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Game Analysis of Product Supply Chain Considering Lead Time Compression and Demand Forecast Information Updating

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Abstract

In a supplier-led decentralized decision-making second-level supply chain, consideration can compress lead times and update demand forecast information. This paper discusses the order volume decision of the retailer and the lead time and wholesale price decision of the supplier, analyzes the interaction between the retailer and the supplier's decision and the influence of the cost of lead time reduction on the retailer and the supplier's decision. The results show that the optimal order quantity of retailers is low in equilibrium, which leads to the service level of supply chain is less than 50% and the lead time of supply chain is too long. Encouraging retailers to increase order quantity is the key to improve supply chain service level and reduce supply chain lead time. Reducing the lead time and reducing the cost can not only enable retailers to increase the order quantity, improve the service level of the supply chain to the market demand, but also enable suppliers to reduce the order lead time and improve the response speed of the supply chain to the market demand.

Keywords: Supply chain optimization, Lead time compression, Demand forecast information update, Steinberg game

1. Introduction

Time management is one of the most powerful sources of supply chain competitive advantage. The core of supply chain management strategy based on time competition is lead time compression. Lead time compression can bring synergies to the supply chain to achieve conflicting multi-objective improvement. However, lead time compression cannot guarantee Pareto improvement of supply chain members' returns, and suppliers' profits will decrease under some conditions, which will bring benefit reverse to supply chain members. In the decentralized decision-making supply chain, lead time compression can not be effectively implemented, so it is necessary to study the decision-making process and influencing factors of supply chain members in order to take effective measures to ensure the effective implementation of lead time compression strategy.

At present, most studies on lead time compression focus on the impact of lead time on inventory. Studies show that shortening lead time can reduce safety inventory, reduce inventory capital risk, accelerate customer response, improve customer service level, and enhance enterprise competitiveness. Lead time compression not only affects the inventory level, but also directly affects the accuracy of demand forecasting. The shorter the lead time, the smaller the forecast time span, the more effective information can be obtained, and the smaller the error of demand prediction. According to a survey by Wal-Mart, in the textile and apparel industry, if the goods are shipped 26 weeks before the start of the selling season (that is, based on the forecast 26 weeks in advance), the demand forecast error (out of stock or backlog) is about 40%. If the shipment is made 16 weeks before the start of the season (i.e. based on the forecast 16 weeks in advance), the demand forecast error is about 20%. If purchases are made very close to the start of the season, the forecast error is only about 10%. Therefore, the research on lead time compression needs to consider the impact of demand information update on demand forecasting accuracy. Chen et al., Lu et al., and So et al first analyzed the impact of lead time changes on inventory in a single point inventory system under the assumption of demand information update. For example, Chen et al. assumed that the relationship between demand forecasting and lead time is linear, and the closer the point of sale, the higher the accuracy of prediction. In order to minimize the retailer's cost, Chen et al. studied the optimization of retailer's order quantity and order time point, and pointed out that this modeling idea can be extended to the supply chain environment. In the context of a two-level supply chain consisting of retailers and suppliers, Iyer et al., based on Chen et al. 's research ideas, assumed that demand forecasting adopted Bayes method and could be modified with prior information, analyzed the impact of lead compression on the returns of supply chain members, and proposed measures to improve the Pareto returns of both sides. Lu Qihui et al. proposed a compensation strategy on the basis of Iyer et al., that is, suppliers provide compensation to retailers for unsold goods and realize Pareto improvement of retailers' and suppliers' profits. However, Lu Qihui et al and Iyer et al did not take lead time as a decision variable and did not reveal the impact of lead time compression on the supply chain and its members' earnings. Song Huaming et al. adopted Chen et al.'s hypothesis and took lead time as a system variable to reveal the impact of lead time compression on the supply chain and its members' returns in the secondary supply chain and how to achieve supply chain channel coordination. The results show that with the improvement of service level, the pressure of lead time compression on suppliers is increasing, and suppliers will suffer more and more losses. Tyer, Lu Qihui, Song Huaming et al., from the perspective of supply chain contract design, studied how to promote Pareto improvement of supply chain members' returns through effective contracts in the secondary supply chain with demand information update under the compressed lead time, and made clear the decision-making process and influencing factors of supply chain members conducive to designing more efficient incentive mechanisms.

To sum up, this paper takes lead time as the supplier's decision variable, and the cost of lead time compression is borne by the supplier. In a supplier-dominated decentralized decision-making two-level supply chain, based on the Steinberg game model, this paper discusses the retailer's order volume decision, supplier's lead time and wholesale price decision, and the interaction between supplier and retail decision and the cost of lead time compression Discuss the impact of changes on retailer and supplier decisions.

2. Problem Description

In a decentralized decision-making secondary supply chain consisting of retailers and suppliers, the supplier dominates, leading the retailer to produce and sell a single product. In a single sales cycle, the retailer has only one opportunity to place an order. Retailers hope that suppliers can shorten the order lead time, so as to obtain more adequate information and improve the accuracy of demand forecasting, so as to reduce their own holding costs and out-of-stock costs and obtain greater benefits; On the other hand, suppliers want to extend the order lead time and reduce the extra cost caused by the compression of the lead time, so as to optimize their own profits. Therefore, as a leader, suppliers first determine the optimal wholesale price and order lead time according to their marginal production cost and lead time compression cost to maximize their own benefits; As a follower, the retailer chooses the optimal order quantity according to the wholesale price and order lead time set by the supplier, as well as its own unit carrying cost and out-of-stock cost, in order to maximize the expected revenue.

The time range of the retailer from submitting the order to receiving the goods (that is, the order lead time range of the supply chain) is [0,T], and the time of the retailer submitting the order is 0. If the retailer submits the order not at time 0, but at a certain time point $T-L(0\leq L\leq T)$, the retailer can collect information within [0, t-L] and predict the market demand at time point L to improve the accuracy of demand prediction. In [L,T], the supplier produces to order and delivers, and L is the retailer's order lead time (i.e. the order lead time of the supply chain). It is assumed that with the compression of the lead time, the information collected by retailers is more and more sufficient, and the accuracy of market demand prediction is higher and higher. Let x be the market demand for the product and x be a random variable subject to normal distribution. When the lead time is $L(0\leq L\leq T)$, the density function of x is f(x,L) and the distribution function is f(x,L). Note the density function and distribution function of the standard normal distribution as $\varphi(y)$, $\emptyset(y)$ respectively. The mathematical expectation of the random variable x is μ, which is a constant. For suppliers, the lead time compression cost per unit product has a linear relationship with the lead time, assuming that $C(L)=b(T-L)$, where b represents the marginal cost of lead time compression.

Let p be the retailer's market selling price, h is the inventory holding cost, such as the loss caused by price cutting, inventory costs, etc., π is the loss of stock per unit product, such as the penalty for breach of contract, the loss caused by customer loss, etc., c is the supplier's marginal production cost, w is the supplier's wholesale price to the retailer, where $p\geq w\geq c$ (otherwise $w<c$, the supplier is unprofitable, $w>p$ No profit for retailers). q is the quantity ordered by the retailer, and R(q) is the retailer's expected revenue when the order quantity is q. The retailer's cost includes the expected inventory cost when the order quantity is larger than the demand, the expected shortage loss when the order quantity is larger than the demand, and the purchase cost.

3. Decision Analysis Based on Stackelberg Model

Based on the model equilibrium analysis, this section further discusses the interaction between retailer and supplier decision making and the impact of lead time compression cost on retailer and supplier decision making.

3.1 Interaction Between Retailer and Supplier Decisions

In this section, based on the model equilibrium analysis, the interactive influence relationship between retailer and supplier decision making is discussed, and the following propositions can be obtained:

Proposition 1: The service level of supply chain is defined as s=F(q), and the service level of supply chain is less than 50% when equilibrium exists.

Proposition 1 shows that in the two-level supply chain with decentralized decision-making, the service level of the entire supply chain is too low, which is easy to lead to the loss of customers and is not conducive to the improvement of supply chain competitiveness.

Proposition 2: When equilibrium exists, the retailer's optimal order quantity is inversely related to the supplier's lead time and wholesale price.

Proposition 2 shows that the retailer's optimal order quantity decreases with the increase of the supplier's wholesale price and increases with the compression of the lead time. If suppliers raise wholesale prices, retailers will order smaller quantities. If suppliers compress lead times, retailers will order larger quantities.

Proposition 3: When equilibrium exists, supplier's optimal lead time is inversely proportional to retailer's order quantity.

Proposition 3 shows that the supplier's optimal lead time decreases gradually as the retailer increases the order size. If retailers order larger quantities, suppliers will reduce order lead times.

According to propositions 1, 2 and 3, in a decentralized decision-making second-level supply chain with lead time compression considering demand renewal, the optimal order quantity of retailers is low, even far lower than the mean of random demand, so the service level of the supply chain is low, and the probability of stock shortage is high, which damages the competitiveness of the supply chain. Because the optimal order lead time of suppliers is inversely proportional to the order quantity of retailers, the order quantity of retailers is too low, and the suppliers are unwilling to reduce the order lead time, resulting in the slow response speed of the supply chain to the demand, and further damaging the competitiveness of the supply chain. It is not difficult to find that in order to improve the service level of the supply chain, compress the lead time of the supply chain, and speed up the response to the market demand, suppliers take appropriate incentive measures to encourage retailers to increase the order quantity under the condition of ensuring the improvement of both sides' income Pareto is one of the breakthroughs to achieve the goal. Suppliers can adopt buyback contract, revenue sharing contract, volume discount contract and other incentives to encourage retailers to increase the order volume.

3.2 The Impact of Lead Time Cost Compression on Retailer and Supplier Decisions

Based on the model equilibrium analysis, this section discusses the influence of lead time compression cost on retailer and supplier decision making.

Proposition 4: When equilibrium exists, there is an inverse relationship between retailer's optimal order size and lead time compression cost.

Proposition 4 shows that with the increase of the cost of lead time compression, the optimal order quantity of the retailer gradually decreases in the presence of equilibrium. If the supplier can effectively reduce the lead time and compress the cost, then the retailer is willing to increase the order size.

Proposition 5: When equilibrium exists, the supplier's optimal order lead time is proportional to the cost of lead time compression.

Proposition 5 shows that with the increase of lead time compression cost, the supplier's optimal order lead time gradually increases when equilibrium exists. If the supplier can effectively control the lead time and reduce the cost, then the supplier can consider shortening the order lead time. According to propositions 4 and 5, lead time compression directly affects the decisions of retailers and suppliers. Effectively reducing the lead time and reducing the cost can not only enable retailers to increase the order quantity, improve the service level of the supply chain, but also compress the order lead time and improve the response speed of the supply chain to the market demand. in order to control the lead time and reduce the cost, on the one hand, suppliers can adopt innovative approaches to intensive management without increasing resource investment, such as the application of Just in time and Concurrent Engineering. On the other hand, suppliers can control the lead time to reduce costs through cost sharing.

4. Concluding Remarks

Lead time compression is one of the important sources of competitive advantage in supply chain based on time competition. However, lead time compression cannot guarantee Pareto improvement of supply chain members' returns. In order to ensure the smooth implementation of lead time compression in supply chain, it is necessary to study the decision-making process and influencing factors of supply chain members. Therefore, based on the Steinberg game model, this paper discusses the supplier's optimal lead time and wholesale price decision, as well as the retailer's order volume decision in a decentralized decision-making two-level supply chain considering demand renewal, and analyzes the interaction between supplier and retailer's decision, as well as the influence of the change of lead time compression cost on retailer and supplier's decision. The results show that: in the decentralized decision-making supply chain considering lead time compression and demand renewal, the optimal order quantity of retailers is low, which leads to the service level of supply chain is less than 50% and the lead time of supply chain is too long; Taking appropriate measures to encourage retailers to increase order quantity is the key to improve supply chain service level and reduce supply chain lead time. Effectively controlling the lead time and reducing the cost can not only enable retailers to increase the order quantity, improve the service level of the supply chain to the market demand, but also enable suppliers to reduce the order lead time and improve the response speed of the supply chain to the market demand. Therefore, based on buyback contracts, revenue sharing contracts, volume discount contracts and other incentives to encourage suppliers to increase the order volume can be taken as the direction of further research.

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