Supply Chain Learning and Spillovers in Vendor Managed Inventory

Yuliang Yao a,1, Yan Dong b, and Martin Dresner c

a Lehigh University, b University of Minnesota, c University of Maryland

1. Introduction

In recent years, supply chain technologies and processes (vendor managed inventory (VMI), continuous replenishment (CR), electronic data interchange (EDI), etc.) have become strategic imperatives for firms in increasingly competitive industries (Williams and Frolick 2001). Extensive research has examined the performance outcomes from these supply chain initiatives. For example, it has been well documented that EDI reduces transaction costs and errors (e.g., Wang and Seidmann 1995, Srinivasan et al. 1994, Riggins and Mukhopadhyay 1994), and that VMI and similar programs reduce inventory and stockouts (e.g., Lee et al. 1999; Raghunathan and Yeh 2001; Cetinkaya and Lee 2000; Cheung and Lee 2002; Iyer and Bergen 1997; Fry et al. 2001). On the other hand, Clark and Hammond (1997) and Cachon and Fisher (1997) caution that performance benefits attributed to VMI at the Campbell Soup Company may have been achieved merely through information sharing. Moreover, anecdotal evidence has shown that the implementation of the supply chain initiatives often falls apart. For example, after experimenting with VMI programs for twelve months with its vendors, Spartan Stores, a Michigan co-op, terminated this program, citing planning inefficiency by the vendors and increased costs (KPMG Report 1996).

The mixed outcomes may, in part, be attributed to the complexity of the programs that involve not only multiple departments within an organization, but also multiple firms within a supply chain. Furthermore, since these initiatives are usually implemented over a prolonged period, the ability to adapt to and learn from implementation experience may be essential to the success of the programs. An important issue — the learning process during the implementation — has been largely ignored in the discussion of supply chain technologies.

A large body of research has examined organizational learning. The fields of economics, operations, technology management, have all contributed to our understanding of an organization’s learning capability. The research generally agrees that organizations are capable of creating, retaining, and transferring knowledge (e.g., Argote 1999; Argote et al. 2003). Knowledge (learning) spillovers, either within an organization or across organizations, are thought to be a source of productivity growth (e.g., Thornton and Thompson 2001). However, fundamental questions arise when the learning uses technologies that involve supply chain collaborations. For example, do supply chain partners transfer knowledge between firms? Do knowledge transfers between firms add significantly to the ability of firms to learn?

In this paper, we treat firms as “learning” objects that wish to increase their understanding of supply chain technologies in order to improve performance. We examine three stocks of knowledge learned from different sources — (1) A firm’s own experience with a particular technology; (2) A firm’s own experience with another technology; and (3) A supply chain partner’s experience with a technology — and compare how each stock of knowledge contributes to performance improvements. In particular, we study the learning process and spillovers from the implementation of VMI between a manufacturer and its distributors. We also examine the learning spillover effect from the previous implementation of EDI. Our primary

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1 Coresponding Author. 621 Taylor Street, Bethlehem, PA 18015. Email: yuy3@lehigh.edu, Tel: (610) 758-6726.
finding is that all three stocks of knowledge have a positive and significant impact on a distributor’s performance, as measured by inventory levels and total stockouts. Surprisingly, the knowledge spillover from the manufacturer has a much stronger impact than the two stocks of knowledge internal to the distributors. This research also uncovers a possible scenario in which knowledge spillovers from previous technology programs are “forgotten” over time.

2. Research Methodology

Item and firm level data were collected from a third party information services provider of EDI and VMI technologies and services. The services are purchased by manufacturers and used to facilitate information sharing and inventory management with their distributors. Many firms start first with EDI and subsequently implement VMI. With EDI enabled information sharing, distributors share their inventory status, demand figures, and sales information with a manufacturer through a standard EDI protocol, UCS 852. In addition, with VMI, the manufacturer decides the timing and the quantity of inventory replenishments.

A stratified random sample was selected of twenty distributors in the electronic component industry, all served by the same manufacturer. The sample was stratified so that ten of the distributors had been using VMI for more than a year at the time the data were collected, while ten distributors had been using VMI for less than a year. Twenty items that were carried by all of the sampled distributors were randomly selected. Weekly data for the most recent 52 weeks of available data (the week of April 28, 2002 to the week of April 20, 2003) were collected on distributor inventory levels, stockouts at the distributors, item prices, and distributor weekly sales. As well, firm level data on the chosen distributors were also collected, including annual sales in dollars and the date in which VMI was implemented.

Our econometric model is drawn from the standard tradeoffs in the inventory theory. While an inventory system’s performance can be measured by inventory levels, firm performance is also subject to the product availability the system provides. Therefore, to capture the overall performance of inventory systems, both inventory levels and product availability are considered (Lee et al. 1999; Clark and Hammond 1997). Due to the endogeneity between inventory levels and total stockouts, we use a two stage least square (2SLS) estimation approach. Two models are used to estimate each equation. The first model has only linear terms for the three types of learning experiences, while the second model adds squared terms for the learning experiences to allow for flexibly for within-period returns to scale (Benkard 2000; Argote et al. 1990; and Thornton and Thompson 2001). Therefore, we can specify our models as follows:

**Model 1:**

\[
INV = \beta_0 + \beta_1 TS + \beta_2 E_1 + \beta_3 E_2 + \beta_4 E_3 + \beta_5 sales + \beta_6 size + \beta_7 week
\]

\[
TS = \gamma_0 + \gamma_1 INV + \gamma_2 E_1 + \gamma_3 E_2 + \gamma_4 E_3 + \gamma_5 sales + \gamma_6 price + \gamma_7 week
\]

**Model 2:**

\[
INV = \beta_0 + \beta_1 TS + \beta_2 E_1 + \beta_3 E_2 + \beta_4 E_3 + \beta_5 (E_1)^2 + \beta_6 (E_2)^2 + \beta_7 (E_3)^2 + \beta_8 sales + \beta_9 size + \beta_{10} week
\]

\[
TS = \gamma_0 + \gamma_1 INV + \gamma_2 E_1 + \gamma_3 E_2 + \gamma_4 E_3 + \gamma_5 (E_1)^2 + \gamma_6 (E_2)^2 + \gamma_7 (E_3)^2 + \gamma_8 sales + \gamma_9 price + \gamma_{10} week
\]

where:
- Total Stockouts (TS) is the counted days of stockouts for an item managed during a week.
- Inventory Level (INV) is the average on-hand dollar quantity for an item during a week.
VMI Learning ($E_1$) is the logged accumulated days that VMI has been implemented for a distributor.

Learning Spillover from EDI to VMI ($E_2$) is the logged differences in days from when EDI was implemented to when VMI was implemented.

Learning Spillover from Manufacturer to Distributor ($E_3$) is the logged total accumulative days of VMI conducted by the manufacturer with distributors, excluding the focal distributor.

Weekly Sales (SALES) is the total quantity sold for an item at a distributor during a week.

Item Price (PRICE) is the purchasing price for an item at a distributor.

Annual Sales (SIZE) is the logged dollar amount of annual sales for a distributor.

Calendar Week (WEEK) is a variable created to control for the effects of technological developments over time.

$\beta$ and $\gamma$ are parameters to be estimated.

4. Preliminary Results and Discussion

Figure 1 plots the source of the distributor’s performance improvements by using the regression estimates from Model 2. These charts show that, on average, inventory levels and total stockouts decrease as the stocks of learned knowledge increase, although, the decreases may come only after initial increases in inventory and stockouts. For example, inventory (Figure 1a) and total stockouts (Figure 1b) increase as the distributor’s self-learning increases, before decreasing rapidly. Thus there may be a “breaking-in” or adjustment period before a firm benefits fully from the technology.

The distributor’s learning from previously implemented EDI programs is associated with lower inventory levels (figure 1c) and reduced total stockouts (figure 1d) initially, but inventory and stockout levels become flat over time. On the other hand, the distributor’s learning from the manufacturer consistently reduces inventory levels (figure 1e) and total stockouts (figure 1f) over time, indicating supply chain knowledge spillovers have a strong and positive effect on improving performance through the implementation of VMI.

In the theoretical literature, knowledge spillovers across organizations have been well recognized as a major source of performance improvement or productivity growth (Levitt and March 1988). A number of previous empirical studies have also found evidence of sizeable spillovers (e.g., Thornton and Thompson 2001; Argote et al. 1990; Irwin and Klenow 1994). But most of these spillovers have been horizontal spillovers; i.e. spillovers among competitors. Our research finds that vertical knowledge spillovers can also be significant.

The magnitude of the cross program knowledge spillovers is estimated to be similar to those arising from the distributor’s self-learning of VMI. We do find that the value of knowledge spillovers from EDI programs tends to diminish over time, suggesting an organizational “forgetting” when the knowledge is no longer relevant (Argote et al. 1990; Benkard 2000).

Finally, the paper provides possible implications for practitioners. First, our results suggest that firms may not realize the benefits from VMI until some time after the program has been implemented. Second, firms may benefit most from learning spillovers from previous technology implementations if the same employees are involved in new program implementations. Third, a firm may want to minimize wait time between the implementation of two technology programs to facilitate learning spillovers. Finally, firms strategically may want to choose supply chain partners who have experience with a technology that is to be implemented.
Our findings suggest implementing the program with an experienced partner (who has implemented similar programs with other firms) helps to improve performance.

References
Figure 1: Learning and Spillovers (Regression Estimates)

**Figure 1a**

Inventory vs. Stockouts

**VMI Self Learning (E₁)**

Parameters:
- Intercept: 203.372
- Slope: -18.1253

**Figure 1b**

Inventory vs. Stockouts

**VMI Self Learning (E₁)**

Parameters:
- Intercept: 0
- Slope: 7.6587

**Figure 1c**

Inventory vs. Stockouts

**Learning Spillover from EDI to VMI (E₂)**

Parameters:
- Intercept: 241.051
- Slope: 6.98286

**Figure 1d**

Inventory vs. Stockouts

**Learning Spillover from EDI to VMI (E₂)**

Parameters:
- Intercept: 0
- Slope: 4.7185

**Figure 1e**

Inventory vs. Stockouts

**Learning Spillover from Manufacturer to Distributor (E₃)**

Parameters:
- Intercept: 469.576
- Slope: 8.91543

**Figure 1f**

Inventory vs. Stockouts

**Learning Spillover from Manufacturer to Distributor (E₃)**

Parameters:
- Intercept: 0
- Slope: 8.91543