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Learning curves in collaborative planning, forecasting, and replenishment (CPFR) information systems: An empirical analysis from a mobile phone manufacturer

Yuliang Yao[a], Rajiv Kohli[b,*], Susan A. Sherer[a], Jerold Cederlund[c]

[a] College of Business & Economics, Lehigh University, Bethlehem, PA, United States
[b] Mason School of Business, College of William & Mary, Williamsburg, VA, United States
[c] ARRIS, Suwanee, GA, United States

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ABSTRACT

While Collaborative Planning, Forecasting, and Replenishment (CPFR) information systems have been increasingly deployed to improve supply chain operations in a cross section of industries, the extant literature has largely overlooked the learning effects within organizations, thereby resulting in incomplete assessment of their business value. Using an operational-level panel data for nine product lines over 2.5 years, we empirically examine the learning curves in CPFR between Motorola, a mobile phone manufacturer, and one of its U.S.-based national retail partners. We found that the two key components of CPFR, collaborative forecasting (CF) and collaborative replenishment (CR), exhibit distinct learning curves. Forecast accuracy improves immediately following CPFR implementation but the rate of improvement slows over time, whereas inventory levels increase at first and begin decreasing after a period. Further, we found different learning effects in terms of inventory levels when products are later replaced with new form factors. Product replacements have lower inventory levels than their antecedents, at least for low-end products. We discuss important implications for theory and practice at the interface of information systems and operations management.

1. Introduction

Collaborative Planning, Forecasting, and Replenishment (CPFR), based upon supply chain collaboration standards established by the Voluntary Interindustry Commerce Solutions (VICS) Association, are information systems that enable partnering firms to integrate their inventory planning, forecasting and replenishment processes by sharing information, developing joint forecasts and jointly crafting replenishment plans. Since 1998, when VICS first adopted a set of standards for CPFR information systems, more than 300 companies have engaged in CPFR practices leading to substantial benefits to suppliers, such as Procter and Gamble and Kimberly-Clark and retail chains, such as Wal-Mart and Best Buy (VICS, 2007). Although conceptually simple, CPFR implementations are complex in practice as they require exchange of large amounts of data for forecasting a wide range of products. They must account for varying promotional activities, involve multiple functional areas from multiple firms, take an extended period of time to implement, and integrate possibly incompatible business processes between CPFR partners (Doiron, 2004). Despite the benefits reported for information sharing in supply chains (Im and Rai, 2008; Klein and Rai 2009; Patnayakuni et al., 2006), some firms have questioned the benefits of CPFR and even firms that embrace CPFR often limit the scale of CFPR implementation, primarily due to the inability to assess its benefits (Aviv, 2002).

Although the literature on CPFR has been growing, most previous CPFR studies have been design focused (e.g., Wang et al., 2010; Chen et al., 2009) or analytical (e.g., Fu et al., 2010; Aviv, 2002) and few studies provide empirical validation of the analytical results, thus limiting our understanding of the payoff from this emerging information system (IS). Empirical validation is important in that it provides deeper understanding of the phenomenon by linking theory with real-world cases (Fisher, 2007). In addition, little research has examined products in a dynamic business environment characterized by constant new product launches coupled with rapidly changing customer demand where accurate forecasting is critical to business performance.

Sanders (2008) compared studies of seller–buyer relationships and concluded that operations management has focused upon the impact of IT (e.g., CPFR) in specific contexts while the information systems (IS) discipline has generally focused on actual use of the IT. She concluded that little attention had been given

* Corresponding author.
E-mail address: rajiv.kohli@mason.wm.edu (R. Kohli).

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to the benefits accrued to suppliers from the use of these technologies for their operations. Although a number of papers have studied IT enabled inter-firm collaboration (e.g., Mukhopadhyay et al., 1995; Mukhopadhyay and Kekre, 2002; Patnayakuni et al., 2006), most of them examined the business value or antecedents of such collaboration. Few papers have approached the issue from a learning theory perspective. For example, Im and Rai (2008) examined learning in knowledge sharing in supply chains and found that both exploratory and exploitative knowledge sharing lead to relationship performance gains, enabled by the ambidextrous management of the relationship and ontological commitment. Hult et al. (2003) had earlier established organizational learning as a strategic resource and found learning to have had a positive impact on cycle time and overall firm performance. We address these gaps by empirically examining the benefits of learning from CPFR for products in a dynamic business environment (i.e., mobile phones) through a theoretical lens of organizational learning.

The organizational learning framework has been widely used as a theoretical foundation in economics, strategy and operations management. For example, it has been used to explain learning curves in manufacturing (Argote and Epple, 1990; Smunt and Watts, 2003; Li and Rajagopalan, 1997) and learning spillovers (Baum and Ingram, 1998). However, it has seldom been applied to empirically analyze the learning curve in supply chain collaboration programs. Doing so will help us understand the course through which these programs improve performance.

We examine a CPFR implementation for a number of products between Motorola, Inc. and one of its key U.S. retail customers. As a leading manufacturer of mobile devices, Motorola offers various models of cell phones that have a life cycle averaging little more than a year, sometimes as low as six months, making accurate forecasting a critical yet complex requirement. Using operational-level supply chain panel data for nine mobile phone products that utilized CPFR spanning over 30 months, we evaluate organizational learning curves emerging from CPFR implementation, as well as CPFR learning spillovers between products. Consistent with previous works that modeled two key components of CPFR, namely collaborative forecasting (CF) and collaborative replenishment (CR) (Aviv, 2001, 2002), we examine the learning curves for CF and CR respectively in our analysis. We use two performance metrics – *forecast error* for CF and *inventory level* for CR – in examining how the business value of CPFR is realized through learning that occurs during a product's life cycle as well as through spillover between products. The key objective of this research is to examine the CPFR post-implementation learning pattern and to address (i) whether the learning curve is non-linear on forecast error and inventory, and (ii) whether the learning curve varies based on the sequence of product launch.

The two key findings of this study are: (i) forecast error and inventory levels exhibit distinct learning curves over time—forecast error declines immediately following CPFR implementation but the rate of improvement slows over time, whereas inventory levels increase at first and begin decreasing; and (ii) products launched earlier exhibit different learning curves than products launched later; that is, replacement products have lower inventory levels than their antecedents, at least for low-end products. Our findings lend support to some of the analytical results in prior literature (e.g., Aviv, 2001, 2002) that CPFR may lead to performance improvement in terms of forecast and inventory management. Additionally, our findings complement previous research by demonstrating that the learning curves through which the performance benefits are realized are non-linear and, more interestingly, the learning curves for CF and CR exhibit different patterns. Our estimates show that the inventory level may increase for a period of time before it starts decreasing. Failure to recognize such learning curve patterns may lead organizations to draw premature and flawed conclusions about the value of CPFR.

The paper is structured as follows. In Section 2, we review the literature on previous studies in supply chain collaboration in both the operations management (OM) and information systems (IS) literatures, as well as research on CPFR and organizational learning theory. In Section 3, we develop a model and four hypotheses about the learning curve of CPFR. In Section 4, we describe our data and research setting, develop an econometric model, and in Section 5 we report the results of our analysis. In Section 6, we discuss our findings and implications for theory and for practice. In Section 6, we present our contribution, limitations of the study and areas for future research. Finally, in Section 8 we present our conclusions.

2. Prior literature and theory

2.1. Collaborative planning, forecasting, and replenishment

Previous research in OM and IS literatures has accumulated a significant body of knowledge pertaining to the benefits of information sharing in supply chains as well as the benefits of information technology (IT) enabled coordination information systems[1]. Several empirical studies compare performance pre- and post-information sharing and collaboration. For example, Clark and Hammond (1997) utilized grocery products supply chain data to study information sharing and continuous replenishment program (CRP) implementations and operations. They reported a 50–100% increase in inventory turns (i.e., number of times inventory is sold and replaced) but found that information sharing alone without CRP does not significantly improve performance. Cachon and Fisher (1997) researched the benefits from information sharing and CRP to the Campbell Soup Company in terms of inventory reductions, and concluded that these benefits were achieved primarily through information sharing. Several studies have considered factors that impact benefits from IT enabled collaboration. Klein and Rai (2009) found that both trust and buyer IT customization are important antecedents to benefits. Im and Rai (2008) found that knowledge sharing leads to benefits but is enabled by management and IT design, in particular, contextual ambidexterity, defined as the behavioral capacity of a long-term relationship to allow for the simultaneous pursuit of alignment and adaptability, and ontological commitment, defined as the reliance of partnering firms on digital boundary objects to span their knowledge boundaries.

Most of the research on benefits from CPFR has used a modeling approach. Aviv (2002) modeled how the ability of partners to observe market signals can improve forecasting performance and concluded that the success of CPFR implementation depends on the uniqueness of forecasting capabilities of partners. In a later work, Aviv (2007) concluded that the benefits of collaboration vary depending upon the partners' ability to anticipate demand and suggested that supply chain partners must agree upon a reference demand model that both parties can collectively observe. Raghunathan (1999) modeled the impact of retailers' choosing to participate in CPFR and found a greater decrease in manufacturer's costs when a second independent noncompeting retailer participates compared to when only one retailer participates, while the nonparticipating retailer's costs increase. While firms benefit from CPFR, sharing of inventory and demand data can expose them to unwanted risks, such as leaks of confidential information to competitors. Unless firms are convinced of sustained and long-term benefits from collaboration, the prospect of investments and risks

[1] For a review, please see Sahin and Robinson (2002) and Patnayakuni et al. (2006).