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The value of lead time reduction and stabilization: A comparison between traditional and collaborative supply chains

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ABSTRACT

This work quantifies the financial impact of the mean and the variability of production and shipping lead times on multi-echelon supply chains. We combine agent-based modelling and Taguchi methods, through which we develop a framework for supporting entrepreneurial investment decisions. A throughput-based analysis reveals that decreasing mean lead times improves the internal operation of production and distribution systems, while reducing lead time variability enhances the satisfaction of consumers. In this regard, we contrast traditional and collaborative supply chains. We find that the latter are not only more profitable than the former, but also more robust to variations in lead times.

1. Introduction

The increased competition of the current business environment has encouraged managers to seek for areas to focus on so that firm profitability improves. This situation has increased the attention on two different but interrelated fields: lead time improvement, that is, reduction and stabilization (Chaharsooghi and Heydari, 2010); and the conceptual approach to supply chain management, namely, holism versus reductionism (Ponte et al., 2016).

On the one hand, lead times greatly affect the production and ordering decisions made by all types of firms. It interacts with other sources of inefficiencies in supply chains, such as the variability of consumer demand, and managing inventories becomes much more complex. Larger and highly variable lead times entail dealing with a greater degree of uncertainty. In this sense, the performance of supply chains may dramatically suffer both from an internal (operational) and an external (customer-focused) perspective (de Treville et al., 2004).

Accordingly, the harmful impact of lead times on production and distribution systems is widely recognized by practitioners and academics (Heydari et al., 2016). Despite this, managers usually underestimate the overall costs arising from lead time, which makes them underinvest in lead time improvement. De Treville et al. (2014) concluded that this occurs because managers struggle to quantify the actual financial impact of lead times—which greatly obstructs decision making in this field. This view justifies the need for investigating the true impact of lead times on the financial performance of supply chains.

On the other hand, a premium has been placed on collaboration as a key source of competitive advantages for supply chains. Holistic approaches to supply chain management, which are built on collaboration, are based on analyzing and optimizing the system

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in its entirety, unlike traditional reductionist solutions, in which the overall behavior of the supply chain emerges as the interaction of the local strategies of its members (Simatupang and Sridharan, 2005).

Given the integrated nature of supply chains, collaborative solutions have widely shown to outperform traditional systems (e.g. Disney and Towill, 2003; Kollberg et al., 2006; Costas et al., 2015; Gunasekaran et al., 2017). Both integrative practices and methodologies, like the Vendor Managed Inventory (Çetinkaya and Lee, 2000) and Collaborative Planning, Forecasting and Replenishment (Holmström et al., 2002), and holistic management philosophies, such as Lean production (Womack and Jones, 1996) and the Theory of Constraints (Goldratt, 1990), have proven to be effective in dealing with common supply chain issues.

In this sense, it is vastly accepted that collaborative approaches play a crucial role in improving overall performance. However, they are far from being widespread in practice (Holweg et al., 2005). Sociological and structural resistors tend to undermine the cooperative behavior and opportunistic attitudes commonly arise, which leads supply chain collaboration to failure (Fawcett et al., 2015). This underscores the need for further exploring the dynamics of these systems.

In this context, the general objective of this research article is to contrast the financial consequences of lead times in traditional and collaborative supply chains. We intend to contribute to the understanding of how lead times affect the internal operation and customer satisfaction of these two opposite archetypes of multi-echelon systems. From this perspective, we aim to craft a framework for supporting business decisions in the area of lead time investment.

1.1. Literature review and motivation: the impact of lead times on supply chains

Several studies have shown how lead times, both in mean and in variability, threaten the efficiency of supply chains. After reviewing the literature, Bandaly et al. (2016) noted that these papers can be divided into two main lines of research according to the metrics they examine. The first line focuses on the internal, or operational, performance of the supply chain, while the second one focuses on its external performance, which relates to the customer service level (CSL).

The internal analysis is commonly carried out from the viewpoint of the Bullwhip Effect (Wang and Disney, 2016)—a dynamic phenomenon which amplifies the variability of orders throughput the supply chain; hence creating a climate of instability and being a major source of economic losses in all kinds of industries (e.g. Fransoo and Wouters, 2000; Geary et al., 2006; Ponte et al., 2015). Lee et al. (1997) discussed that lead times were one of the main contributors to this phenomenon. From this perspective, several works showed that the longer the mean lead time, the stronger the Bullwhip Effect (Chen et al., 2000; Agrawal et al., 2009; Hosoda et al., 2015). Other studies demonstrated that the variability in lead times also increases dramatically the Bullwhip Effect (Chatfield et al., 2004; Kim et al., 2006; Wang and Disney, 2017). Interestingly, the Bullwhip problem simultaneously leads to an increase in the lead time variability, which may result in a damaging 'vicious circle' (So and Zheng, 2003).

The impact of lead times on the external performance of supply chains has often been analyzed through the balance between customer satisfaction and safety stock required. For instance, Kelepouris et al. (2008) demonstrated that an increase in mean lead times tends to result in a decreased customer satisfaction—thus, more safety stock is required to achieve a target CSL. This positive relationship between the lead time and the safety stock can also be observed in classic safety stock models, e.g. Chen et al. (2000). Meanwhile, Simchi-Levi and Zhao (2005) concluded that sum of holding and stock-out costs dramatically increases as the variability of lead times grows. The benefits in inventories derived from using facilities with low variance of lead times can also be seen in Wanke and Saliby (2009).

In this regard, the literature includes some intriguing findings, such as those by Song (1994), who showed that stochastically larger lead times do not always lead to higher optimal average costs. Chopra et al. (2004) confirmed these results by observing a lead time paradox, according to which less variable lead times may increase the safety stock needed. They showed that this paradox emerges for relatively low target service levels, i.e. below 70%. Tyworth and Saldanha (2014) put into perspective this interesting paradox by demonstrating that reducing the variability in lead times consistently increases the savings in the inventory system. Song et al. (2010) also observed that less variable lead times always reduce the optimal cost.

From this perspective, some authors have considered a dilemma between the two dimensions of lead times: the mean versus the variance. They have explored which one damages more the performance of supply chains. Understanding how differently they impact on performance would enable managers to select between different investment strategies in the lead time field (Christensen et al., 2007; Chaharsooghi and Heydari, 2010). In this regard, we have conflictive prescriptions regarding the appropriate lever to improve supply chain performance. For example, Chopra et al. (2004) concluded that reducing inventories need decreasing the mean rather than the variability of lead times in a reorder point model; while He et al. (2005) showed that the variance, but not the mean, affects significantly the total cost of an EOQ model with backlogging. After analyzing surveys from 210 firms, Christensen et al. (2007) concluded that the financial result of firms is very sensitive to lead time variability, while the mean has no direct impact. The results by Chaharsooghi and Heydari (2010) in a four-echelon system revealed that the variance of lead times has a stronger impact on performance metrics. Nevertheless, Bandaly et al. (2016) studied the beer industry through a simulation-based optimization model and found that lead time variability does not deteriorate the performance of the supply chain under certain scenarios.

Due to the complexity of the mathematical analysis, most previous studies explore a single echelon of the supply chain. In this sense, the impact of lead times on supply chain performance has been barely investigated in multi-echelon systems—relevant exceptions are Chaharsooghi and Heydari (2010) and Bandaly et al. (2016). The single-echelon studies provide us with relevant insights on the consequences of lead times, but may ignore some real-world effects emerging from the interaction of the supply chain echelons. Note that the single-echelon approach leads to the fact that the lead time is generally treated as a single variable. Leng and Parlar (2009) stated that this may result in unrealistic solutions as in practice lead times involve several components, such as production and shipping lead times. Suri (1998) showed that many firms can reduce lead times in all phases of their supply chains.