Research on the Supply Chain Contract of Considering PDL and the Price Factor under the Quality Guarantee of the E-commerce

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Abstract. This paper, under the e-commerce environment, studies the coordination of supply chain which involves the price factor and promised delivery lead-time (PDL). Under linear demand function, we construct the wholesale price contract and the revenue sharing contract. The research shows that under the e-commerce environment, the traditional wholesale price contract can’t achieve the supply chain coordination, but the coordination can be achieved by the revenue sharing contract in the condition that the wholesale price of suppliers equals to the cost of production. At this moment, retailer gains $\lambda$ of the total revenue, and supplier gets the residue $(1 - \lambda)$.

Introduction

With the rapid development of information technology and Internet technology, online selling is gradually revealed a trend that it will replace the dominant traditional channel sales. Today's retail industry, young people are the most quantity of the main consumption army. They like to choose online shopping this kind of fast, convenient and money saving consumption patterns. So, now you can always found a heap of various package express in the library, gym or dormitory in front of the open space, no matter what university it is. With the flourishing development of e-commerce, the e-commerce platform and customer differentiation occurred in different forms. Such as domestic JD, Vipshop, of course, more like Tmall mall, Dangdang and other similar sites, both of their product quality have a god reputation. Goods delivery time and quality of the former kind site are guaranteed; but the latter site delivery time is often delayed, and the quality of the goods is uneven.

Below what happened around me, it might give us a good inspiration about the theme. Not long ago a friend talked me a very interesting shopping experience. When her children need buy a story book for learning, she chose JD not Dangdang though its price is more expensive. It’s unusual. And her words—JD can deliver the book in two days—made a deep impression to me. This story happened around us deeply reveals a new concept of consumption: on the quality guarantee of the e-commerce, the impact of commodity demand in addition to the price factor, PDL is also a very important factor. Though in the usual channels, most affecting the demand are price and quality, but in JD guaranteed the quality of e-commerce platform, customer demand for quality is weakened, they are more valued price and the PDL. This shift in thinking may be associated with the current fast-paced life experiences. But the formation and popularization of the consumption concept, will have a major impact on the existing vendor operation decision-making and operation mode of electronic commerce. How to tap the potential demand motive and form vendor’s rational decision on this basis, this will have a very important theoretical and practical significance for the future healthy development of e-commerce in China.

The study of PDL, in recent years has been popular in the operations management of the direction, many researchers have made beneficial exploration from different perspectives.

The first is a single enterprise delivery commitment, CJ Liao& CH Shyu (1991) studies in the case of the certain order quantity, continuous inventory check strategy is used to establish the inventory model of lead time is controllable, lead time is the only variable in the model [1]. The study shows that we can use the additional cost and shorten the lead time to improve customer service on the one hand, and to reduce the safety stock on the other hand. Daya (1994) modify the model based on CJ Liao, the order quantity is seen as the decision variables [2]. Liang Yuh Ouyang (2002) makes...
further modifications to the model, the reorder quantity is as well seen as decision variables, and analyzes the optimal lead time problem [3]. These early studies about lead time are mainly within the enterprise production environment as a starting point to focus on the performance of the enterprise.

With the deepening of the research, some scholars prefer to study delivery from the aspect of marketing decision making, this will involve a lot of production capacity and pricing problem. Palaka (1998) studies in the price and delivery time is a linear function of demand, considering the profit maximization under restriction of service level [4]. Ray & Jewkes (2004) based on Palaka et al. (1998) consider a decision model in which price and demand are sensitive to demand, and consider the maximum of the expected profits under certain service level [5]. Shao Jianjun (2007) studies the alternative between different market and their own capacity constraints, how to influence the market price of the product and delivery time decisions [6]. It is not hard to see from the documents, with the deepening of research, the research of scholars has gradually changed from the internal environment of enterprises to the market, but these documents consider market mainly traditional markets, rarely involves the electric dealer market. In the traditional market environment, enterprise more is as an independent individual, by predicting the demand changes to make the corresponding production capacity, PDL decision, and then analyzed the effects of these decisions on firm performance.

Some scholars research the market demand and lead time from the perspective of supply chain. Ma Shihua (2006) studies the decision-making of supply chain based on time is sensitive to the price problem in the simple newsboy model [7]. Studies have shown that under centralized decision-making supply chain performance is superior to performance of suppliers and retailers when making decentralized decision. Li Yibin (2010) establishes a stackelberg game where manufacturers is given priority by using game tools, in order model, and analyzes the relationship between lead time and pricing effects on supply chain performance [8]. Li Yina (2010) establishes joint supply chain inventory optimization model of the controllable lead time, by the supplier and the retailer together determine the order quantity and delivery time, and by sharing cost strategy [9]. Research shows that reasonable lower lead time can reduce inventory cost, and the cost allocation model is operable. From these documents we can see that the performance is the key of supply chain coordination. In these studies, they don’t conduct the thorough research to the segmentation of e-commerce platform, especially the e-commerce platform we study in this paper. Namely on the platform of product quality is guaranteed, what kind of change will happen about customer demand, and how will this change affect the supply chain management decision-making.

In view of this, this paper will use a linear function contains price, fixed PDL to approximatively depict user needs in which having a good quality reputation e-commerce platform. And in this case, we research the supply chain composed of a single supplier and a single retailer, and we research supply chain members how to coordinate the pricing and operation decision in the case of a given level of service and lead time. Through the analysis of profit between supplier and retailer, we study the individual and overall performance under the decentralized supply chain and centralized decision-making. Studies have shown that under the wholesale price contract, decentralized decision making of the supply chain in terms of quantity and income is far less than the quantity of centralized decision-making and earnings, which shows that the wholesale price contract can’t coordinate the supply chain. Therefore, we use the revenue sharing contract to improve this situation, and give relevant contract parameter, studies have shown that revenue sharing contract can achieve supply chain coordination. In addition, in the study we also found a very interesting phenomenon, that is under the centralized decision-making supply chain's commitment to the delivery time is greater than the PDL under decentralized decision making, this phenomenon is contrary to our intuition, our reasons for this phenomenon also has carried on the simple analysis.

**The Basic Model Description**

In this paper, the basic model is as follows: in a product quality guaranteed e-commerce platform, consider two participants of two stage supply chain: suppliers and retailers. The supplier sells goods to retailers with the wholesale price for \( w \), retailers order goods from suppliers according to the
Market demand (The order quantity is $q$), at the same time retailers ensure the PDL $l$ to customers. In addition, the supplier delivery time of products and retailers delivering the product to the user's time must be less than the retailers pledging to the customer delivery, for this purpose retailers promise delivery time to pay for the cost is $c(l)$. Finally, retailers will obtain corresponding profit by selling goods at the price of $p$. In this paper, we assume that supplier and retailer are risk-neutral and rational economic man, the information is symmetric, and they will make decisions based on the principle of profit maximization.

In addition, because the study background of this thesis is an e-commerce platform where the quality of the product has a certain guarantee, so the demand function must take this particularity in construction into account. So this study don’t take the product quality as an important factor of demand structure like WuJun (2013) did [10], but based on the actual investigation, and use the linear demand function as stidham, Li Yibin (2010) does [8]. Specific practices are as follows: due to the operation of e-commerce and traditional channels is very different, it makes the traditional way—No pay no goods—occurs in terms of time and space separation, and results delay between them. This nature makes the PDL and service is very important in the electronic trading, combined with the fast pace of modern life. And it makes customer requirements for the time of delivery is very high, they even for a shorter delivery time and would rather pay some additional charges. According to some related websites questionnaire survey found: in the platform of quality guaranteed, price, given promise delivery time are important factors to decide whether order online payment happened, this is similar to the feeling of most customers shopping on JD. In view of this, we simplify conditions in order to highlight the platform features, this paper makes the assumption that the retailer's order ($q$) is equal to the market demand $D$, the demand is associated with price and PDL.

Market demand is not only influenced by the retailer's price, but also affected by commodity promised delivery date, which PDL contains the product service from the retailers and suppliers, the higher the quality of their services, the shorter the promised delivery date is, the higher the corresponding product market demand. The linear relationship also conforms to the common sense and logical, linear demand function formula (1) as follows:

$$D = a - p - \delta l$$

In this paper, we use the symbol: $r$: retailers; $p$: the retail price of a commodity; $l$: retailers promise lead time of delivery; $a$: the size of the market (Assuming the product market is relatively stable, the value is a positive constant value); $\delta$: retailer's market test coefficient of PDL ($\delta > 0$), it measures the effect that the changes of the retailers PDL about the market demand, when $\delta$ is larger, the smaller retailers’PDL reduction can bring the bigger increase of market demand; $s$: suppliers; $w$: the wholesale price of the suppliers; $c$: the production cost of the suppliers; $\Pi_s$, $\Pi_w$: respectively, are seen as the supply chain's total income dispersion and Total revenue under centralized decision; For the convenience of analysis, the assumption of the retailer's PDL cost is exponential, and the retailer's promise delivery lead-time cost test coefficient is $\rho$ ($\rho > 0$), when $\rho$ is greater, which indicates that the corresponding cost is higher. The retailers paying the cost for PDL is:

$$c(l) = \rho l^2/2$$

The Wholesale Price Contract Model

According to the basic model of the second section description, the realization of the basic model of the wholesale price contract is:

Expected profit function for suppliers:
\[ \Pi_* = \max_{(w, \theta)} \{w - c \} \{a - p - \delta l\} \]  \hspace{1cm} (3)

Expected profit function for retailers:

\[ \Pi_r = \max_{(p, \delta)} \{p - w\} \{a - p - \delta l\} - \rho l^2 / 2 \]  \hspace{1cm} (4)

**Proposition 1**: price, the PDL are as the core of e-commerce platform where product quality guaranteed, the wholesale price contract can not coordinate the implementation of the supply chain.

**Proof**:

**Decentralized Decision Making**

Retailers and suppliers will make decisions according to their own profit maximization principle under decentralized decision making. Since we assume that the supplier first determines the wholesale price, the retailers decide the retail price, so according to the inverse regression, do partial derivative of formula’(4) sum, and make its partial derivative is zero, the solution:

\[ p = \frac{a \rho + (\rho - \delta^2) w}{2 \rho - \delta^2} \]  \hspace{1cm} (5)

\[ l = \frac{(w - a) \delta}{2 \rho - \delta^2} \]  \hspace{1cm} (6)

In order to let expression is simple, and easy to discuss, make:

\[ m = \rho / (2 \rho - \delta^2) \] \hspace{1cm} (m>0) \hspace{1cm} (7)

Take the formula (5), (6), (7) into the formula (1) expression can be obtained after finishing the demand function:

\[ D = ma - mw + mc \] \hspace{1cm} (8)

Take the formula (5), (6), (8) into the formula (3), and take the partial derivatives of \(w\) and \(\theta\), available:

\[ \partial \Pi_r / \partial w = ma - 2mw + mc \] \hspace{1cm} (9)

According to the hypothesis and extreme solution condition, it’s easy to know the formula (9) exist extreme value, it can be obtained by solving the extreme value condition:

\[ w^* = (a + c) / 2 \] \hspace{1cm} (10)

Take the formula (10), (7) back into the formula (5), (6) can get, under decentralized decision making, the optimal selling price \(p_{d*}\) and the most optimal PDL \(l^*\), and the optimal order \(D^*\):

\[ p_{d*} = \frac{a + c + m(a - c)}{2} \] \hspace{1cm} (11)

\[ l_{d*} = \frac{m \delta (c - a)}{2 \rho} \] \hspace{1cm} (12)

\[ D_{d*} = \frac{m (a - c)}{2} \] \hspace{1cm} (13)
Take the formula (10), (11), (12), (13) back into the formula (3), (4) can get, under decentralized decision-making, the retailer's optimal profit and the supplier's optimal benefits:

\[
\Pi_i^* = \frac{m}{4} (a - c)^2
\]  \hspace{1cm} (14)

\[
\Pi_s^* = \frac{m}{8\rho} \left(2\rho - \delta^2\right) = \frac{m}{8} (a - c)^2
\]  \hspace{1cm} (15)

So under decentralized decision making, the performance of a supply chain

\[
\Pi^* = \Pi_i^* + \Pi_s^* = \frac{3m}{8} (a - c)^2
\]  \hspace{1cm} (16)

**Centralized Decision Making**

Under centralized decision making, it is assumed that earnings of the supply chain \(\Pi^*\):

\[
\Pi^* = \max_{(p, \theta, \rho)} \left(p - c\right) \left(a - \rho - \delta\theta\right) - \rho \theta^2/2
\]  \hspace{1cm} (17)

To formula (17), respectively, taking the partial derivatives of \(p, \theta, \rho\) and solving can get, under the centralized decision-making, optimal sales price \(p^*\) and optimal PDL \(l^*\), and the optimal ordering quantity

\[
D^*_p = p^* = \frac{\rho (a + c) - c \delta^2}{2 \rho - \delta^2} = m (a + c) - \frac{cm \delta^2}{\rho}
\]  \hspace{1cm} (18)

\[
l^*_w = \delta m (c - a)/\rho
\]  \hspace{1cm} (19)

\[
D^*_w = m(a - c)
\]  \hspace{1cm} (20)

Take the formula (18), (19), (20) back into the formula (17) can get supply chain overall income under centralized decision-making as follows:

\[
\Pi^* = \frac{m}{2} (a - c)^2 = A \text{ (Make it equal to A)}
\]  \hspace{1cm} (21)

Compare formula (16) and formula (21), it is easy to know:

\[
\Pi^* = \frac{m}{2} (a - c)^2 > \frac{3m}{8} (a - c)^2 = \Pi^*
\]  \hspace{1cm} (22)

In additional, compare formula (19) and formula (12), as well as the formula (20) and formula (13), you can get:

\[
D^*_w = m(a - c) > \frac{m}{2} (a - c) = D^*_w
\]  \hspace{1cm} (23)

\[
l^*_w = \frac{\delta m (c - a)}{\rho} > \frac{m \delta (c - a)}{2 \rho} = l^*_w
\]  \hspace{1cm} (24)

Through formula (23) and formula (24) can be seen: In decentralized decision making, due to the retailer's order and total profit of the supply chain are lower than order under centralized decision-making and profit, so the Proposition 1 is proved. At the same time, formula (24) shows a very
interesting conclusion, that is: our linear demand function is abstract, under the decentralized decision-making, the retailer PDL is actually smaller than PDL under centralized decision. It seems counterintuitive. Because of the collaboration between suppliers and retailers under centralized decision-making, should make the time of delivery of goods much shorter, but why the collaboration time become longer here? One possible reason is due to the centralized decision making retailer's optimal order $D^*$ significantly bigger. This causes under the centralized decision-making while a single commodity commitment is shorter, but the promise of all the goods delivery time is longer. About the further reasons for this phenomenon and influence on decision-making, we will also continue to study in the future.

**Revenue Sharing Contract Model**

The Revenue Sharing Contract was first originated in the United States in the leasing industry, and achieved great success in the industry in the operation, and then gradually expanded to other industries. In the contract, the supplier first sell goods to retailers with their wholesale price $w$, which is close to or even lower than the manufacturing cost, retailers sell them with the market sales price $p$ and get profits; in addition, in order to make up for the loss of supplier, retailers can only get their own gains at the rate of $\lambda$ (Shared distribution coefficient, and prior consultation). And then return the rest of $(1-\lambda)$ to the supplier, and ultimately ensure that the benefits of both levels higher than the decentralized control status under the contract, or even achieve the optimal performance of supply chain under centralized decision-making.

**Proposition 2:** price, the PDL are as the core of e-commerce platform where product quality guaranteed, When meet $w = c$, revenue sharing coefficient $\lambda - 2 l \rho \rho \delta^2 / m (a - c')$ revenue sharing contract can coordinate the supply chain, and at this point in the supply chain overall income is equal to the overall revenue under centralized decision-making supply chain.

**Proof:**

**Model analysis:**

According to the previous description, we can get retailers’ expected earnings under revenue sharing contract, which $\lambda$ is a shared partition coefficient:

$$\Pi_{r_{\lambda \epsilon}} = \max_{(p, l)} \lambda \left[ (p - w,)(a - p - \delta l) - \rho l^2 / 2 \right]$$

(25)

According to the extremum solution condition, it’s easy to know Retailers under the condition of satisfy the premise of maximal profit, $p$ and $l$ in the formula (25) first order partial derivative should be zero, through simplification can be:

$$p = \frac{a \rho + (\rho - \delta^2)w}{2 \rho - \delta^2}$$

(26)

$$l = \frac{(a - w,) \delta}{2 \rho - \delta^2}$$

(27)

Then take the formula (26), (27) and (7) into the formula (25) and simplifying, we can get retailers’ the optimal expected revenue under revenue sharing:

$$\Pi_{r_{\lambda \epsilon}} = \lambda \left[ m^2 (a - w,)^2 - m^2 (a - w,)^2 \delta^2 / (2 \rho) \right] - \lambda \left[ m (w, - a)^2 / 2 \right]$$

(28)
Because the supplier is a pioneer, so supplier should provide revenue sharing contract to retailer, at the same time, assuming that the retailer’s retained earnings is $U_{\text{sr}}$, the retailer’s participation constraint as follows:

$$\Pi_{\text{sr}} \geq U_{\text{sr}}.$$  \hspace{1cm} (29) \hspace{1cm} \\

*To solve the model:*

Assumption under the revenue sharing contract, the supply chain can achieve coordination, the description depending on the model should be:

$$\begin{align*}
\Pi_{\text{sr}}^* &= (1-\lambda)\Pi_{\text{sr}}, \\
\Pi_{\text{sr}}^* + \Pi_{\text{sr}}^* &= \Pi_w
\end{align*} \hspace{1cm} \text{ (30)}$$

Take the formula (28) and formula (21) into the formula (30) can get:

$$m(a-w_c)^2/2 = m(a-c)^2/2$$  \hspace{1cm} (31) \hspace{1cm} \\

Comparison on both ends of formula (31), it’s easy to know when $w_c = c$, formula (31) is established. In addition suppliers should allow retailers to participate in this contract, as long as formula (29) the equality can be established, that is:

$$\Pi_{\text{sr}} = U_{\text{sr}}.$$  \hspace{1cm} (32) \hspace{1cm} \\

At this point in the supply chain the market sales price $p_{\text{sr}}^*$, PDL $l_{\text{sr}}^*$, and market term $D_{\text{sr}}^*$ should meet:

$$p_{\text{sr}}^* = m(a+c) - \frac{cm\delta^2}{\rho}$$  \hspace{1cm} (33) \hspace{1cm} \\
$$l_{\text{sr}}^* = \frac{\delta m(c-a)}{\rho}$$  \hspace{1cm} (34) \hspace{1cm} \\
$$D_{\text{sr}}^* = m(a-c)$$  \hspace{1cm} (35) \hspace{1cm} \\

In addition, in the case, the supply chain revenue sharing coefficient should satisfy:

$$\hat{U}_{\text{sr}} = \hat{\lambda} A = \hat{\lambda} \frac{m(a-c)^2}{2}$$  \hspace{1cm} (36) \hspace{1cm} \\
$$\hat{\lambda} = \frac{2 \hat{U}_{\text{sr}}}{m(a-c)^2}$$  \hspace{1cm} (37) \hspace{1cm} \\

Therefore, when $w_c = c$ and $\Pi_{\text{sr}} = U_{\text{sr}}$, revenue sharing contract can coordinate the supply chain, the proposition 2 is proved. Revenue sharing coefficient at this time is $\hat{\lambda} = \frac{2 \hat{U}_{\text{sr}}}{m(a-c)^2}$.

*Conclusion*

This paper does research considering a linear function contains price, fixed PDL to depict demand characteristics in which having a good quality reputation e-commerce platform. The demand function to a certain extent, objectively reflect the customer's demand features; then under the constraint of the demand function, we have studied the newsboy model’s simple operation of supply chain.
Study shows that: if the supply chain consider price and the promise delivery lead-time under the condition of linear demand, the supply chain cannot achieve coordination under wholesale price contract, at the this time, the supply chain presented an interesting condition. The optimal ordering quantity and the supply chain's overall revenue under decentralized decision making are smaller than optimal quantity and the overall yield under centralized decision-making, but at this time under decentralized decision making optimal PDL is better than the PDL under centralized decision making. This is a phenomenon that never happened in previous studies. In addition, this paper also improves the wholesale price contract by using the revenue sharing contract. The results show that when the supplier's wholesale price is equal to the cost of his production, at the same time, the supply chain can achieve coordination. By the time, retailers obtain total revenue of $\lambda A$, and suppliers get the rest of the $(1-\lambda)A$.

References


