several firms were missing raw materials inventory, work-in-process inventory, and finished goods inventory figures. For these firms the missing values were not replaced with the mean value. Thus the sample size is smaller for the inventory-based performance measures than for the other performance measures.

All of the performance measures were calculated for the year prior to a firm's adoption of an IT-based SCM systems system as well as for one and two years after this adoption. As illustrated in equation 1 for ROA, the change in the industry median over the same period was subtracted from the change in each performance measure to remove industry and economy-wide effects. Industry median thus serves as a benchmark that increases the meaningfulness of the resultant performance measures (Melnyk et al., 2004):

$$(ROA_{FIRM.POST} – ROA_{FIRM.PRE}) – (ROA_{INDUSTRY.POST} – ROA_{INDUSTRY.PRE}) \quad (1)$$

Except for relative market share, all variables were similarly adjusted by the change in industry median. The result is that observed changes in financial performance that can be attributed to the adoption of the SCM system rather than to industry wide effects. Relative market share, however, is calculated differently -- as the sales of the adopting firm divided by industry median sales. Because the change in performance measure is a change in this relative level of sales, the change in the industry median is not subtracted as it is in the other performance measures. Descriptive statistics for all of the variables used in empirical tests can be found in Table 3.

Insert Table 3 Approximately Here

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[3] Tests performed on only the firms without missing values are substantially equivalent.

Results of Empirical Tests

A general linear model (GLM) was used to test if the mean change in performance is significantly different from zero controlling for additional factors in the model. The dependent variable in each GLM specification is one of the ten performance measures. The changes in financial performance were measured over two periods, from one year before adoption to one year after and from one year before to two years after adoption for a total of 20 GLMs. A dummy variable indicating if the adopting firm was in a high-tech industry was included as a random factor in the model. Three covariates were also included in the model to control for differences in firm size (market capitalization), spending on research and development (R&D expense as a percentage of sales), and year of SCM adoption. Size is an important control variable because Hendricks and Singhal (2003) find that smaller firms had a larger loss of market value due to SC glitches than larger firms.

Figure 3 shows the industry median adjusted change in performance for each performance measure in our modified value chain for IT-based SCM systems adopting firms calculated as shown in equation 1. As shown in Figure 3, adopting firms for the most part experienced significant improvements in performance both one year and two years after their adoption of IT-based SCM systems. Significant improvements can be observed for each of the inbound and outbound performance measures, for the Year 2 results regarding support processes (it is noteworthy that, while not significant, SGA expenses for Year 1 did drop 2.3%), and for the overall performance measures of total inventory turnover and return on sales.. Thus, hypotheses 1 and 3 received strong support while hypothesis 4 and 5 received moderate support. The effect that was observed regarding ROA might be explained by the less-than-direct impact of SCM on a firm's assets, especially in the short-term. However, we can offer no obvious explanation as to why the expected results regarding operations performance (hypothesis 3) were not observed.

Insert Figure 3 Approximately Here

As argued previously, SCM systems are more likely to benefit companies in high-tech industries that undergo rapid change, continuous technological development, and that require flexibility and the ability to respond quickly to competitors' actions. Our analyses examine if the results for the high-tech firms are significantly different from zero as well as significantly different from those observed for the non high-tech firms. Figure 4 shows the industry adjusted median change in performance for high-tech firms adopting IT-based SCM systems, calculated as shown in equation 1. Figure 5 compares the difference between the change in performance after adopting IT-based SCM systems for high-tech and non high-tech firms.

Insert Figures 4 and 5 Approximately Here

As shown in Figure 4, high-tech firms have similar performance benefits from adopting SCM as the overall sample. High-tech firms had significant increases in gross profit margin one year and two years after adopting SCM but, unlike the general population, saw no significant increases in raw material inventory turnover in the years following adoption of IT-based SCM systems. As shown in Figure 5, these increases in gross profit margin were significantly better than the increases in gross profit margin by the non high-tech firms. High-tech firms did not see benefits from SCM systems in the operations portion of their value chain one year or two years following adoption. Asset turnover for high-tech firms actually decreased compared to non high-tech firms, as detailed in Figure 5. High-tech firms did see marked improvements in outbound processes after adopting SCM with the increase in relative market share being significantly higher than the increase observed with the non high-tech firms. Regarding overall performance, total inventory turnover did increase for the high-tech firms but was not statistically better than that observed for the non high-tech firms. Finally, an increase in ROS one and two years after adopting SCM was observed in the high-tech firms, an outcome that was significantly better than the non high-tech firms. Interestingly, these results regarding the high-tech firms tended to be consistent with the study's hypotheses for the more holistic performance measures but inconsistent for the performance measures situated with a more limited set of value chain activities – suggesting that for these high-tech firms, it is the ability of IT-enabled SCM systems to integrate processes across the entire supply chain that are most important. Given these mixed results for the sixth hypothesis it is considered weakly supported.

To further examine the financial effects of the implementation of IT-based SCM systems within this sample of firms, we performed post-hoc regression analyses that considered select characteristics of the SCM implementation to see if these attributes had an effect on the overall performance measures. Given the mixed results reported regarding hypothesis 6, it was decided to include the high-tech dummy variable in order to again assess the salience of IT-based SCM systems for firms where being nimble and quick to react to changing market and industry conditions is important.

We also included the scope of the SCM implementation, i.e., the variable LGSCOPE is a dummy variable coded one if the SCM system implementation was company-wide and coded zero if the SCM system was implemented in only a few divisions or geographic areas. Two opposing arguments can be provided to support such a variable: on one hand, firms that adopt an incremental approach to implementing SCM initiatives might be more successful than 'big-bang' projects because of the learning than can occur through a phased approach as well as the lessened complexity of orchestrating the SCM implementation as a sequence of smaller projects; on the other hand, dramatic financial improvement may only be detectable when an IT-based SCM system is implemented company-wide within the organization.

A third characteristic of SCM initiatives examined is inventory intensity. The variable INVDUM is coded one if the total inventory of the firm as a percentage of total assets is greater than the sample median total inventory as a percentage of total assets, and zero if it is below the median. Due to the importance of SCM for managing inventory, firms that are inventory intensive might very well be expected to observe larger payoffs from IT-based SCM systems.

It is also possible that IT-based SCM systems might pay off more in firms with large quantities of raw materials inventory. This is measured by the variable RMINV. RMINV is one when the raw materials inventory of the firm as a percentage of total inventory is greater than the sample median raw materials inventory of the firm as a percentage of total inventory, and zero if it is below the median. The post-hoc analysis includes two control variables, year and size, to control for the time period and size of the company. This leaves us the following regression equation:

$$\mathrm{DV} = \beta_0 + \beta_1 HIGHTECH + \beta_2 LGSCOPE + \beta_3 INVDUM + \beta_4 RMINV + \beta_5 SIZE + \beta_6 YEAR + \varepsilon$$

Where:

HIGHTECH = dummy variable that is 1 if the firm is in a high-tech industry, otherwise 0

LGSCOPE = dummy variable that is 1 if the SCM system is being implemented company-wide, 0 if the SCM is being implemented in one or only a few divisions or geographic areas

INVDUM = dummy variable for inventory intensive firms: 1 if the total inventory of the firm as a percentage of total assets is greater than the sample median total inventory as a percentage of total assets, 0 if it is below the median

RMINV = dummy variable to distinguish firms with large raw materials inventory to manage: 1 if the raw materials inventory of the firm as a percentage of total inventory is greater than the sample median raw materials inventory of the firm as a percentage of total inventory, 0 if it is below the median

SIZE = natural log of total market cap, year -1

YEAR = year of implementation announcement

To perform this post-hoc analysis, we considered three overall financial performance measures as dependent variables: ROA, ROS, and Total Inventory Turnover. We then average the two time periods together to get a single variable for each performance measure. For example, ROA change year -1 to +1 was averaged with ROA change year -1 to +2 to get a single score for average change in ROA for each firm. The average change in performance over the two time periods serves as the dependent variable in the regression estimations.

The results of the three regressions are included in Table 4. The first regression predicts the effect of SCM characteristics on ROA. The results suggest a negative and significant coefficient on large scope, suggesting that as the scope of the SCM initiative increases, the smaller the ROA. In predicting ROS, we find a similar negative and statistically significant coefficient on large scope that suggests that as the scope of SCM initiatives increase, the smaller the change in ROS. Confirming our GLM results, high-tech firms implementing IT-based SCM systems have correspondingly higher ROS than non high-tech firms implementing IT-based SCM systems. The last regression suggests that high-tech firms implementing SC initiatives have correspondingly greater increases in inventory turnover as compared to non high-tech firms. Overall, this post-hoc analysis provides additional support for hypothesis 6 and suggests that the increased complexity of large-scope IT-based SCM systems system implementation initiatives (but not inventory intensity) can in fact reduce, at least in the short term, the financial benefits likely to be observed.

Insert Table 4 Approximately Here

Discussion of Results, Limitations, and Conclusion

Our results show that adopting IT-based SCM systems results in significant performance benefits, particularly for firms in high-tech industries. By developing a model of the firm based on a simplified value chain, we were able to examine key performance measures for each area of the firm and overall firm performance. For the entire sample, results consistent with those hypothesized were observed with each sector of the value chain model except for the operational processes sector. For the firms in high-tech industries, similar outcomes were observed with significantly higher performance improvements tending to be observed with the measures that reflected holistic SC performance, suggesting that the primary benefit to high-tech firms of IT-based SCM systems lies in these systems' capability to integrate across the value chain.

Interestingly for high-tech firms, work-in-process inventory turnover declined significantly after implementing SCM. This is possibly due to the fact that work-in-process inventory is more likely a function of the capacity of the factory or manufacturing environment than the ability to effectively manage inventory. For example, end of the year work-in-process inventory is likely to be high in firms with active orders at the end of the year being built on an as-needed basis, and low in firms with a large stock of finished goods inventory that allows the factory floor to be closed down at the end of the year, resulting in little or no work-in-process inventory. Thus it is hard to determine whether increased or decreased work-in-process inventory turnover is a sign of improved performance, especially with high-tech firms facing very volatile competitive environments.

This study has several limitations. First, the firms in the sample are not randomly selected but have been included because they or their SCM system supplier issued a press release announcing the adoption of an IT-based SCM systems system. There might be systematic differences in firms that announce SCM adoption and those that do not. In particular, those that announce might be more confident of improvements in performance. If firms can accurately judge the probability of improved performance from SCM systems prior to implementation, then the firms that do not announce adoption of SCM probably have lower average performance gains from SCM system adoption than the firms in the sample used in this study.

The sample used in this study also suffers from a potential survivorship bias problem. Because the empirical tests required four years of data on Compustat in order to compare pre- and post- SCM adoption performance, any firm that had extremely poor performance and went bankrupt after implementing SCM did not make the final sample used in empirical tests, biasing the results in favor of our hypotheses.

In conclusion, we believe this study makes three primary contributions. The first is the development of a model of the firm based on a simplified value chain that allows testing for improvements in all value-adding processes. The second is the use of audited financial statement accounts to predict and test where and how SCM systems pay off for manufacturing firms. The third is analyzing the difference that selected industry (high-tech vs. non high-tech) and firm characteristics can make on the financial performance associated with an SCM initiative. We hope that these contributions prove useful to other scholars striving to understand the nature of the benefits to be derived from implementing IT-based SCM systems.

Table 1

Panel A
Distribution of sample firms by year.

Year	Frequency	Percent
1994	2	1.6
1995	4	3.3
1996	12	9.8
1997	15	12.2
1998	35	28.5
1999	31	25.2
2000	24	19.5
Total	123	100.0

Panel B
Distribution of sample firms by 2-Digit SIC Code.

2-Digit SIC	Frequency	Percent
20 Food & Kindred Products	10	8.1
21 Tobacco Products	0	0
22 Textile Mill Products	2	1.6
23 Apparel & Other Textile Products	7	5.7
24 Lumber & Wood Products	1	.8
25 Furniture & Fixtures	1	.8
26 Paper & Allied Products	1	.8
27 Printing & Publishing	3	2.4
28 Chemical & Allied Products	17	13.8
29 Petroleum & Coal Products	5	4.1
30 Rubber & Miscellaneous Plastics Products	5	4.1
31 Leather & Leather Products	3	2.4
32 Stone, Clay, & Glass Products	3	2.4
33 Primary Metal Industries	7	5.7
34 Fabricated Metal Products	3	2.4
35 Industrial Machinery & Equipment	21	17.1
36 Electronic & Other Electric Equipment	19	15.4
37 Transportation Equipment	12	9.8
38 Instruments & Related Products	2	1.6
39 Miscellaneous Manufacturing Industries	1	.8
Total	123	100.0

Table 2
Distribution of High-tech Firms by 3-Digit SIC Code.

3-Digit SIC		Frequency	Percent
283	Drugs	5	13.9
357	Computer and Office Equipment	14	38.9
360	Electrical Machinery and Equipment, Excluding Computers	0	0
361	Electrical Transmissions and Distribution Equipment	2	5.6
362	Electrical Industrial Apparatus	1	2.8
363	Household Appliances	0	0
364	Electric Lighting and Wiring Equipment	0	0
365	Household Audio, Video Equipment, Audio Receiving	0	0
366	Communication Equipment	5	13.9
367	Electronic Components, Semiconductors	9	25.0
368	Computer Hardware	0	0
Total		36	100.0

Table 3
Descriptive Statistics

	N	Mean	Std. Dev.	Min.	Max.
GM -1 to +1*	123	0.018	0.106	-0.337	0.338
GM -1 to +2	123	0.013	0.095	-0.259	0.280
RM IT -1 to +1	75	7.334	28.751	-48.462	112.312
RM IT -1 to +2	76	10.028	39.010	-49.857	298.664
AT -1 to +1	123	0.077	0.482	-1.473	1.436
AT -1 to +2	123	0.087	0.555	-1.561	1.789
WIP IT -1 to +1	59	3.423	111.139	-317.036	326.479
WIP IT -1 to +2	60	-12.405	150.201	-530.617	334.164
RMS -1 to +1	123	36.426	123.545	-130.987	690.652
RMS -1 to +2	123	29.415	134.660	-339.167	809.632
FG IT -1 to +1	81	5.820	24.544	-63.512	85.315
FG IT -1 to +2	81	5.035	27.880	-73.800	114.827
SG&A -1 to +1	123	-0.017	0.149	-0.720	0.477
SG&A -1 to +2	123	-0.024	0.171	-0.618	0.622
IT -1 to +1	123	0.606	2.729	-5.881	14.496
IT -1 to +2	123	0.376	2.134	-7.439	7.377
ROA -1 to +1	123	0.100	7.329	-24.355	23.994
ROA -1 to +2	123	0.594	7.905	-23.576	25.528
ROS -1 to +1	123	0.005	0.060	-0.129	0.280
ROS -1 to +2	123	0.010	0.070	-0.153	0.228
LNSIZE	123	8.796	2.397	-0.945	16.625
YEAR	123	1998.163	1.445	1994.000	2000.000
HIGHTECH	123	0.293	0.457	0.000	1.000

* All financial performance variables are changes from one year before implementation (-1) to either one (+1) or two years (+2) after implementation as indicated.

Where:

GM = Gross Profit Margin = Gross Profit/Sales
RM IT = Raw Materials Inventory (RMI) Turnover = Cost of Goods Sold/RMI
AT = Total Assets Turnover = Sales/Total Assets
WIP IT = Work-in-Process Inventory (WIPI) Turnover = Cost of Goods Sold/WIPI
RMS = Relative Market Share = Sales/Median Industry Sales
FG IT = Finished Goods Inventory (FGI) Turnover = Cost of Goods Sold/FGI
SG&A = Selling General, and Administrative Expenses (SG&A) = SG&A/Sales
IT = Inventory Turnover = Cost of Goods Sold/Total Inventory
ROA = Return on Assets = Income Before Extraordinary Items/Total Assets
ROS = Return on Sales = Income Before Extraordinary Items/Net sales
HIGHTECH = Dummy variable coded one when the firm is a member of a high-tech industry (see Table 2).
LNSIZE = Natural Log of Total Market Capitalization

Table 4
Regression Results

$$DV = \beta_0 + \beta_1 HIGHTECH + \beta_2 LGSCOPE + \beta_3 INVDUM + \beta_4 RMINV + \beta_5 SIZE + \beta_6 YEAR + \varepsilon$$

		Dependent Variable		
	Predicted Sign	**ROA**	**ROS**	**IT**
HIGHTECH	+	.078 * .869 (.194)	**.317** **3.697 (.000)**	**.149** **1.660 (.050)**
LGSCOPE	-/+	**-.179** **-1.986 (.049)**	**-.223** **-2.600 (.011)**	.155 1.725 (.087)
INVDUM	+	-.071 -.709 (.760)	-.074 -.781 (.782)	.004 .040 (.484)
RMINV	+	-.130 -1.442 (.924)	-.052 -.610 (.729)	.127 1.418 (.080)
SIZE	Control Variable	-.165 -1.654 (.101)	-.138 -1.446 (.151)	.103 1.036 (.302)
YEAR	Control Variable	.037 .402 (.689)	.037 .423 (.673)	-.071 -.774 (.441)
	F-stat (sig.):	1.513 (.180)	3.668 (.002)	1.632 (.145)
	Adj. R^2:	.025	.116	.030

* Standardized Coefficient, followed by t-statistic, and p-value on the second line. Differences in **bold** are significant at p<.05. p-values are for one-tailed tests of significance where there are directional hypotheses; otherwise 2-tailed p-values are reported.

ROA = Return on Assets
ROS = Return on Sales
IT = Total Inventory Turnover
HIGHTECH = dummy variable that is 1 if the firm is in a high-tech industry, otherwise 0
LGSCOPE = dummy variable that is 1 if the SCM system is being implemented company-wide, 0 if the SCM is being implemented in one or only a few divisions or geographic areas
INVDUM = dummy variable for inventory intensive firms: 1 if the total inventory of the firm as a percentage of total assets is greater than the sample median total inventory as a percentage of total assets, 0 if it is below the median
RMINV = dummy variable to distinguish pure manufacturers from assemblers: 1 if the raw materials inventory of the firm as a percentage of total inventory is greater than the sample median raw materials inventory of the firm as a percentage of total inventory, 0 if it is below the median
SIZE = natural log of total market cap, year -1
YEAR = year of implementation announcement

Figure 1
Simplified Value Chain Model

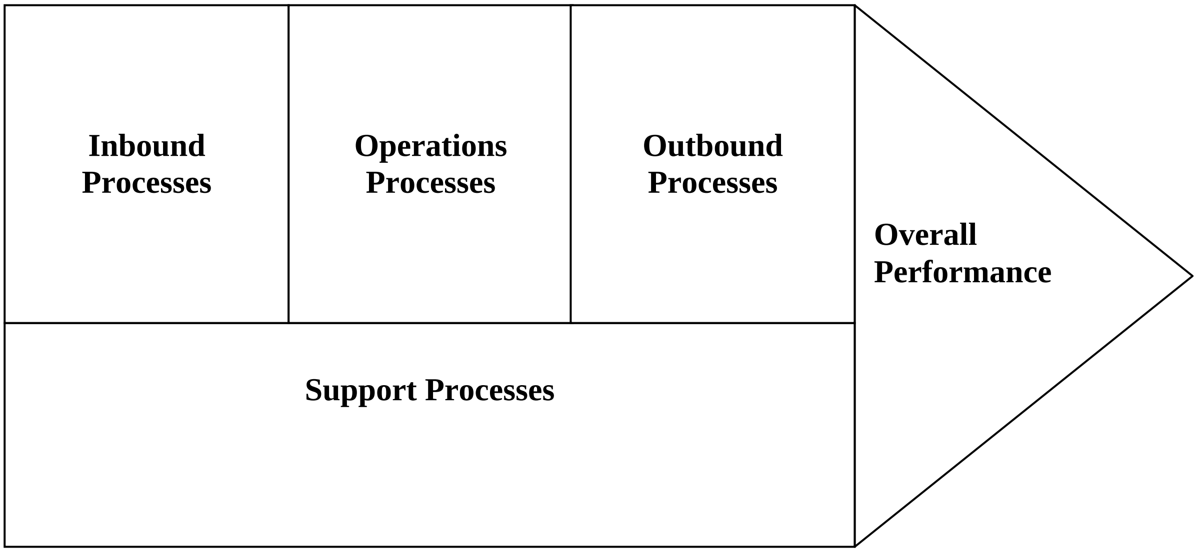
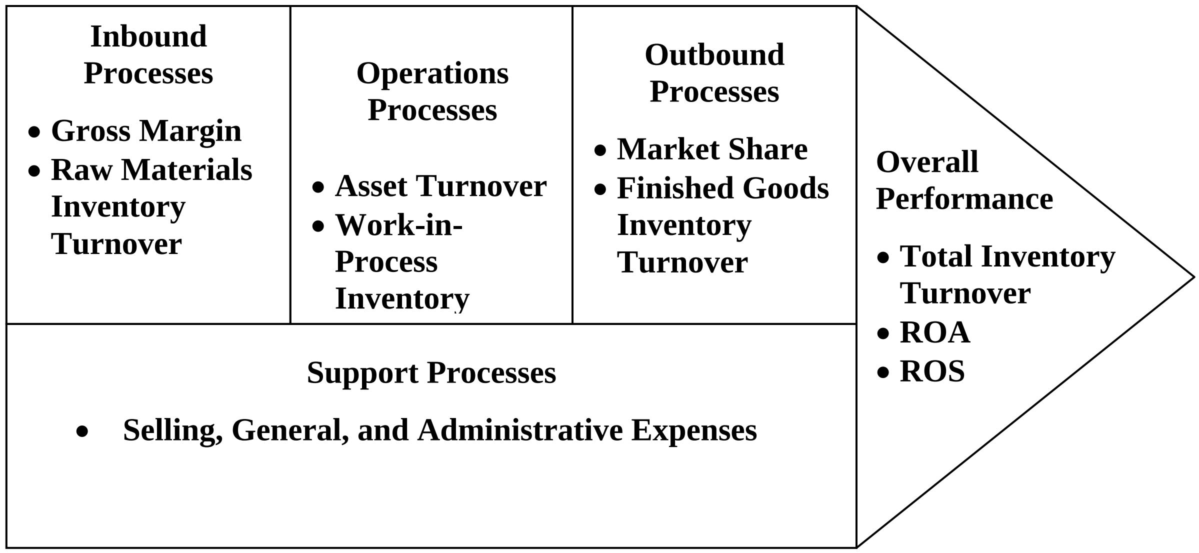


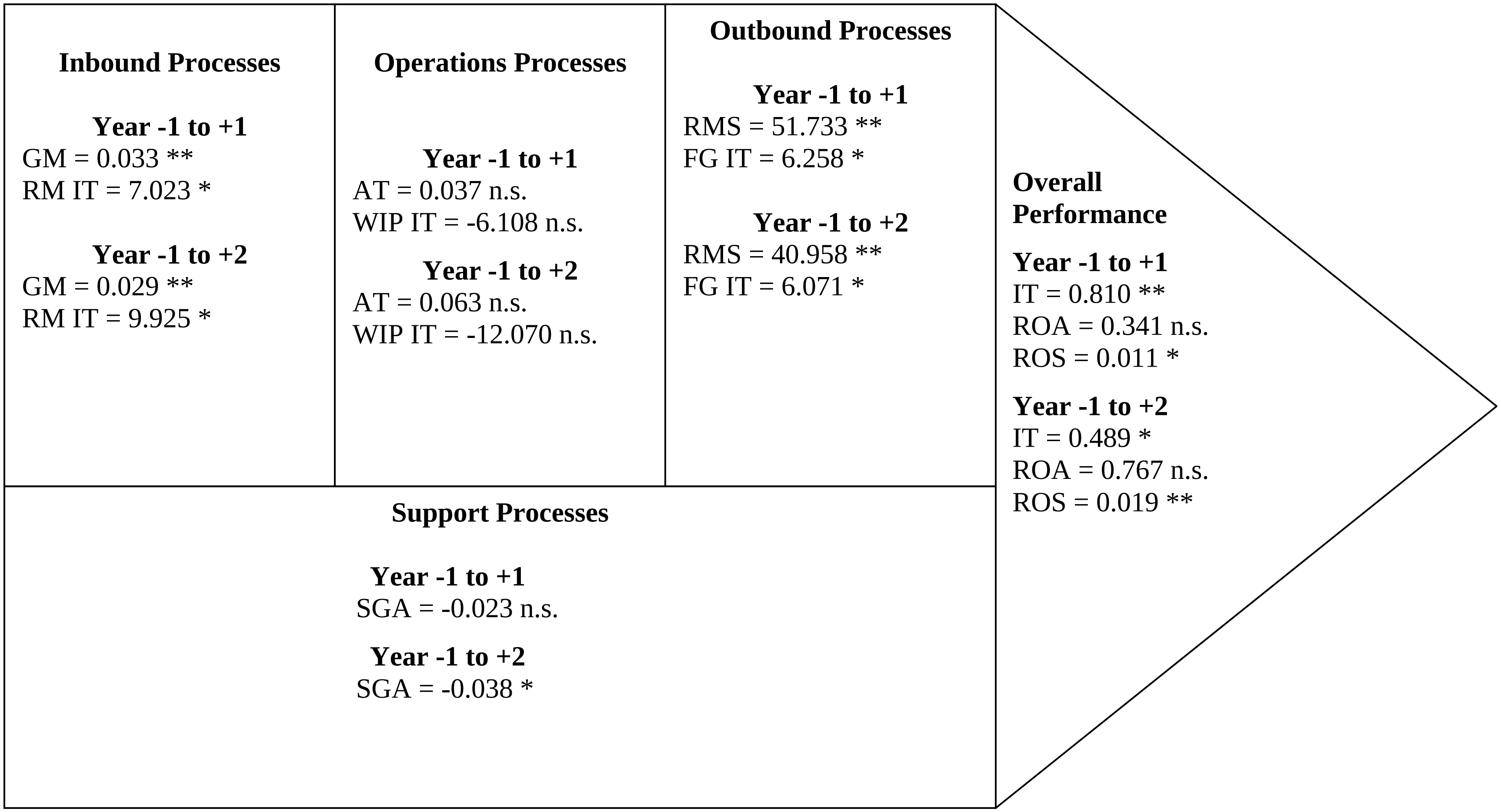
Figure 2
The value chain model with performance measures.



Where:

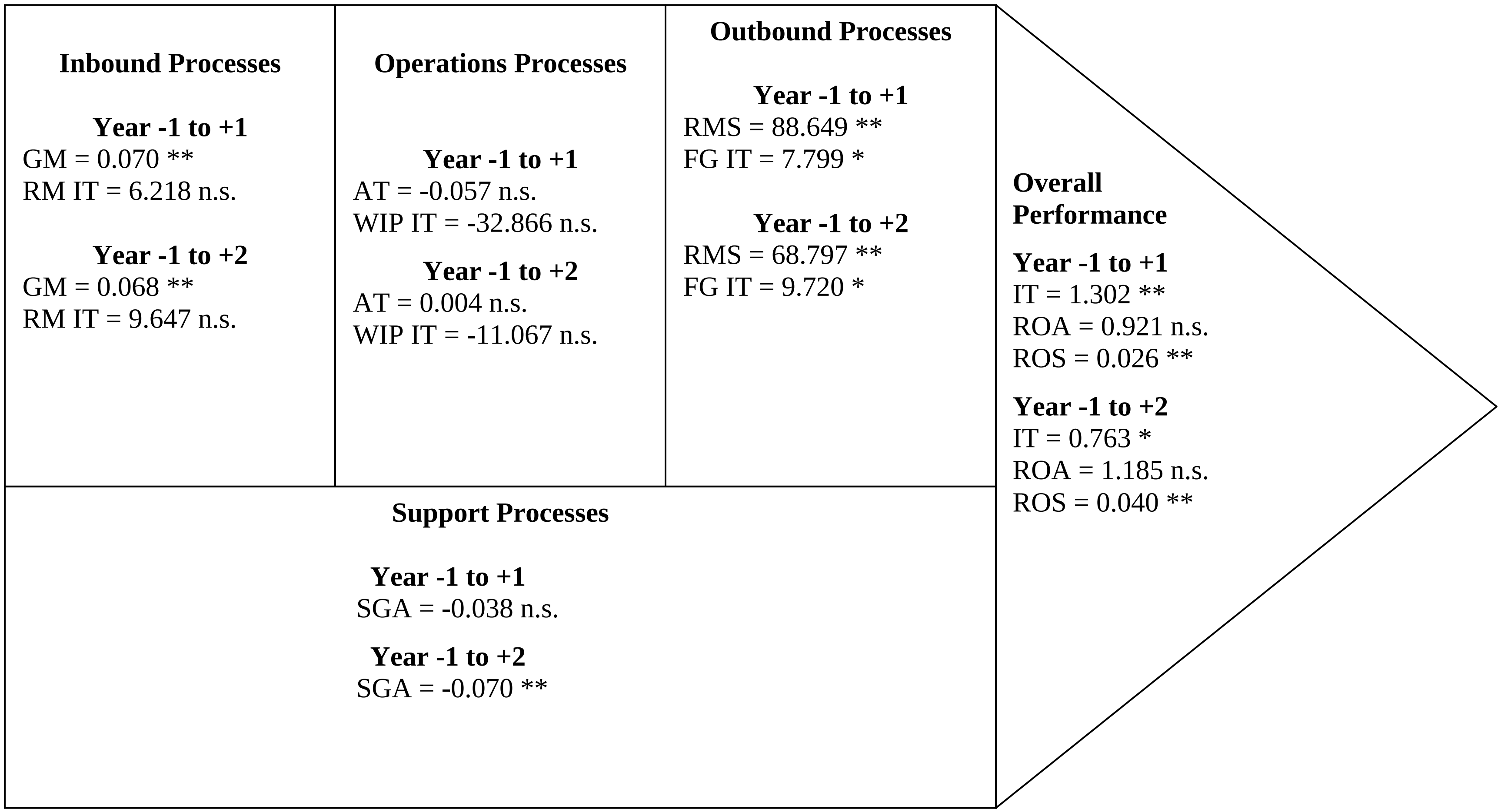
Gross Margin = Gross Profit/Sales
Raw Materials Inventory (RMI) Turnover = Cost of Goods Sold/RMI
Asset Turnover = Sales/Total Assets
Work-in-Process Inventory (WIPI) Turnover = Cost of Goods Sold/WIPI
Market Share = Sales/Median Industry Sales
Finished Goods Inventory (FGI) Turnover = Cost of Goods Sold/FGI
Selling General, and Administrative Expenses (SG&A) = SG&A/Sales
Inventory Turnover = Cost of Goods Sold/Total Inventory
ROA = Return on Assets = Income Before Extraordinary Items/Total Assets
ROS = Return on Sales = Income Before Extraordinary Items/Net sales

FIGURE 3
GLM Results, All Firms



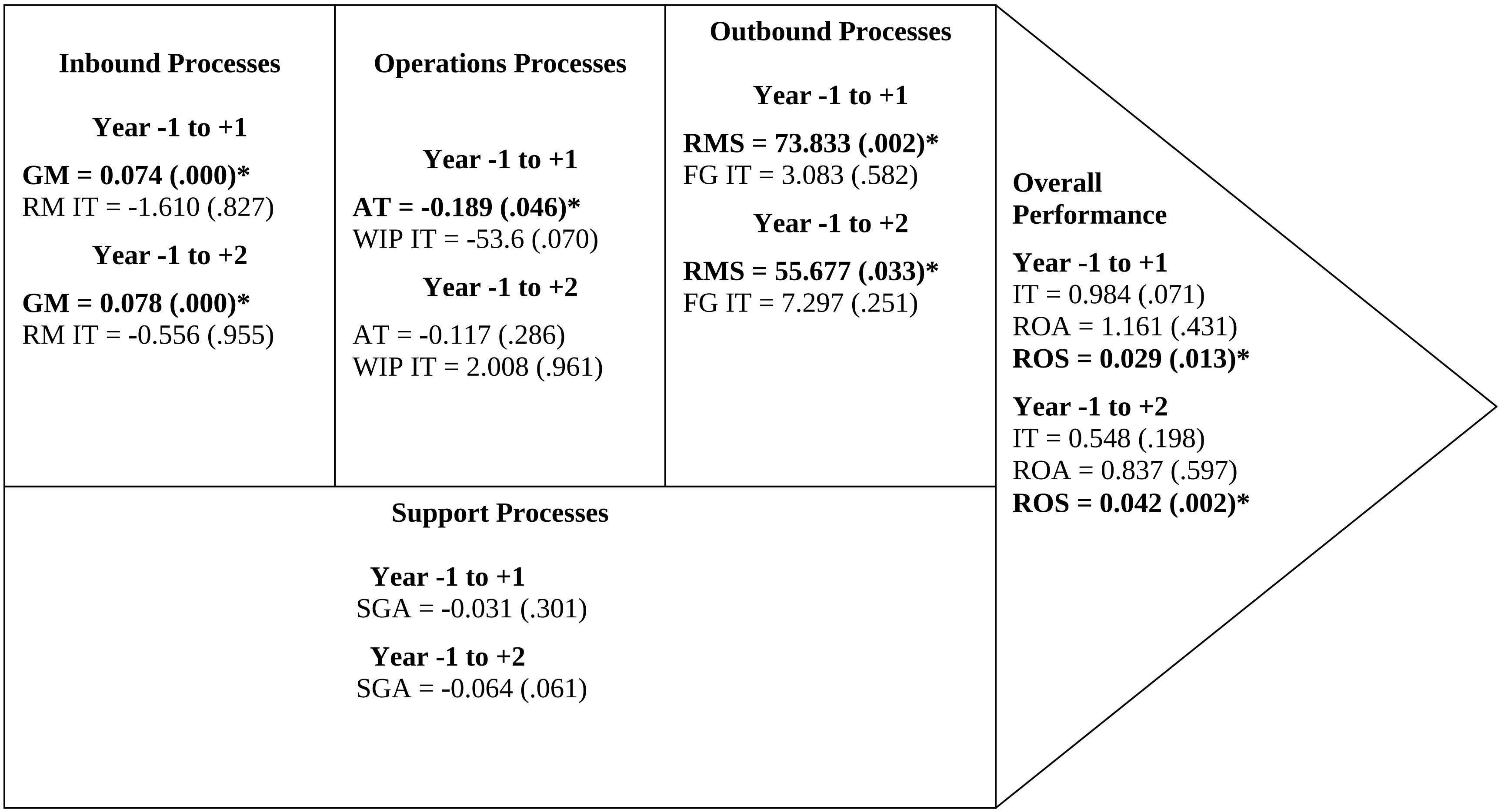
* p<.05, ** p<.01; n.s. = not significant; p-values are for one-tailed tests of significance;

FIGURE 4
GLM Results, High-tech Firms



* p<.05, ** p<.01; n.s. = not significant; p-values are for one-tailed tests of significance;

FIGURE 5
GLM Results, High-tech Firms vs. Non high-tech Firms
Mean Difference in Change in Performance (p-value in parentheses)



* Two-tailed tests; Differences in **bold** are significant at p<.05.

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