AN INVESTIGATION INTO THE EFFECT OF FULL-SCALE SUPPLY CHAIN MANAGEMENT SOFTWARE ADOPTIONS ON INVENTORY BALANCES AND TURNS

by

Alan I. Blankley
University of North Carolina at Charlotte

Moutaz Khouja
University of North Carolina at Charlotte

and

Casper E. Wiggins
University of North Carolina at Charlotte

INTRODUCTION

In contrast to many forms of information technology (IT) expenditures, spending on supply chain management software promises direct and measurable benefits. i2 Technologies, a leading vendor of supply-chain management software, for example, stated in the early 2000's that the firm's mission was to provide customers with $75 billion in measurable value by 2005. A major part of this value creation is attributable to direct, financial statement impacts following implementation of the software (Miller-Williams 2001, pg. 5). In this paper, we examine the financial statement impact of SCM software implementations. Specifically, we examine the effect that firm-wide (full-scale) adoptions of SCM software have on inventory balance and turn metrics.

While it is probable that SCM software provides value in many ways to implementing firms, it is likely that the most fundamental sources of economic benefits are attributable to the resultant inventory reductions and improved inventory management. Vendors certainly make these claims. In a 1997 white paper, for example, i2 Technologies claimed that typical implementation projects led to reductions of Work-in-Process and Finished Goods inventories of up to 50% (*Intelligent Supply Chain Planning* 1997). More importantly, improvements in inventory turns and other intermediate process measures are considered to be direct (first order) effects of SCM software implementation, whereas improvements in the overall financial performance are indirect (second order) effects (Dehning and Richardson 2002; Gunasekaran and Ngai. 2004). SCM software may also provide less tangible operational benefits, such as streamlined processes, increased delivery speed, improved customer service, or increased domain-knowledge specificity (Subramani 2003), but these are not as reliably measured as the effect on inventories. Since it is likely that the greatest operational effect SCM implementations will have is on inventory, and inventory amounts are recognized each period in the firm's financial statements, these effects should be measurable, *a posteriori*, by examining the data available in firms' balance sheets and notes to the financial statements.

We examine the impact of SCM systems on inventory metrics first through developing a three-stage supply chain inventory model. We then conduct a small numerical experiment to test the model. Finally, we undertake an empirical examination of firms that implemented SCM systems during 1999. We examine the inventory metrics for a sample of implementers for three years following the year of implementation, and for a control group of non-implementers for the contemporaneous years. We limit the study to three years after implementation since technological changes, exogenous changes in economic conditions, and unrelated process improvements may occur to such an extent in the years following implementation that any effects of implementation would tend to become less observable. In addition, many of the non-implementer firms implemented SCM software in the years following our test period, so any comparison between implementing and non-implementing firms becomes less reliable the farther from our test period we examine.

We find that firm-wide implementation is significant in explaining improvement in inventory metrics, relative to pre-implementation metrics for our sample. Our empirical tests indicate that implementing SCM software across only a portion of the firm does not impact inventory metrics, but that the scale of implementation does. More precisely, we find that firms implementing SCM software across the entire company significantly improve both inventory turns and inventory as a percent of revenue relative to partially-implementing firms and non-implementers.

LITERATURE REVIEW

Kahl (1999) defines SCM software as applications that "provide real-time analytical systems to manage the flow of product and information throughout the supply chain network of trading partners and customers." Generally speaking, SCM software suites include functional applications or modules such as sourcing, production planning, inventory management and allocation, warehousing, transportation, demand planning or forecasting, and customer service. Managing the supply chain, which includes suppliers, manufacturing centers, warehouses, distribution centers, and retail outlets, as well as the inventory that flows between them, involves a set of approaches designed to integrate these components efficiently (Simchi-Levi, Kaminsky, and Simchi-Levi 2000). Not only must the product itself flow efficiently – that is, in a manner which minimizes system-wide costs among the various entities in the supply chain – but so also must information. The promise of SCM software is that it enables efficient communication among the entities in a supply chain so that the chain can be effectively managed or coordinated. Each application is designed to coordinate the activities of entities along or within the supply chain and to provide real-time information which, in theory, enables rapid response, enhanced customer service, more accurate planning, and, of course, lower inventory levels.

Gurbaxani and Whang (1991) suggested that IT reduces transaction costs, control costs, documentation and communication costs, and decision information costs. This IT-sponsored reduction in costs plays a significant role in allowing a firm to exploit optimal scale economies in operations and information. Mitya and Chaya's (1996) findings are consistent with the coordination cost theory of IT value. The primary benefit of IT, according to Mitya and Chaya (1996), is that IT reduces the coordination costs of economic activity both within the firm (internal), and among the firm and its suppliers, customers, and other entities (external).

In a later test of the coordination cost theory, Shin (1999) found that IT spending was strongly correlated with a decline in reported internal coordination costs over a five-year test period. Shin inferred from the results that IT enhances the coordination of economic activities by reducing the cost of those activities. Poston and Grabski (2001) tested the financial statement impact of ERP implementations to determine the association of ERP implementations with the reduction of coordination costs and found limited support for their hypotheses.

Using IT to explore business information can lead to improved understanding of unstructured tasks, customer preferences, sales patterns, shortcomings in business processes, or best practices. Such advantages accrue to the firm through increased communication and coordination within the firm and along the supply chain (Dyer and Nobeoka 2000; Dyer and Singh 1998).

Previous studies of inter-organizational systems (IOS) indicated that firms increased "vertical information integration" between their partners in the value chain by adopting IOS (Bakos and Treacy 1986), and benefit from their use by reduced operational costs and improved customer service, among other benefits (Chatfield and Yetton 2000; El-Sawy et al. 1999). Mukhopadyay (1995) specifically links improvements in inventory carrying costs and inventory obsolescence at Chrysler to implementation of EDI. Mukhopadyay suggests that the improvements documented at Chrysler stem from the improvement in the quality of information provided by the IOS to both Chrysler and its suppliers, allowing management to coordinate activities better and manage inventory more carefully.

More specific to SCM, Subramani (2003) hypothesized that SCM systems may be used to exploit existing business operations (that is, improve operational efficiencies) or explore information leading to new business solutions. He found support for SCM systems exploration increasing domain-knowledge specificity, leading to both operational benefits and strategic benefits, but did not find support linking IT exploitation directly to operational improvements. Dehning et al. (2006) studied the impact of SCM systems on the financial performance of manufacturing firms. Dehning et al. (2006) argue that the improved communication and integration attendant upon SCM systems add value through the supply chain, by allowing firms to automate processes and make timely changes to processes which in turn increases operational performance. Based on Porter's value chain model, they found support for raw materials and finished goods inventory turnover improvements consistent with inbound and outbound logistics efficiencies for both one and two years following implementation. However, they did not find support for the hypothesis that SCM systems improves the performance of operations processes in terms of increased work-in-process inventory turnover. The authors also found moderate support for the hypothesis that firms implementing SCM systems will have overall improved financial performance reflected in increased inventory turns, return on assets (ROA) and return on sales (ROS). An interesting finding of their study is that as the scale of implementation increases, the improvement in ROA and ROS decreases, which is in the opposite direction of the anticipated results. In addition, as the scale of implementation increases, they found only marginal evidence of improvement in total inventory turns. One possible explanation is that the overall financial measures may not show improvements until glitches that may cause some execution problems are worked out of the system (Hendricks and Singhal 2003).

Based on the results of prior research, we believe SCM systems offer firms the potential to exploit the system to develop operational improvements related specifically to inventory – that is, a reduction of inventory necessary to support the anticipated level of sales and improvement in inventory turnover. While there may be the long-run potential to directly affect second-order financial results, we believe that first-order operational improvements, particularly with respect to inventory, should be more immediately observable. Indeed, Dehning et al's (2006) results indicate that SCM system implementations lead to improvements in inventory activity metrics, but they found that the scale of the implementation was negatively related to second-order profitability metrics, and they found no real evidence that it was associated with inventory turnover. These results are intriguing, and suggest that further study is needed to examine the implementation impact of full-scale SCM implementations. Rather than focusing on financial profitability results, which are impacted by many events unrelated to SCM software implementations, we focus specifically on inventory improvements. While Dehning et al. (2006) found no statistical evidence of the impact of scale on inventory turnover in their sample, their results nonetheless suggested that the scale of implementation may have some influence on inventory turns. In addition, inventory management research suggests this possibility.

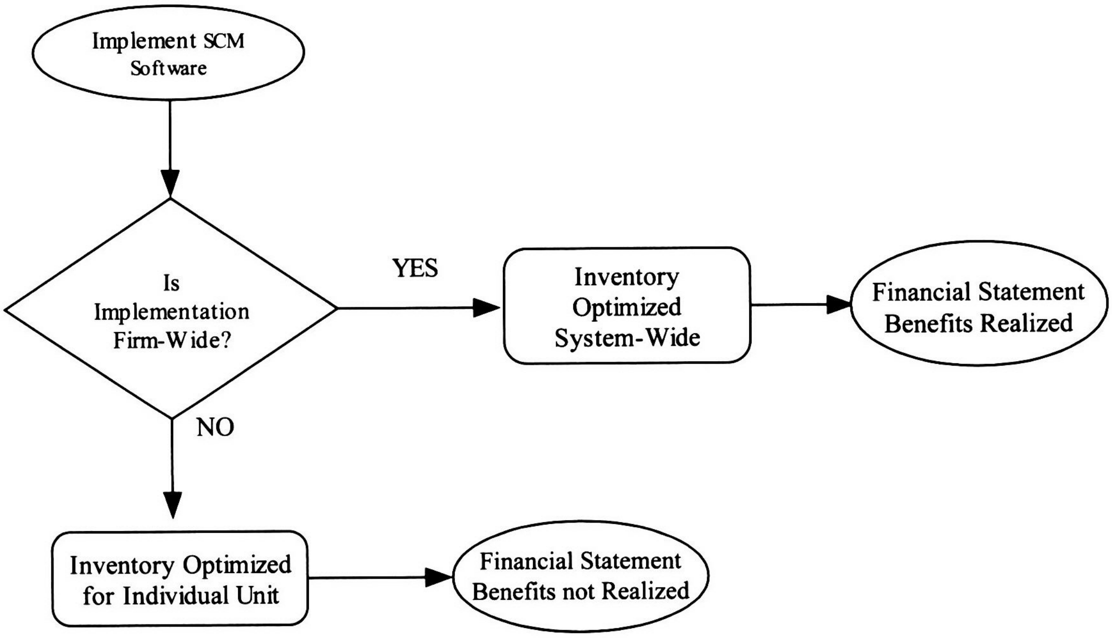
Well-established work in inventory theory indicates that system-wide inventory optimization leads to significant benefits. In the case of SCM implementation, then, for the firm to reap the greatest benefits from the coordination of activities and quality of information the software potentially provides, the firm would need to undertake firm-wide implementation. While a system-wide optimization approach may result in some operating policies at certain stages being suboptimal (Gavirneni 2002), the overall improvement for the whole system is greater. The willingness to undertake system-wide optimization by the members of the chain, or the units within the firm, is frequently described as part of a cooperative supply chain where the long run performance of the whole system is optimized (Aviv 2001). If only certain members of the supply chain implement SCM software, and these members dominate the rest of the chain, an asymmetrical distribution of inventory may be the end result (Iacovou, Benbasat, and Dexter 1995).

Similar conclusions with regard to partial implementation of just-in-time (JIT) inventory have been drawn in the literature. Empirical inventory management research indicates that in spite of the popularity of the JIT approach, suppliers still hold large quantities of products but ship them to their customers in small batches (Landry et al. 1998). In a study of the auto industry, Helper (1991) found that only 48% of suppliers surveyed used JIT production with their JIT delivery. The rest of the suppliers stockpiled inventory to meet their customers' JIT requirements. This approach to JIT in which suppliers carry large amounts of inventory was evident in a survey in which more than half of all suppliers questioned in the United States agreed that JIT only transfers inventory responsibility from customers to suppliers (Helper and Sako 1995). In other words, with many of these JIT implementations, the implementation was only partial and JIT delivery was not matched by JIT production. Because this approach does more in the way of shifting inventory than reducing it, the overall inventory in the system is not significantly reduced.

We believe the same dynamic affects SCM software implementations. If firms implement the software across only a portion of the firm, efficiencies that otherwise might have resulted from improved quality of information and coordination across other units within the firm are less likely to occur, resulting in inventory shifting across the firm's units, ultimately failing to impact the firms' financial statements. Figure 1 below presents a simple model of the relationship between SCM implementations, inventory and financial statement impact.

FIGURE 1

MODEL OF SCM SYSTEM IMPLEMENTATIONS LEADING TO INVENTORY EFFECTS



ANALYTICAL MODEL

To illustrate how a partial implementation of SCM software will result in a suboptimal solution from a system-wide perspective, and may not lead to a decrease in total inventory, we formulate and solve a three-stage supply chain inventory model. This can be thought of as three stages within the same firm or, alternatively, a supply chain consisting of a supplier, a manufacturer, and a retailer. We show that if a firm undertakes a partial implementation, and, as a result, each entity optimizes its own position based on its customers' demand, then the reduction in inventory and cost are not as large as they otherwise would have been had there been a system-wide implementation. This result occurs because a SCM software implementation across only a portion of the firm may allow that portion to optimize its particular inventory holdings, but would lack the visibility across the entire firm that a firm-wide implementation would provide. Thus, while the unit implementing SCM software may reduce its inventory holdings, or improve its inventory metrics to some optimal level for that unit and its customers, it may shift inventory to other units within the firm in order to do so. We theorize that a firm-wide implementation would provide the visibility and quality of information across the firm necessary to allow management to optimize inventory holdings for the entire firm rather than simply for individual units. A partial implementation fails to provide such visibility and instead encourages individual units to optimize solely with respect to that unit. To develop the model, we make the following assumptions:

a. the product is processed on a single machine/system at each level;
b. production and usage rates are deterministic and constant;
c. holding cost increases linearly with the number of units held;
d. the last downstream unit in the chain assembles the product or provides the retail outlet; and
e. the whole lot is produced before shipments occur.

Several assumptions have been made in the literature with regard to the way stages within the firm coordinate their activities. Banerjee (1986) assumed that the order quantity of the downstream stage and the production lot size of the upstream stage are equal and found the joint optimal lot size. Goyal (1988) allowed the upstream stage's lot size to be an integer multiplier of the downstream stage's order quantity, assumed that the whole lot is produced before the first shipment is made, and the shipments are of equal size. Lu (1995) allowed the first shipment to be made before the whole lot is produced at the upstream stage but kept the equal shipment size assumption. Goyal (1995) also allowed the first shipment to be made before the whole lot is produced. Goyal (2000) introduced a policy in which the first shipment has a small size and the next (*n*-1) shipments are equal to the size of the first shipment multiplied by the ratio of production to the demand rates. All of these models focus on a two-stage supply chain. We develop a model of a three-stage supply chain which can be further extended to model an m-stage supply chain.

We use the following notation:

i = 1, 2, or 3, an index denoting stage within the firm, 1 is the most upstream stage,
D = annual demand (units per year),
P_i = annual production rate at stage i (units per year),
S_i = setup or ordering cost for stage i ($ per order),
h_i = annual per unit inventory holding cost for stage i ($ per unit per year),
Q_i = the optimal order/production lot size for stage i (units per order),
n_i = an integer multiplier associated with stage i,
TC_i = the total annual cost for stage i ($ per year), and

$TC = \sum_i TC_i$, the total annual cost for the whole firm ($ per year).

Assuming that incoming material for the stage 1 unit has little value, Goyal (1988) showed that the total annual cost to stage 1 is:

$$TC_1 = \frac{D}{n_2 n_1 Q} S_1 + \frac{n_2 Q}{2} h_1 (n_1 (1 + \frac{D}{P_1}) - 1 \qquad (1)$$

The average inventory of stage 1 is given by the coefficient of h_1 in Equation (1). The total annual cost for the stage 2 unit is

$$TC_2 = \frac{D}{n_2 Q} S_2 + \frac{Q}{2} h_2 (n_2 (1 + \frac{D}{P_2}) - 1) + \frac{n_2 Q}{2P_2} D h_1 \qquad (2)$$

The last term in Equation (2) is the cost of holding the incoming material as it is being processed during the production portion of the cycle. The average inventory of stage 2 is given by the sum of the coefficients of h_1 and h_2 in Equation (2). The total annual cost for the stage 3 unit is

$$TC_3 = \frac{D}{Q} S_3 + \frac{Q}{2} h_3 \qquad (3)$$

The average inventory of stage 3 is given by the coefficient of h_3 in Equation (3). If each entity across the firm starting with stage 3 minimizes its total annual cost and uses the resulting optimal order quantity then the optimal solutions are given by:

$$Q^* = \sqrt{\frac{2DS_3}{h_3}} \tag{4}$$

$$n_2^* = \sqrt{\frac{2DP_2S_2}{[D(h_1+h_2)+h_2P_2]Q^2}} \tag{5}$$

$$N_2^* = \lfloor n_2^* \rfloor or \lceil n_2^* \rceil \tag{6}$$

$$n_1^* = \sqrt{\frac{2DP_1S_1}{h_1n_2^2Q^2(D+P_1)}} \tag{7}$$

and

$$N_1^* = \lfloor n_1^* \rfloor or \lceil n_1^* \rceil \tag{8}$$

Equations (6) and (8) ensure that the production quantity at each upstream stage is an integer multiplier of the order quantity of the adjacent downstream stage customer. If the lower integer from equations (6) or (8) is zero, then a value of one should be used. If the total annual cost for the whole supply chain is minimized (i.e. system-wide optimization), then the optimality conditions are given by:

$$n_1^* = \sqrt{\frac{[D(h_1+h_2)+(h_2-h_1)P_2]P_1S_1}{h_1P_2S_2(D+P_1)}} \tag{9}$$

$$n_2^* = \sqrt{\frac{(h_3-h_2)(n_1S_2+S_3)P_2P_3}{n_1S_1[DP_2n_1h_1+D(h_1+h_2)P_1+(h_2+h_1(n_1-1)P_2P_1)]}} \tag{10}$$

and

$$Q^* = \sqrt{\frac{2P_2P_1D(n_2n_1S_3+n_1S_2+S_1)}{n_2n_1[(h_3+h_2(n_2-1)+n_2h_1(n_1-1))P_2P_1+Dn_2(n_1h_1P_2+(h_1+h_2)P_1)]}} \tag{11}$$

The model indicates that individual unit optimization does not necessarily lead to firm-wide optimization. In order to optimize the inventory holdings across the entire firm, it may be necessary for some units to maintain inventory levels that are sub-optimal for that particular unit. We theorize that a partial SCM software implementation allows for individual unit inventory optimization, but not firm-wide optimization. On the other hand, a firm-wide SCM software implementation provides the means necessary to optimize firm-wide inventory.

NUMERICAL EXPERIMENT

To evaluate the changes in inventory and the potential cost savings from system-wide optimization vs. partial implementation at the last stage, we performed a small numerical experiment. For the last stage, the holding cost was set to $h_3 = \$1$ per unit per year, the demand rate was set to $D = 20{,}000$ units per year, and the ordering cost was set to $S_3 = \$50$ per order. The setup cost for the upstream stages were $S_2 = \$350$ and \$400 per order and $S_1 = \$550$ and \$600 per order to reflect the increased complexity of the setup relative to the ordering cost at the last stage. The holding cost for the upstream stages were $h_2 = \$0.668$ and \$0.588 per unit per year and $h_1 = \$0.444$ and \$0.392 per unit per year to reflect different degrees of value-added in the process. The production rates for the upstream stages were $P_2 = 50{,}000$ and 90,000 units per year and $P_1 = 140{,}000$ and 180,000 units per year to reflect the possibility that upstream stages may have several customers. The reduction in average inventory, the percentage reduction in average inventory, and the percentage savings in total annual cost of the system-wide optimal solution delivered through firm-wide implementation of the SCM software over the total cost based on partial implementation are shown in Table 1. As the table shows, reduction in average inventory can be as high as 19%, and averages 8.6% for the full implementers. Savings associated with firm-wide implementation over the partial implementation averages 2.3%, and can be as high as 4.9%.[1]

TABLE 1

RESULTS OF NUMERICAL EXPERIMENT

P_2	P_1	h_2	h_1	S_2	S_1	Reduction in Average Inventory	% Reduction in Average Inventory	% Savings in Total Cost
50000	140000	0.667	0.444	350	550	1241	-19.0	-1.8
50000	140000	0.667	0.444	350	600	1110	-17.0	-0.9
50000	140000	0.667	0.444	400	550	1110	-17.0	-2.4
50000	140000	0.667	0.444	400	600	982	-15.0	-1.7
50000	140000	0.667	0.392	350	550	285	-4.4	-1.7
50000	140000	0.667	0.392	350	600	178	-2.7	-1.6
50000	140000	0.667	0.392	400	550	1051	-16.1	-1.1
50000	140000	0.667	0.392	400	600	-31	0.5	-1.5
50000	140000	0.588	0.392	350	550	735	-11.2	-1.0
50000	140000	0.588	0.392	350	600	46	-0.7	-1.3
50000	140000	0.588	0.392	400	550	598	-9.1	-2.0
50000	140000	0.588	0.392	400	600	464	-7.1	-1.3
50000	140000	0.588	0.346	350	550	3	0.0	-1.3
50000	140000	0.588	0.346	350	600	-109	1.7	-1.3
50000	140000	0.588	0.346	400	550	533	-8.1	-0.8
50000	140000	0.588	0.346	400	600	-327	5.0	-1.4
50000	180000	0.667	0.444	350	550	1165	-18.2	-1.5
50000	180000	0.667	0.444	350	600	278	-4.3	-1.7

[1] While this set of parameters show reasonable reduction in inventory, others may not, or may even have more reduction. However, system-wide optimization will always lead to lower inventory cost. One aspect that has not been incorporated above is the cost of poor quality. We have ignored the cost of poor quality due to the complexity of incorporating it; had we considered this cost in the model, we could have shown much greater reduction in inventory across the system. The incorporation of the rework and scrap costs has been shown to lead to further reduction in system wide inventory levels and can result in complete synchronization where the integer multipliers for upstream stages become one (Khouja 2003). Ignoring the cost of poor quality therefore biases the model in favor of greater inventory holdings. Even so, the model indicates significant inventory reductions for full-scale implementers.

TABLE 1 (continued)

50000	180000	0.667	0.444	400	550	1036	-16.2	-2.2
50000	180000	0.667	0.444	400	600	909	-14.2	-1.4
50000	180000	0.667	0.392	350	550	235	-3.7	-1.7
50000	180000	0.667	0.392	350	600	130	-2.0	-1.6
50000	180000	0.667	0.392	400	550	981	-15.3	-0.9
50000	180000	0.667	0.392	400	600	-76	1.2	-1.6
50000	180000	0.588	0.392	350	550	664	-10.4	-0.8
50000	180000	0.588	0.392	350	600	-2	0.0	-1.3
50000	180000	0.588	0.392	400	550	529	-8.3	-1.8
50000	180000	0.588	0.392	400	600	397	-6.2	-1.2
50000	180000	0.588	0.346	350	550	-41	0.6	-1.3
50000	180000	0.588	0.346	350	600	-151	2.4	-1.3
50000	180000	0.588	0.346	400	550	468	-7.3	-0.6
50000	180000	0.588	0.346	400	600	-366	5.7	-1.4
90000	140000	0.667	0.444	350	550	1098	-19.0	-3.9
90000	140000	0.667	0.444	350	600	745	-12.9	-3.3
90000	140000	0.667	0.444	400	550	745	-12.9	-4.9
90000	140000	0.667	0.444	400	600	631	-10.9	-4.3
90000	140000	0.667	0.392	350	550	817	-14.1	-2.5
90000	140000	0.667	0.392	350	600	700	-12.1	-1.9
90000	140000	0.667	0.392	400	550	700	-12.1	-3.5
90000	140000	0.667	0.392	400	600	586	-10.1	-2.9
90000	140000	0.588	0.392	350	550	646	-11.2	-3.6
90000	140000	0.588	0.392	350	600	525	-9.1	-3.1
90000	140000	0.588	0.392	400	550	525	-9.1	-4.7
90000	140000	0.588	0.392	400	600	407	-7.0	-4.2
90000	140000	0.588	0.346	350	550	603	-10.4	-2.3
90000	140000	0.588	0.346	350	600	480	-8.3	-1.8
90000	140000	0.588	0.346	400	550	480	-8.3	-3.5
90000	140000	0.588	0.346	400	600	361	-6.2	-3.0
90000	180000	0.667	0.444	350	550	1029	-18.2	-3.7
90000	180000	0.667	0.444	350	600	679	-12.0	-3.1
90000	180000	0.667	0.444	400	550	679	-12.0	-4.7
90000	180000	0.667	0.444	400	600	567	-10.0	-4.1
90000	180000	0.667	0.392	350	550	753	-13.3	-2.3
90000	180000	0.667	0.392	350	600	638	-11.3	-1.7
90000	180000	0.667	0.392	400	550	638	-11.3	-3.4
90000	180000	0.667	0.392	400	600	525	-9.3	-2.8
90000	180000	0.588	0.392	350	550	583	-10.3	-3.5
90000	180000	0.588	0.392	350	600	464	-8.2	-2.9
90000	180000	0.588	0.392	400	550	464	-8.2	-4.6
90000	180000	0.588	0.392	400	600	347	-6.1	-4.1
90000	180000	0.588	0.346	350	550	543	-9.6	-2.2
90000	180000	0.588	0.346	350	600	423	-7.5	-1.6
90000	180000	0.588	0.346	400	550	423	-7.5	-3.4
90000	180000	0.588	0.346	400	600	305	-5.4	-2.9
Mean						**517.7**	**-8.6**	**-2.3**

METHODOLOGY

Hypothesis

The results of the model and the numerical results suggest that firm-wide implementation of SCM software can lead to greater inventory reductions and cost savings than partial-implementations. In order to examine the question further, we examined empirical data for a small sample of firms prior to, and following, their 1999 implementation of SCM software. We also included a sample of firms not using SCM software over the same time frame as a control group. To conduct the examination, we looked at inventory balances (relative to sales) and inventory turn metrics for one year prior to the implementation year and then compared those metrics against those obtained for one, two, and three years following the implementation. Accordingly our hypothesis is:

> **H_A: All else being equal, entities performing full-scale implementations will show greater inventory balance reductions and better inventory turn improvements than those implementing the software over only a portion of the firm (partial-scale implementers) or non-implementing firms.**

This hypothesis implies that implementation alone is not sufficient to secure inventory benefits when compared to full-scale implementation. The scale of the implementation ultimately drives the inventory metrics results due to the ability of the firm to optimize inventory system-wide.

Data Collection

Data were collected in two ways: first through a short questionnaire mailing and then supplemented through an analysis of business wire announcements. We began by examining the customer list posted on i2 Technologies' web site. We first determined whether the particular customer was public or private, then, for the public firms, we determined the 4-digit SIC code. We then mailed a short survey to every firm in the Compustat database listed under each of those SIC codes. After eliminating those whose address or contact person could not be determined, we sent questionnaires to 434 firms, of which 59 responded (13.6% response rate). Each recipient was asked if the firm had implemented SCM software. If not, they were asked to return the mailing after noting that. If they had, we inquired as to the date (month & year) of the implementation, the applications purchased, the scale of the implementation, and the vendor from which they had purchased the software. Of the respondents, 16 had implemented SCM software. We were unable to use 5 of these responses in our study either because the date of implementation was missing or the implementation was too recent. Twelve firms noted they were in the process of implementing SCM software, and 31 indicated that they had not implemented any SCM software (although several said they were investigating that possibility). This resulted in a useable sample of 11 implementing firms and 31 non-implementing firms derived from the survey.

To supplement this sample, we then investigated implementation announcements available on the business news wire services. Specifically, we searched Lexis-Nexis Academic Universe for the business wire news services' announcements using several different search terms. We searched using the terms "supply chain software," or "supply chain management" or "i2 technologies" or "Manugistics" in combination with "implement" or "implementation" or "license" or "purchase." The investigation resulted in 474 announcements, of which 78 announcements were potentially useable for our study. A useable observation was the announcement of an implementation ("going live") or licensing agreement where both the implementing firm and the vendor were identified, and the announcement contained information as to the scale of the implementation. For these firms, we examined the announcements to obtain information concerning the scale of the implementation and the scope of products purchased. Announcements where the scale of implementation or scope of product purchases were ambiguous or not mentioned were not usable.

Combining the 11 implementing firms gathered from the survey with the 78 firms collected from the news wire, we were able to obtain information for 89 firms that had indicated they had implemented SCM software. We used the 31 firms from the survey that indicated they had not implemented any SCM software as our control group of non-implementing firms. In order to compare the implementing group contemporaneously with the non-implementing group, we then dropped all firms that did not implement in 1999, reducing the implementing group used in our regression models to 41 firms.[2] Thus, for all tests involving comparisons of implementers with non-implementers, we had a sample size of 72, consisting of 41 implementing firms and 31 non-implementing firms.[3] All quantitative data used in the study were obtained from Standard & Poor's Research Insight.[4]

Our sample included both manufacturing (approximately 78% of implementing firms and 70% of non-implementing firms) and service firms (approximately 22% of implementers and 30% of non-implementers). The firms in the two sectors differ in the number of stages at which inventory may be held. A service firm, especially in retail, may hold inventory at a warehouse which then distributes it to retail locations. Some retailers may hold little inventory in warehouses and rely on cross-docking where arriving inventory is transferred to trucks to be delivered to stores without being stored in the warehouse. Manufacturing firms better fit Porter's (1985) model of inbound logistics (raw materials), operations processes of one or more stages (work in progress), and outbound logistics (finished goods). For both manufacturing and service firms, the implementation of SCM software, partial or full, is claimed to lead to improvement in inventory turns. However, manufacturing firms, because of the larger number of stages where inventory may be held, may be more affected by the scope of the implementation than service firms.

Dependent Variables

We measure inventory improvement using two different variables. The first variable of interest is the average inventory balance scaled by revenue. We adjusted the inventory amounts reported by each firm using LIFO (Last-in, First-out) to FIFO (First-in, First-out) for all years in order to mitigate the effect of different cost flow assumptions on the reported financial statement values of inventory (COGS amounts used in the inventory turn measures were similarly adjusted). This allows us a more consistent, and legitimate comparison.[5] We take the difference in the average inventory amounts between each of the three years following implementation (years t+1, t+2. and t+3, where t=implementation year) and the year prior to the implementation (t-1) in order to gauge the relative improvement in inventory holdings from pre-implementation to post-implementation. The variable is specified below:

$$\frac{\left[\left(Inventory_{t+j-1} + Inventory_{t+j}\right)/2\right]}{Revenue_{t+j}} - \frac{\left[\left(Inventory_{t-1} + Inventory_{t-2}\right)/2\right]}{Revenue_{t-1}}$$

where j = 1, 2,or 3 depending on the year being tested, and
t = the year of implementation, 1999

This ratio is an important measure of the levels of inventory necessary to support changing sales levels. Inventory holdings support sales to the extent that firms hold inventory in order to meet sales projections, satisfy current customer demand, avoid stockouts, and reduce operational risk. If SCM software increases the quality of information available to management, which in turn promotes better coordination of activities and reduction of operating risk, then, *ceteris paribus*, we expect that the average level of inventory maintained to support sales volumes throughout the year should decrease as a percent of sales.

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[2] A second, and equally important reason to restrict the sample to only those firms implementing in 1999 is that including implementing firms across a several-year time span would tend to introduce exogeneity bias into the results by assuming stable conditions across the different implementation years. Specifically, differences in technological capabilities in the software throughout the years and also in economic conditions across time make an examination of implementation across multiple years less reliable.

[3] Observations varied slightly from these numbers due to missing data depending on the year analyzed.

[4] The dual procedure used to obtain sample firms allowed us to obtain a group of implementing firms of sufficient size to conduct statistical tests; it also allowed us to obtain a group of firms that were not using SCM software, so we could confidently compare the two groups. Because the sample was not randomly selected, the generalizability of our results is limited. We are not able to draw inferences concerning the larger population of firms. It does, however, allow us to examine the impact of SCM implementations for this group of firms in a rigorous manner, given the data limitations, and to ascertain whether the results obtained for these firms are consistent with our analytical model.

[5] In periods of rising prices, firms using LIFO are subject to possible distortions on their balance sheets as companies sell through LIFO layers. As a LIFO firm reduces inventory holdings, the cost of inventory reflected on its balance sheet may get very small, reflecting (very) early costs. Compared to a FIFO firm, the LIFO firm having the same unit reduction in inventory may appear, based on its balance sheet value, to have a much greater reduction. White, Sondhi, and Fried (1997) suggest that, from a balance sheet perspective, inventories based on FIFO are preferable to those presented under LIFO.

Our second measure of inventory improvement is inventory turnover from the years t+1, t+2, and t+3 less inventory turnover from year t-1, calculated as follows:

$$\frac{Cost\ of\ Goods\ Sold_{t+j}}{(Inventory_{t+j-1} + Inventory_{t+j})/2} - \frac{Cost\ of\ Goods\ Sold_{t-1}}{(Inventory_{t-1} + Inventory_{t-2})/2}$$

where j = 1, 2, or 3 depending on the year being tested, and
t = implementation year, 1999

This variable represents an important metric for the firm. It captures not only the sell-though rate of inventory, but implicitly captures the velocity of operations. Given that SCM software increases the information available as well as the speed with which information becomes available, then we expect that implementing firms should increase the number of inventory turns. This may be accomplished either by reducing inventory balances or by increasing the level of sales (velocity) over the same time period, or by some combination of the two.

Independent Variables

In order to test our hypotheses, we have two variables of interest and three control variables. Our first variable of interest is an indicator variable for the scale of the implementation, coded 1 if the implementing firm implemented the software firm-wide, 0 if the implementation was less than firm-wide. This variable allows us to test the impact of full-scale vs. partial implementations. The second variable is an indicator variable for implementer, coded 1 if the firm implemented SCM software, and 0 otherwise. This variable captures the effect of the implementation, without respect to the scale of the implementation. By including this variable, and a sample of non-implementing firms, we are able to differentiate between the effect of implementation on inventory metrics and the effect of full-scale implementation on inventory metrics.

We also include three control variables, one to control for firm size, one to control for vendor, and one to control for the scope of products purchased for the implementation. It may be that larger firms have more resources and expertise to bring to bear on inventory problems, and that there is a greater incentive to control inventory holdings as a result. In addition, larger firms may be more likely to have processes in place that allow for more effective or efficient control over inventory holdings. On the other hand, it may be that larger firms have greater congestion and coordination problems with respect to inventory, and for that reason, are less likely to be able to exert control over inventory holdings. In either case, the possibility exists that size systematically influences inventory balances and turns. In order to control for these possible effects, we include total assets to control for potential size effects in the model.[6]

It is also possible that the scope of the implementation impacts inventory metrics. If a firm implements the full suite of products, rather than selected modules, information flow and the quality of information may be enhanced leading to inventory optimization. On the other hand, not all modules have the same impact on inventory holdings. For example, the transportation planning module is likely to have less impact on inventory than, say, demand planning. Nevertheless, the scope of the implementation may have some impact on inventory, and to control for the effect due to scope, we include a product variable, coded 1 if the firm purchased and implemented the full suite of SCM software, and zero otherwise.

Finally, it may also be that the major vendors, which have been supplying SCM systems the longest and allegedly have the greatest expertise in the area, provide products offering superior functionality, integration, or coordination characteristics, which could lead to greater improvements in inventory levels and turns than SCM software offered by other vendors. Alternatively, the major vendors may tend to attract the largest customers having

[6] Using total assets to proxy for size effects is relatively common in accounting studies or in studies using accounting data (see, for example, Zmijewski and Hageman's (1981) study of the size hypothesis; Watts and Zimmerman (1986); Fama and French (2001); or Rama and Read (2006)). Size variables commonly used in accounting studies include total assets, book value, market capitalization, sales, and others (for example, see Bamber, Bamber, and Schoderbek (1993), Hall and Stammerjohan (1997), Heninger (2001), and Ge and McVay (2005)). We use the log of total assets to control for size in our study since total assets was not normally distributed in our sample.

the most complex and difficult inventory issues, and thus the most complicated implementations.[7] In order to control for any effect the vendors themselves may have had on inventory metrics, we coded the variable a one if the vendor was i2 Technologies or Manugistics, and a zero if the firm implemented SCM software from some other vendor or did not implement SCM software at all.

RESULTS

Descriptive Results

Table 2 presents descriptive data concerning the set of full-scale implementers, partial implementers, and non-implementers. Panel A shows total assets, inventory, and sales descriptive statistics for full-scale implementing firms; panel B shows the same information for partial-scale implementing firms; panel C displays similar information for non-implementing firms.

TABLE 2

DESCRIPTIVE STATISTICS FOR FULL-SCALE, PARTIAL-SCALE, AND NON-IMPLEMENTING FIRMS FOR IMPLEMENTATION YEAR

Panel A: Full –Scale Implementing Firms

Variable	Total Assets (millions of $)	Inventory (millions of $)	Sales (millions of $)
Mean	2991.1	736	4549.3
Median	1294.4	319.3	1725.5
Min	25.2	0.9	5.4
Max	17081.	6556.	38483
Std Dev	4218.8	1447.9	8578.4
N	20	20	20

Panel B: Partial-Scale Implementing Firms

Variable	Total Assets (millions of $)	Inventory (millions of $)	Sales (millions of $)
Mean	29792.0	2596.4	21493.6
Median	15534.0	1741.8	11613.9
Min	397.3	67.2	502.9
Max	277329.0	8614.0	162558.0
Std Dev	65064.9	2641.3	38098.6
N	17	16	17

[7] The size of the customers for each group is consistent with this possibility. In our sample implementers of i2 Technologies or Manugistics products had average total assets of $18.2 million. Implementers of other SCM software and non-implementers had total assets of $4.19 million. A t-test indicated that the size differences were significant at p< .01.

Panel C: Non-Implementing Firms

Variable	Total Assets (millions of $)	Inventory (millions of $)	Sales (millions of $)
Mean	2699.47	369.38	3593.9
Median	432.35	79.71	656.55
Min	89.72	4.77	45.09
Max	29163	2974	37478.08
Std Dev	6021.09	776.2	8141.42
N	40	37	40

This table contains data from 1999, the implementation year, for each group of firms. There are 20 full-scale implementing firms, between 16-17 partially-implementing firms, and between 37-40 non-implementing firms, depending on the variable. Full-scale implementing firms appear smaller than partial-implementers, but appear relatively similar to non-implementers. Non-implementers' mean total assets were $2,699 (in millions) and full-scale implementers total assets were $2,991. Partial implementers, on the other hand, had mean total assets of $29,792. Median values indicate that partially-implementing firms were ten times larger than full-scale implementers, which in turn were nearly three times larger than non-implementers. Differences in mean inventory levels follow the same pattern, although the disparities are not as acute. Full-scale implementers' mean inventory ($736 million) is about twice as large as non-implementers' inventory ($369), but only about one-third the level of partial-implementers ($2,596). In general, the results for sales are similar. The differences in the size of the firms across the three groups supports the necessity of including a variable in our model to control for size effects. For that reason, we include the log of total assets in the model.

Scaling inventory by revenue, however, appears to mitigate the size differences in the dependent variable. Table 3, panel A provides descriptive statistics on average inventory scaled by revenue for full-scale, partial-scale, and non-implementers for years t-1 through year t+3. Mean inventory levels relative to revenue for full-scale implementers ranges from .171 in year t-1 to .139 in year t+3. For partial implementers, the values range from .139 in year t-1 to .119 in year t+3. For non-implementers, the values range from about .155 in t-1 to .192 in year t+3. Median values also indicate similarity among the groups.

TABLE 3

DESCRIPTIVE STATISTICS FOR DEPENDENT VARIABLES BY IMPLEMENTATION GROUP

Panel A: Average Inventory Scaled by Total Net Revenue

Group	Statistic	Year t-1	Year t	Year t+1	Year t+2	Year t+3
Full-Scale Firms	N	20	20	20	17	17
	Mean	.171	.152	.149	.150	.139
	Median	.137	.152	.121	.116	.124
	Std. Dev.	.133	.129	.133	.130	.102
Partial-Scale Firms	N	16	16	16	16	16
	Mean	.139	.152	.147	.128	.119
	Median	.136	.152	.147	.122	.115
	Std. Dev.	.061	.071	.062	.067	.057
Non-implementing Firms	N	36	36	35	29	29
	Mean	.155	.162	.157	.162	.192
	Median	.142	.134	.129	.139	.140
	Std. Dev.	.084	.105	.094	.101	.178

Panel B: Inventory Turnover Ratio

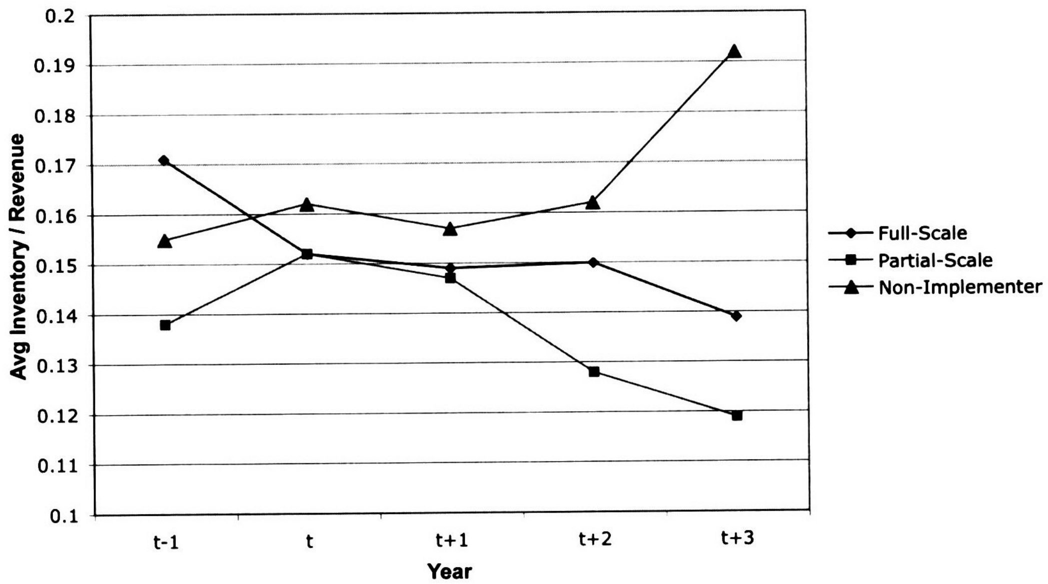
Group	Statistic	Year t-1	Year t	Year t+1	Year t+2	Year t+3
Full-Scale Firms Turnover	N	19	20	20	17	17
	Mean	5.64	6.65	7.09	6.01	6.41
	Median	3.81	5.23	5.51	4.95	5.21
	Std. Dev.	3.96	4.54	5.09	4.14	4.63
Partial-Scale Firms Turnover	N	16	16	16	15	16
	Mean	7.37	7.01	6.84	6.87	8.52
	Median	6.49	6.60	6.13	6.07	7.35
	Std. Dev.	4.36	4.58	3.93	4.17	6.07
Non-implementing Firms Turnover	N	36	37	36	29	29
	Mean	5.88	5.87	5.85	5.88	6.42
	Median	5.09	4.85	4.74	4.58	4.57
	Std. Dev.	3.82	3.77	3.88	4.25	5.15

In the implementation year, mean values for all three groups are similar. Both full-scale and partial-scale implementers had inventory levels representing 15.2% of revenue, while non-implementers' inventory levels were 16.2% of revenue. While scaling by revenue appears to mitigate the impact of firm size on the dependent variable, it does not impact the effect of firm size on changes in the variable, further indicating the importance of controlling for size directly in the model.

FIGURE 2

CHARTS OF MEAN INVENTORY-TO-REVENUE BY YEAR

Panel A: Mean Average Inventory scaled by Total Revenue for Full-Scale, Partial-Scale, and Non-Implementers (t = implementation year)



Panel B: Median Average Inventory scaled by Total Revenue for Full-Scale, Partial-Scale, and Non-Implementers (t = implementation year)

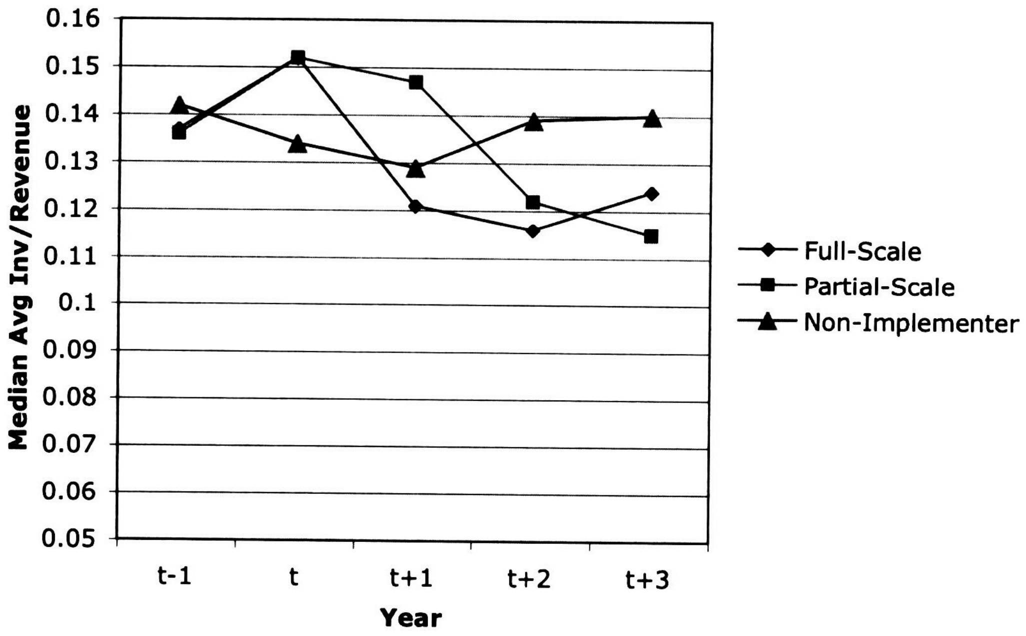


Figure 2, panel A, displays a chart of the inventory-to-sales variable for years t-1 through t+3. In t-1, full-scale implementers maintained the highest ratio of inventory-to-sales of any of the three groups at 17% of revenue. The value declines by year t, perhaps representing process improvements in preparation for, or during, the implementation. The value declines again by year t+1, to 14.9% of revenue, stays steady in year t+2 and then declines again in year t+3 to 13.9% of revenue. Partial-scale implementers inventory is 13.8% of revenue in year t-1, and increases in year t to 15.2%. Year t+1 inventory levels show only slight improvement to 14.7% of revenue, but then declines to 12.8% of revenue in t+2. Year t+3 shows a further decline of inventory to 11.9% of revenue. Non-implementers' inventory levels are at 15.5% of revenue in year t-1, but increase in year t to 16.2% of revenue. Inventory levels fall slightly in t+1, but then increase in years t+2 and again in t+3. Mean values appear to indicate a difference between implementers and non-implementers in that implementers' inventory levels tend to decline from year t to year t+3, while non-implementers' inventory levels tend to increase. A noticeable difference occurs between full-scale and partial-scale implementers, however, when considering the pre-implementation inventory levels. Full-scale implementers' inventory levels decrease significantly from year t-1 to t+1, while partial-scale implementers' inventory levels actually increase from t-1 to t+1, and the decline from t-1 to t+2 is not as large as it is for full-scale implementers.

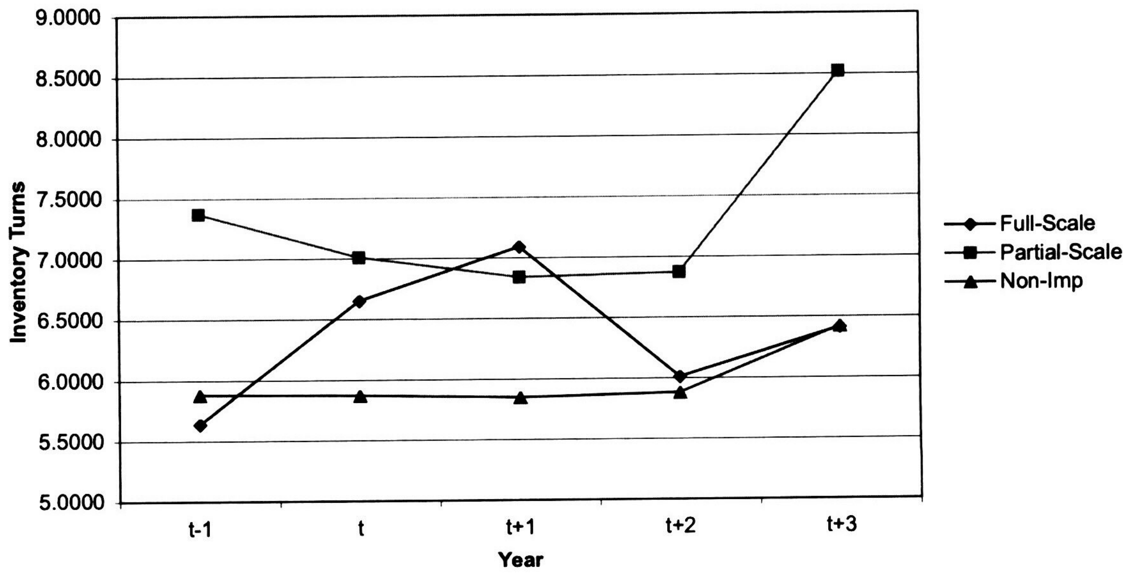
Panel B charts median inventory-to-revenue values for the three groups. Note that non-implementer medians decline slightly from t-1 to t+1, but then increase to t-1 levels in the final two years, so that any inventory improvement is not sustained over the whole period. Full-scale implementer median values follow the same general pattern that partial-scale implementers display, but the full-scale median values fall dramatically after year t and are lower than partial-scale median values through t+2. By t+3, the partial-scale implementer median declines beneath the full-scale median. It may be that partial-scale implementing firms take longer to realize benefits from implementation than full-scale firms and that by the end of three years after implementation, those benefits have begun to impact inventory metrics.

With respect to inventory turnover in Table 3 panel B, we note that partial-scale implementing firms consistently have more turns per year than either full-scale implementers or non-implementers. Both mean and median statistics support this observation. Partial-scale implementers have mean inventory turns ranging from a low of 6.84 in year t+1 to a high of 8.52 in year t+3, while full-scale implementers have a mean of 5.64 in t-1 to 7.09 in t+1. The non-implementers have less variability and range from a mean of 5.87 in year t to 6.42 in year t+3. Figure 3 below charts the mean and median inventory turns for each group.

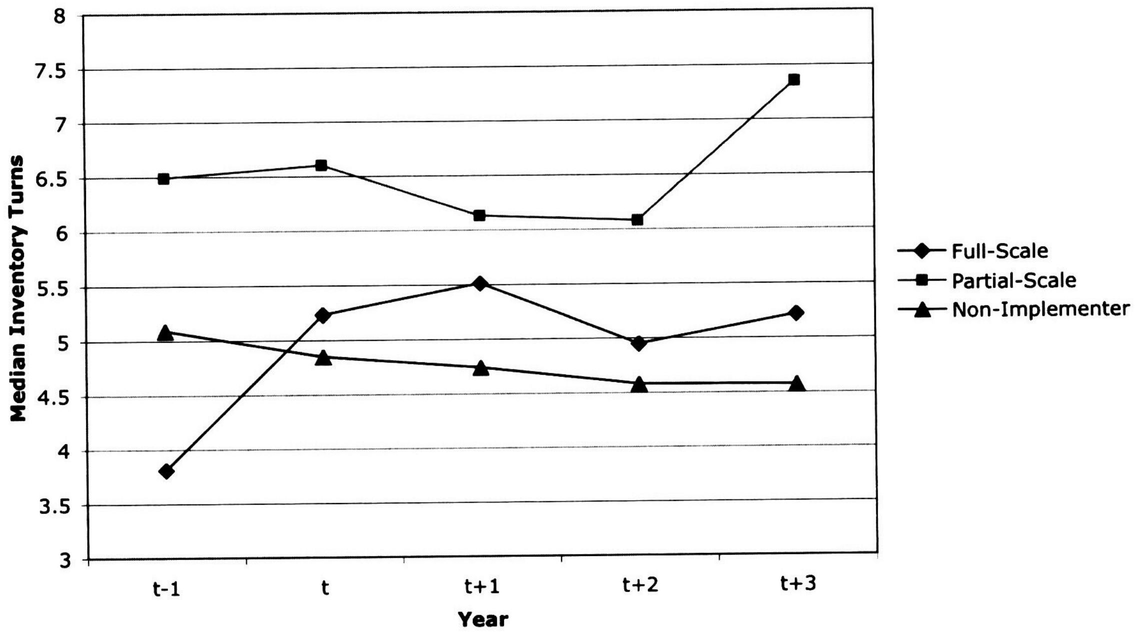
FIGURE 3

CHARTS OF MEAN AND MEDIAN INVENTORY TURNS BY YEAR

Panel A: Mean Inventory Turns for Full-Scale, Partial-Scale, and Non-Implementers (t = implementation year)



Panel B: Median Inventory Turns for Full-Scale, Partial-Scale, and Non-Implementers (t = implementation year)



From Figure 3, we notice that inventory turns increase substantially for full-scale implementers from t-1 to t+1 while they decline for partial-scale implementers over the same period. While turns decline in year t+2 for full-scale implementers, the t+2 value still represents an improvement over t-1. For partial-scale implementers, year t+2 turns are still below t-1 values. Both groups see improvement from year t+2 to t+3, although the partial-scale group enjoys the greatest improvement. These results are consistent with the notion that full-scale implementation improves inventory turnover soon after implementation. The results also indicate that the benefits continue relative to pre-implementation metrics, although the magnitude of the improvement appears to fall as time passes. Non-implementers show no improvement in inventory turnover until year t+3. The results are also consistent with the notion that benefits accrue immediately to full-scale implementers while the benefits accruing to partial implementation appear later. Of course, while it is certainly possible that benefits from implementation may take three years to be fully realized, the fact that all three groups – including the non-implementing group – increased turns three years after implementation suggests that other elements were at play in the observed improvement rather than the implementation. In other words, it may be that evidence from three years after implementation is not necessarily capturing the effects of implementation, but the effect of some exogenous force(s) on firms' inventory turn metrics. Panel B charts median inventory turns for the three groups, and the results are similar.

We started examining the data by conducting t-tests of inventory turns and average inventory scaled by revenue based on their scale classification. Results from Table 4 below indicate that the mean difference in average inventory scaled by revenue for full-scale implementers for all three years was significantly lower than the mean difference for partial-scale implementers ($p < .04$ for all three years). This result suggests that firms implementing SCM software on a firm-wide basis enjoy significantly lower inventory-to-revenue holdings relative to their own pre-implementation levels than partial-scale implementers do for up to three years following implementation. With respect to inventory turnover, full-scale implementers appear to have significantly higher turnover metrics relative to their own pre-implementation values for the first two years following implementation than partial-scale implementers. In other words, it appears that full-scale implementers improve their inventory metrics to a greater extent than partial-scale implementers do.[8]

TABLE 4

RESULTS FOR TESTS OF DIFFERENCES IN MEANS FOR FULL-SCALE FIRMS VS. PARTIAL-SCALE FIRMS

Variable	Full-Scale Mean	Partial-Scale Mean	T-Stat	P-Value
AISDiff1	-0.022	.0079	1.86	.038
AISDiff2	-0.034	.0026	1.95	.032
AISDiff3	-0.044	-.0070	1.93	.035
ITDiff1	0.870	-0.529	-3.04	.003
ITDiff2	0.490	-0.707	-2.51	.009
ITDiff3	0.889	-0.185	-1.55	.065

$AISDiff1 = [Avg.\ Inventory / Net\ Sales]_{(t+1)} - [Avg.\ Inventory / Net\ Sales]_{(t-1)}$
$AISDiff2 = [Avg.\ Inventory / Net\ Sales]_{(t+2)} - [Avg.\ Inventory / Net\ Sales]_{(t-1)}$
$AISDiff3 = [Avg.\ Inventory / Net\ Sales]_{(t+3)} - [Avg.\ Inventory / Net\ Sales]_{(t-1)}$

$ITDiff1 = Inventory\ Turns_{(t+1)} - Inventory\ Turns_{(t-1)}$
$ITDiff2 = Inventory\ Turns_{(t+2)} - Inventory\ Turns_{(t-1)}$
$ITDiff3 = Inventory\ Turns_{(t+3)} - Inventory\ Turns_{(t-1)}$

[8] Because of the relatively small sample size, we also conducted a nonparametric one-way ANOVA on the data. We do not report the results in the paper because they were the same as the t-test results. In general, F-statistics were significant at <.1 (.063) for the first model year, and less than .018 for the second and third model years when testing differences in the AISDiff variable between full-scale and partial-scale firms, and were significant at .022 or less for the first two years following implementation for the inventory turns variable. The F-statistic for inventory turnover for year t+3 was not significant at .05 (it was significant at p.< .10).

While the t-test results are interesting, they do not control for other possible influences on inventory metrics, like firm size, products purchased, or vendor characteristics. In order to control for these influences, we examined the data using the following models containing the variables discussed earlier.

(1) $AISDiff_{t+j} = \beta_o + \beta_1 Imp + \beta_2 Scale + \beta_3 Product + \beta_4 Vendor + \beta_6 TA + \varepsilon$
(2) $ITDiff_{t+j} = \beta_o + \beta_1 Imp + \beta_2 Scale + \beta_3 Product + \beta_4 Vendor + \beta_6 TA + \varepsilon$

Where,

$AISDiff_{t+j}$ = the difference in average inventory scaled by revenue from time t-1 to t+j, where j=1, 2, or 3, respectively
$ITDiff_{t+j}$ = the difference in inventory turns from time t-1 to t+j, where j=1, 2, or 3, respectively
Imp = an indicator variable, coded as 1 if the firm implemented SCM software, 0 otherwise
Scale = an indicator variable, coded as 1 if the firm implemented SCM software firm-wide, 0 otherwise
Product = an indicator variable, coded as 1 if the firm implemented the full suite of SCM products, 0 otherwise
Vendor = an indicator variable, coded as 1 if the vendor was i2 Technologies or Manugistics, 0 if the SCM software was supplied by some other vendor or if the firm did not implement
TA = the log of the firm's total assets at time t, used to control for firm size

H_A states that full-scale implementing firms will demonstrate significantly improved inventory metrics relative to both non-implementers and partial-scale implementers. We examine this hypothesis using the above models. Results are presented in Tables 5 and 6.

TABLE 5

MULTIVARIATE REGRESSION RESULTS FOR AVERAGE INVENTORY SCALED BY REVENUE MODEL

Panel A: OLS Regression results for Dependent Variable AISDiff1

Model F: 1.18 ***Model P-value:*** .3308 ***Adj. R^2:*** .0151

Predicted Sign:		-	-	+/-	+/-	+/-
	Intercept	**Imp**	**Scale**	**Product**	**Vendor**	**TA**
Coefficient	.0681	.0032	-.0383	-.0229	.0197	-.0073
T-Statistic	1.68	0.08	-1.77	-1.11	0.99	-1.39
P-value	.0989	.469	.041	.272	.326	.170

Panel B: OLS Regression results for Dependent Variable AISDiff2

Model F: 4.49 ***Model P-value:*** .0017 ***Adj. R^2:*** .228

Predicted Sign:		-	-	+/-	+/-	+/-
	Intercept	**Imp**	**Scale**	**Product**	**Vendor**	**TA**
Coefficient	.1024	.0111	-.0501	-.0468	.0176	-.0110
T-Statistic	2.94	0.32	-2.70	-2.63	1.03	-2.45
P-value	.0048	.3761	.0046	.0110	.3065	.0176

Panel C: OLS Regression results for Dependent Variable AISDiff3

Model F: 2.89	*Model P-value:* 0.0221		*Adj. R²:* .1378		
Predicted Sign:		-	-	+/-	+/-	+/-
	Intercept	**Imp**	**Scale**	**Product**	**Vendor**	**TA**
Coefficient	.1865	.0024	-.0657	-.0623	.0199	-.0195
T-Statistic	2.56	0.03	-1.69	-1.68	0.56	-2.08
P-value	.0134	.4877	.0484	.0994	.5786	.0424

TABLE 6

MULTIVARIATE REGRESSION RESULTS FOR INVENTORY TURNOVER MODEL

Panel A: OLS Regression Results for Dependent Variable ITDiff1

***Model F:* 3.59**	*Model P-value:* 0.0071		*Adj. R²:* .1800			
Predicted Sign:		+	+	+/-	+/-	+/-
	Intercept	**Imp**	**Scale**	**Product**	**Vendor**	**TA**
Coefficient	-1.0103	1.1023	1.2261	0.3342	-1.1236	-0.0074
T-Statistic	-1.19	1.29	2.72	0.77	-2.71	-0.07
P-value	.238	.100	.004	.442	.009	.946

Panel B: OLS Regression results for Dependent Variable ITDiff2

Model F: 2.55	*Model P-value:* 0.0381		*Adj. R²:* .1163			
Predicted Sign:		+	+	+/-	+/-	+/-
	Intercept	**Imp**	**Scale**	**Product**	**Vendor**	**TA**
Coefficient	-1.4565	-0.4415	1.3495	0.7115	-0.5326	0.1312
T-Statistic	-1.66	-0.50	2.89	1.59	-1.24	1.16
P-value	0.103	.310	.003	.117	.219	.251

Panel C: OLS Regression results for Dependent Variable ITDiff3

Model F: 1.40	*Model P-value:* 0.2398		*Adj. R²:* .0326			
Predicted Sign:		+	+	+/-	+/-	+/-
	Intercept	**Imp**	**Scale**	**Product**	**Vendor**	**TA**
Coefficient	-.4394	-.3533	.9113	1.4796	-.6419	.0429
T-Statistic	-0.29	-0.23	1.14	1.93	-0.87	0.22
P-value	.772	.401	.131	.059	.387	.826

With respect to the AISDiff model years, the model capturing the difference in average inventory to sales from t-1 to t+1 is not significant. However, the model is significant for the t-1 to t+2 period, with an adjusted R^2 of .228. While the implementation variable is not significant, indicating that implementation alone does not impact the difference in the metric across the time periods, the scale variable is significant at p=.0046 with the expected sign, indicating that the scale of the implementation does impacts changes in inventory levels. For the t-1 to t+3 model year, the model is also significant (F=2.89, p=.0221) with the scale variable again proving significant at p=.0484. In both years, the product variable and the total assets variable are also significant at p<.05. Firms implementing SCM software across the entire firm have lower inventory as a percent of sales relative to their pre-implementation levels both two years and three years after the implementation than firms undertaking partial implementations or not implementing at all. Thus, the data support the notion that firm-wide implementers show observable benefits with respect to their inventory levels within two years and through three years following implementation of SCM software.[9] The results also suggest that larger firms and firms implementing a wider range of products showed greater improvement in inventory levels. The vendor variable was not significant in any of the AISDiff model years.

With respect to ITDiff, the first two model years prove significant, with adjusted R^2s of .18 and .116 for the t-1 through t+1 and t-1 through t+2 periods, respectively. See Table 6 below. In neither model does the implementer variable prove significant, but again, the scale variable is significant across both post-implementation years at p=.004 and p=.003, respectively. In the first year following implementation, the vendor variable is significant at the p< .01 level, while in the second year model, the vendor variable is not significant. The sign on the vendor variable in both years is negative, suggesting that firms implementing i2 Technologies or Manugistics software had less improvement in inventory turns than other firms in the first year following implementation. This result is consistent with the notion that the larger vendors have larger customers with more complicated and difficult implementations, which in turn affects the ability to see improvements in inventory turn metrics in the first year following implementation. The year t-1 through t+3 model year did not prove significant.[10]

The empirical analysis confirms the results of our analytical model and numerical experiment. We find no support for the notion that SCM software implementation without regard to the scale of the implementation leads to improved inventory metrics. We do find support, however, for our hypothesis that full-scale implementation leads to improved inventory metrics. After controlling for firm size, the scope of products purchased, implementation, and the vendor, we find that firms implementing SCM software firm-wide had lower inventory levels relative to sales than other firms did within two years of implementing the software, and also had higher inventory turns both one, and two, years following implementation. The results are consistent with the notion that firm-wide implementation of SCM software leads to greater coordination of activities and information across the firm and its supply chain, making available a higher quality of firm-wide information. The improved information flow and ability to coordinate activities allows the firm to optimize inventory system-wide, rather than optimize for a particular operating unit, which leads to improved inventory metrics. Partial implementations, while perhaps optimizing a particular unit's inventory, are less likely to lead to system-wide optimization, and thus fail to generate, or perhaps, are slower to generate observable effects on inventory metrics.

CONCLUSION

The results of our model, numerical experiment, and empirical analysis all suggest that in order to realize operational benefits leading to system-wide optimization of inventory, firms need to implement SCM software across the entire firm. Partial implementations – implementing SCM software across only a portion of the firm – may lead to a particular unit or segment optimizing its own inventory, but does not accomplish the objective of system-wide inventory optimization. System-wide inventory optimization, in turn, leads to observable financial statement effects.

The numerical experiment suggests that optimizing inventory system-wide can lead to reduction in average inventory of as much as 19%, and averages 8.6%. Cost savings associated with firm-wide implementation over partial implementation averages 2.3%, and can be as high as 4.9%.

In addition, our small-sample statistical results provide some empirical evidence that the scale of the implementation affects future inventory levels and turns as suggested by the inventory model and numerical

[9] We also ran the model without non-implementer observations and dropped the implementation indicator variable. This regression model only tested differences in pre- and post-implementation inventory levels for implementing firms. The results were relatively similar. The scale variable had the anticipated sign and was significant at p = .025 or better all three years, although the year t+1 model was not significant at any conventional level of significance, and the year t+3 model was significant at p < .08, but not at .05. The year t+2 model was significant at p =.04 with an adjusted R^2 of .193, and both product and total assets were also significant. In order to examine the relationship between scale and size further, we also ran the models with an interaction term between scale and total assets. The interaction was not significant in any year.

[10] Results of regressions dropping implementing firm observations and the implementation variable again were similar to the results as disclosed in Table 6. The models were significant for the first two years at p<.03, and the scale variable was significant at p<.004 with the anticipated sign in both years. The model year t-1 through t+3 was not significant. We also tested the model by including an interaction term between scale and total assets. The interaction did not show significance in any of the models we tested.

experiment. Firms implementing SCM software firm-wide had significantly lower inventory levels relative to revenue within two years, and through three years, following implementation. Full-scale implementers also improved inventory turns both one and two years following implementation. Neither the inventory-to-sales model, nor the inventory turns model was significant for all three years following implementation, but between the two models, the scale of implementation demonstrated an impact on some facet of firm-wide inventory control and optimization for all three years. Full-scale implementation was associated with an increase in inventory turnover in the first and second year following implementation relative to pre-implementation turns, and was also associated with a decrease in inventory levels relative to pre-implementation levels in the second and third year after implementation. Implementation alone did not provide any explanatory power to our models, but the scale of the implementation did.

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ABOUT THE AUTHORS

Alan I. Blankley (Ph.D. Texas A&M University) is currently an Associate Professor of Accounting in the Belk College of Business at University of North Carolina at Charlotte where he teaches in the areas of financial accounting and accounting information systems. Prior to joining the faculty at UNCC, he taught accounting at Miami University (Ohio) and Western Michigan University. He has worked as a consultant for Hewlett-Packard, Wachovia Bank, and Mercari Technologies. He has also worked for Bentonville Associates Ventures, a consulting firm specializing in both supply chain consulting and retail merchandising.

Moutaz Khouja (Ph.D. Kent State University) is a Professor of Operations Management in the Belk College of Business Administration at the University of North Carolina at Charlotte. He Received his PhD in Operations Management. His publications have appeared in many leading journals including *Decision Sciences*, *Database, IIE Transactions*, *European Journal of Operational Research*, *International Journal of Production Research*, *International Journal of Production Economics*, *Journal of the Operational Research Society*, and *OMEGA*.

Casper E. Wiggins, Jr. (D.B.A. University of Tennessee) is the Associate Dean for Graduate Programs and Research and Interim Director of the MBA Program at the University of North Carolina at Charlotte. He joined the Charlotte faculty in 1999 as the Big Five Distinguished Professor of Accounting and is a former Chair of the Department. Dr. Wiggins previously served on the accounting faculty at Texas A&M University for seventeen years. His primary teaching and research areas are in accounting information systems. Specific areas of interest include controls, risk and security issues. Dr. Wiggins has published over 35 academic and professional articles and is a past co-editor of the *Journal of Information Systems.* He has served numerous roles in the American Accounting Association including chairperson of the Information Systems Section. He is a Texas CPA and has been active in the Texas Society of CPAs at both the local and state levels. Dr. Wiggins received a BA from Wofford College, MBA from the University of Georgia, and a MS from Clemson University.

175 **"A Global Supply Chain Profit Maximization and Transfer Pricing Model"**
Tan Miller and Renato de Matta

In environments where tax rates in local regions do not represent major decision factors, a cost minimization methodology, which represents the most common optimization modeling approach for integrated manufacturing and distribution planning, can help formulate an effective integrated plan. However, when planning flexibility or alternatives exist because of differing local country tax rates and types and intra-company transfer pricing options, cost minimization methodologies may inaccurately identify profit-maximizing global production and distribution plans. Instead, a profit maximization model that explicitly evaluates decisions such as where to incur tax liabilities and how to set intra-company prices may be required to develop an integrated global manufacturing and distribution plan. In this paper, we discuss and formulate a model that yields profit maximizing global production and distribution plans. We discuss the managerial implications of our results, and the potential applications and benefits of the model.

Key Words: Capacity management; Global supply chain; Heuristics; Production and distribution; Production planning; Transfer pricing

201 **"An Investigation into the Effect of Full-scale Supply Chain Management Software Adoptions on Inventory Balances and Turns"**
Alan I. Blankley, Moutaz Khouja, and Casper E. Wiggins

Supply chain management (SCM) software vendors, analysts, and others claim that firms implementing SCM software stand to benefit by being able to reduce inventory holdings and increase inventory turns. We theorize that full-scale implementations lead to system-wide inventory optimization, which in turn leads to cost improvement associated with inventory balances and turns. To examine the question, we develop an analytical model of inventory optimization, then analyze the effects of the model with a numerical experiment, and finally confirm the results with an empirical examination.

We find that firm-wide implementation is significant in explaining improvement in inventory metrics, relative to pre-implementation metrics for our sample. Our empirical tests indicate that implementing SCM software across only a portion of the firm does not impact inventory metrics, but that the scale of implementation does. More precisely, we find that firms implementing SCM software across the entire company significantly improve both inventory turns and inventory as a percent of revenue relative to partially-implementing firms and non-implementers.

Key Words: Inventory turns; Optimization; Software; Supply chain management

225 **"An Investigation of the Value of Cross-docking for Supply Chain Management"**
Michael R. Galbreth, James A. Hill, and Sean Handley

Cross-docking is the practice of transferring materials from an incoming shipment directly to an outgoing shipment without storing them at the transfer point. This essentially eliminates the inventory-holding function of a warehouse and can reduce supply chain costs. We investigate the value of one type of cross-docking in a variety of supply chain environments.

Key Words: Cross-docking; Supply chain management; Transportation