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The Research of the Lead Time and the Profit in Centralized Dual-Channel Supply Chain

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Abstract

Internet has changed customers' consumption patterns a lot. And it also has changed the manufactures' sale model. These phenomena bring us reformation and challenge. In direct channel, price is always cheaper than that in traditional channel and we can get much profit. Empirical studier shows that lead time is one of the major factors influencing consumer acceptance. A short lead time can increase the logistics, but the long lead time will reduce customers' acceptance and the loyalty. Therefore, researching the lead time and the profit is important for dual-channel. In this paper, we study the lead time in centralized dual-channel supply chain and its impact on profit. We build the dual-channel supply chain model including quoted lead time and examine the relationship about the lead time, profit and θ *. This work is very helpful to manufacturers and retailers.*

Keywords: *Dual-channel, Centralized dual-channel supply chain, Lead time*

1. Introduction

In dual-channel supply chain, quoted lead time is a very important factor for manufacture and retailer. Enterprises treat the lead time as the time-based competition. For dual-channel enterprises, lead time and price are the advantages in competition and the direct channel will get much profit. Lead time and price are the basements that the direct channel competes with the traditional channel. A proper lead time will enhance the loyalty of the customers and the cheaper price will bring much profit.

On dual channels, Paralar and Wang [1] developed a two-firm competitive newsboy model where the firms faced independent random demands. Karjalainen [2] also analyzed the case that independent firm demands were aggregated to form industry demand. Choi (1996) [3] showed that the products' price in channel is the key factor for channel conflict. Lippmand and Macardle [4] considered a competitive version of the classical newsboy problem in which a firm must choose an inventory or production level for a perishable good with random demand. They also investigated the impact of competition upon industry inventory. .Chen *et al.*, [5] proposed a consumer channel choice model with service competition in a dual-channel supply chain. Brynjolfsson (2000) [6] made an empirical study of pricing in direct channel. He found that the product price in direct channel is lower 9~16% than that in the traditional retail. And he also found that the product price in direct channels changed frequently. Corbett [7] compared quantity discount mechanisms with symmetric and asymmetric downstream cost information in a decentralized supply chain consisting of one supplier and multiple buyers who may not share their information. Webb (2002) [8] analyzed the channel conflict management strategies from the supplier's perspective. He also put forward some proposals for resolving conflicts. Tsay (2004) [9] reviewed the conflict and coordination in dual-channel. Lau [10] explored a two-echelon newsboy model with asymmetric demand

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information in which the retailer had better market information than the manufacturer, analyzing the effects of improving the retailer's and the manufacturer's market knowledge of their profits and the system profit.

Chiang *et al.*, [11] pointed out that the retailer also benefited from the direct channel by decreasing a wholesale price when there was a price-setting game between the retail and the direct sale channel. Cachon and Fisher [12] found that the value of sharing demand information was very limited under stationary demand. By contrast, Lee *et al.*, [13] showed that the value of information increases as demand was more positively correlated over time. Yao and Liu (2005)[14] studied the static and dynamic equilibrium pricing strategy and the factors that influenced the demand. Yue and Liu (2006) [15] analyzed the influence of the direct channel on the performance of the supply chain. Then he researched the influence of the information sharing on pricing and inventory decisions. Yan [16] presented the problem of determining the optimal price when the manufacturer competed in a retail channel versus a Web-based direct sale channel. Swaminathan and Tayur [17] summarized relevant analytical models and provided a detailed review on strengths and limits of different models in E-business. Dumrongsiri(2008) [18] studied the retailers pricing problem in dual channel supply chain. Hua *et al.*, [19] investigated and compared the optimal delivery lead time and price between the centralized decisionand the decentralized decision in a dual-channel supply chain. Dan *et al.*, [20] compared the optimal price between a centralized and the decentralized supply chain decision and presented a coordination strategy. However, studies on contracts that provide insights on how to coordinate a dual-channel supply chain are limited. Chiang and Monahan [21] presented a dual-channel inventory model with the stochastic demands for two customer segments. Chen *et al.*, [22] investigated the manufacturer's pricing strategies in a dual-channel supply chain and found that the manufacturer's contract with a wholesale price and a price for the direct channel could coordinate the dual-channel supply channel. Lau [23] studied the influence of both symmetric and asymmetric manufacturing cost information on the supply chain members' expected profits in a two-echelon supply chain in three different games under linear and ISO-elastic demand. Salespeople were the eyes and ears of the firms they served, possessing market information critical for a wide range of decisions. Boyaci [24] found that the simple contracts, such as the wholesale price, buyback, revenue-sharing and Vendor Managed Inventory (VMI) contracts, cannot coordinate the dual-supply chain with inventory decisions. Cai [25] discussed the influences of different channel structures and the channel coordination on the profits of supply chain partners and the whole system.

Our work is also related to previous research on lead time decisions in centralized dual-channel supply chain. Liu et al. [26] examined price and delivery lead time decisions in decentralized supply chains based on the Stackelberg game. Yang and Geunes [27] studied inventory and lead time decisions with lead-time-sensitive demand. Differing from their study, we examine in this paper the lead time decision in the centralized dual-channel supply chain.

In this paper, we establish an analytical framework. This framework analyzes the impact on the lead time and the profit in centralized dual channel. The study of this problem will offer a decision aid for manufacture and retailer. The numerical analysis shows that the lead time will influence the profit of manufacture and retailer strongly. The structure of this paper is as follows. The first part is the introduction. The second part is the lead time and profit in centralized dual-channel supply chain. The third part is the numerical analysis and the last part is the conclusion.

2. The Lead Time and Profit in Centralized Dual-Channel Supply Chain

2.1. The Basic Model

We consider that the supply chain is constituted of a manufacturer and a retailer. The manufacturer sells the goods to the retailer, as well as to the customers directly. Customers buy the goods from retailer or buy these goods from the internet. The wholesale price is w. The direct sale price is p_d. The retail price is p_r and the lead time is l. The dual-channel supply chain is shown as Figure 1.

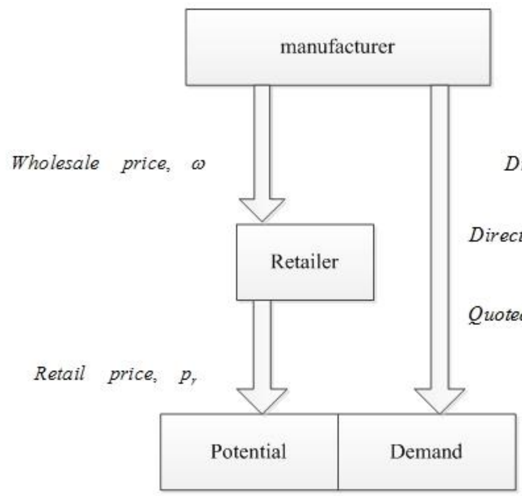

Figure 1. The Dual-channel Supply Chain

We assume that the demand functions are linear. The demand functions are shown as follows:

$$D_d = \theta a - b_1 p_d + c_1 p_r \tag{1}$$

$$D_r = (1-\theta) a - b_2 p_r + c_2 p_d \tag{2}$$

a is the basic demand in the market. The share of the demand of the direct channel is θ. So, $1-\theta$ is the share of the traditional channel demand. b_1 and b_2 are the coefficients of price elasticity of D_d and D_r. c_1 and c_2 is the cross-price sensitivities .

If we consider the lead time, we assume that the demand functions are

$$D_d = \theta a - b_1 p_d + c_1 p_r - \alpha l$$
$$D_r = (1-\theta) a - b_2 p_r + c_2 p_d + \beta l$$

α and β are the lead time sensitivity of the demands in each channel. The total demand is

$$D = D_d + D_r = a - (b_2 - c_1) p_r - (b_1 - c_2) p_d + (\alpha - \beta) l$$

We assume that the cross-price effects are symmetric, namely $c_1 = c_2 = c$. We also assume that $w \le p_d$ and the handling and shipping costs of an order $c(l) = c_0 + \gamma / l, \gamma > 0$ (c_0 is the least incurred logistics cost).

From $D_d \ge 0, D_r \ge 0$, we obtain

$$c_r \le w \le p_r \le Al + M \tag{3}$$

$$c_d + \gamma / l \le p_d \le Bl + M \tag{4}$$

where

$$A = \frac{\beta b_1 - \alpha c}{b_1 b_2 - c^2}, B = \frac{\beta c - \alpha b_2}{b_1 b_2 - c^2}, M = \frac{a_1 c + \alpha_2 b_1}{b_1 b_2 - c^2}, N = \frac{a_1 b_2 + \alpha_2 c}{b_1 b_2 - c^2}$$

$$a_1 = \theta a \text{ and } a_1 = (1-\theta)a$$

From the sake of convenience in discussion, let

$$\delta = \frac{\beta}{\alpha} - \frac{c}{b_1}, E = \frac{\alpha b_1}{b_1 b_2 - c^2},$$
$$P = a_1 - b_1 c_d + c c_r \text{ and } Q = a_2 - b_1 c_r + c c_d$$

We assume that retailer has no merchandizing cost. So, the retailer's profit is

$$\pi_r = (p_r - w) D_r \tag{5}$$

The manufacturer's profit is

$$\pi_m = (w - c_r) D_r + (p_d - c_d - \gamma / l) D_d \tag{6}$$

The profit of the centralized supply chain is

$$\pi = \pi_r + \pi_m = (p_r - c_r) D_r + (p_d - c_d - \gamma / l) D_d \tag{7}$$

2.2. Analysis of Centralized Dual-channel Supply Chain

We analyze the centralized dual-channel supply chain. In the dual-channel supply chain, manufacture decides the traditional retailer's price, the direct sale price and the quoted lead time in direct channel.

We substitute the formula (1) and formula (2) into formula (7), we can get

$$\pi_c = (p_r - c_r)(a_2 - b_2 p_r + c p_d + \beta l) + (p_d - c_d - \gamma / l)(a_1 - b_1 p_d + c p_r - \alpha l) \tag{8}$$

We examine some propositions regarding π_c in order to maximize π_c.

Proposition 1. The dual-channel profit π_c is strictly jointly concave in p_r and p_d, concave in p_r, p_d and l.

Proof:

$$H = \begin{pmatrix} \partial^2 \pi_c / \partial p_r^2 & \partial^2 \pi_c / \partial p_r \partial p_d & \partial^2 \pi_c / \partial p_r \partial l \\ \partial^2 \pi_c / \partial p_d \partial l & \partial^2 \pi_c / \partial p_d^2 & \partial^2 \pi_c / \partial p_d \partial l \\ \partial^2 \pi_c / \partial l \partial p_r & \partial^2 \pi_c / \partial l \partial p_d & \partial^2 \pi_c / \partial l^2 \end{pmatrix}$$
$$= \begin{pmatrix} -2b_2 & 2c & \beta + c\gamma / l^2 \\ 2c & -2b_1 & -\alpha - b_1 \gamma / l^2 \\ \beta + c\gamma / l^2 & -\alpha - b_1 \gamma / l^2 & -2\gamma (a_1 - b_1 p_d + c p_r) / l^3 \end{pmatrix}$$

Since

$$\partial^2 \pi_c / \partial p_r^2 = -2b_2 < 0$$

and

$$\begin{vmatrix} \partial^2 \pi_c / \partial p_r^2 & \partial^2 \pi_c / \partial p_r \partial p_d \\ \partial^2 \pi_c / \partial p_d \partial p_r & \partial^2 \pi_c / \partial p_d^2 \end{vmatrix} = 4 b_1 b_2 - 4c^2 > 0$$

π_c is strictly jointly concave in p_d and p_r

However, due to

$$\partial^2 \pi_c \big/ \partial p_r^2 = -2b_1 < 0$$

And

$$\begin{vmatrix} \partial^2 \pi_c \big/ \partial p_d^2 & \partial^2 \pi_c \big/ \partial p_d \partial l \\ \partial^2 \pi_c \big/ \partial l \partial p_d & \partial^2 \pi_c \big/ \partial l^2 \end{vmatrix} = 4b_1\gamma(a_1 - b_1 p_d + cp_3) \big/ l^3 - (\alpha + b_1\gamma \big/ l^2)^2$$

If l is large enough, the above equation may be negative. So, π_c is indefinite with respect to l and p_d. Hence, π_c is not jointly concave in p_d and p_r at all.

From the proposition 1, we can know that we cannot get the optimal values of p_r, p_d and l by the first-order conditions. But, we learn that π_c has a unique optimal solution for any given l.

Proposition 2. For any given l, the optimal retail price p_r and the optimal direct sale price p_d are given by

$$p_r^*(l) = \frac{A}{2}l + \frac{M + c_r}{2} \tag{9}$$

$$p_d^*(l) = \frac{\gamma}{2}l + \frac{B}{2}l + \frac{N + c_d}{2} \tag{10}$$

The total profit or profit rate $\pi_c^*(l)$ as a function of l is given by

$$\begin{aligned} \pi_c^*(l) = {} & \frac{b_1\gamma^2}{4l^2} - \frac{\gamma P}{2l} + \frac{(a_1 + P)B + (a_2 + Q)A + \alpha c_d - \beta c_r - \beta c_r}{4} l \\ & + \frac{\beta A - \alpha B}{4} l^2 + \frac{2\alpha\gamma + (M - c_r)Q - (N - c_d)P}{4} \end{aligned} \tag{11}$$

Proof:

From the proposition 1, we can know that for any given l, π_c has a unique optimal solution. We take the first-order partial derivatives of p_r and p_d. Let the derivatives be zero, we have

$$\begin{cases} \partial \pi_c \big/ \partial p_r = -2b_2 p_r + 2cp_d + \beta l - c\gamma \big/ l + a_2 + b_2 c_r - cc_d = 0 \\ \partial \pi_c \big/ \partial p_d = -2cp_r - 2b_1 p_d - \alpha l + b_1\gamma \big/ l + a_1 + b_1 c_r - cc_r = 0 \end{cases}$$

Then

$$\begin{cases} p_r^*(l) = \dfrac{A}{2}l + \dfrac{M + c_r}{2} \\ p_d^*(l) = \dfrac{\gamma}{2}l + \dfrac{B}{2}l + \dfrac{N + c_d}{2} \end{cases}$$

From the formula (3) and (4), we have

$$p_r^*(l) = \frac{1}{2}(Al + M) + \frac{c_r}{2} \geq \frac{c_r}{2} + \frac{c_r}{2} = c_r$$

$$p_r^*(l) = \frac{1}{2}(Al + M) + \frac{c_r}{2} \le \frac{1}{2}(Al + M) + \frac{1}{2}(Al + M) = Al + M$$

$$p_d^*(l) = \frac{1}{2}(\frac{\gamma}{l} + c_d) + \frac{1}{2}(Bl + Bl + N) \ge \frac{1}{2}(\frac{\gamma}{l} + c_d) + \frac{1}{2}(\frac{\gamma}{l} + c_d) = \frac{\gamma}{l} + c_d$$

$$p_d^*(l) = \frac{1}{2}(\frac{\gamma}{l} + c_d) + \frac{1}{2}(Bl + N) \le \frac{1}{2}(Bl + N) + \frac{1}{2}(Bl + N) \le Bl + N$$

There equations shows that $p_r^*(l)$ and $p_d^*(l)$ meet formula (3) and formula (4). Substituting formula (9) and formula (10) into formula (8), we can get formula (11).

When θ increases, the optimal retail price and optima direct sale will increase for any given l .

Proposition 3.

①

$$\frac{dp_d^*(l)}{dl} < 0, \frac{dp_r^*(l)}{dl} > \frac{dp_d^*(l)}{dl} \tag{12}$$

②When

$$l > \sqrt{\frac{\gamma}{-B}}, \left|\frac{dp_d^*(l)}{dl}\right| > \left|\frac{dc(l)}{dl}\right|,$$

and when

$$l \le \sqrt{\frac{\gamma}{-B}}, \left|\frac{dp_d^*(l)}{dl}\right| \le \left|\frac{dc(l)}{dl}\right| \tag{13}$$

③When

$$\delta > 0, \frac{dp_r^*(l)}{dl} > 0;$$

When

$$\delta < 0, \frac{dp_r^*(l)}{dl} < 0;$$

And when

$$\delta = 0, \frac{dp_r^*(l)}{dl} = 0 \tag{14}$$

Proof:

(1) From proposition 2, $\frac{dp_d^*(l)}{dl} = -\frac{\gamma}{2l^2} + \frac{B}{2} < 0$ and $\frac{dp_d^*(l)}{dl} - \frac{dp_r^*(l)}{dl} = \frac{\gamma}{2l^2} + \frac{A - B}{2} > 0$, we can derive the rest of the results.

(2) Note that $\frac{dp_r^*(l)}{dl} = \frac{A}{2} = \frac{E\delta}{2}$ and $E > 0$, the results are straightforward to derive.

Proposition 3(1) shows that when l decrease, $p_d^*(l)$ increases. But, we can find that the rate of change of $p_d^*(l)$ is less than that of $p_r^*(l)$.

Proposition 3(2) indicates that when l exceeds a threshold, the direct sale price p_d will increase more than the incurred logistics cost.

$\frac{\beta}{\alpha}$ represents the ratio of customer transferring to the traditional channel from the direct channel due to an increasing lead time. $\frac{c}{b_1}$ represents the ratio of customer transferring to the direct channel from the traditional channel due to an increasing lead time.. So, δ represents the difference between the two ratios.

$$\delta = (1 - \frac{c}{b_1}) - (1 - \frac{\beta}{\alpha})$$

Proposition 3(3) shows that the retailer's pricing behavior p_r is determined by δ . So, it is very important for manufacturers and retailers to make decisions with considering δ .

For maximizing $\pi_c^*(l)$, we need find the optimal l . We distinguish $\pi_c^*(l)$ with reference to l , which generate the first-order condition:

$$\frac{d\pi_c^*(l)}{dl} = -\frac{b_1\gamma^2}{2l^3} + \frac{\gamma P}{2l^2} + \frac{(a_1+P)B+(a_2+Q)A+\alpha c_d-\beta c_r}{4} + \frac{\beta A-\alpha B}{2}l = 0$$

i.e.

$$[(a_1+P)B+(a_2+P)B+(a_2+Q)A+\alpha c_d-\beta c_r]l^3$$
$$+2(\beta A-\alpha B)l^4+2\gamma Pl-2b_1\gamma^2=0$$

3. Numerical Analysis

In this section, we make numerical analysis to compare the lead time decisions and profit .And we also study the relationships among the retail profit, the direct sale profit and the wholesale profit in centralized supply chain. We assume that $a = 10000$, $b_1 \in [150, 300]$, $b_2 \in [150, 300]$, $c \in [30, 240]$, $\alpha \in [200, 5000]$, $\beta \in [50, 2600]$, $c_d \in [80, 200]$, $c_r \in [100, 200]$ and $\gamma \in [20, 80]$. The experimental results are shown as

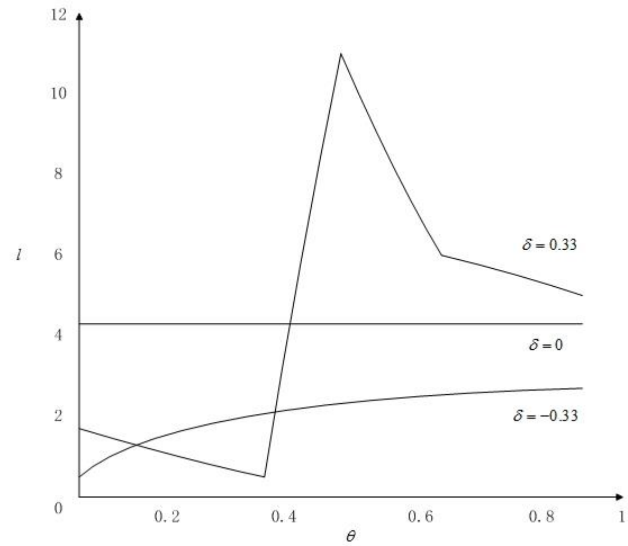

Figure 2. The Relationship between θ and the Lead Time

Figure 2 shows the relationship between θ and the lead time. When $\delta = -0.33$, the lead time increases with the increasing θ. When $\delta = 0$, the lead time is constant. When $\delta = 0.33$, the lead time is polyline. Firstly, the lead time decreases in the interval $\theta \in [0, 0.4]$. Then, the lead time increases in the interval $\theta \in [0.4, 0.5]$. At last, the lead time decreases in the interval $\theta \in [0.5, 1]$. But the speed of fall is different in the interval $\theta \in [0.5, 1]$.

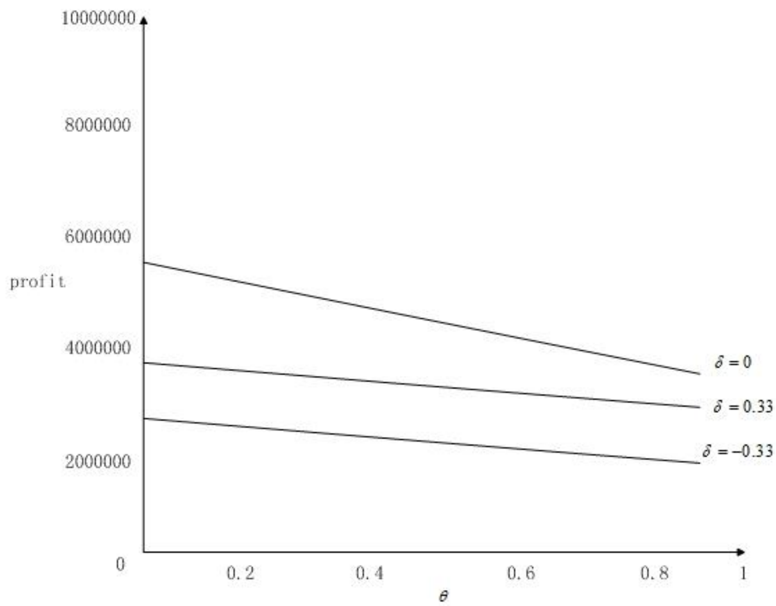

Figure 3. The Relationship between θ and the Profit of Retailer on Traditional Channel

From fugure.3, we can see that the profits of retailer on traditional channel are all straight lines. The profits of retailer all decreases with the increasing θ **.** Retailer can get the most profit when $\delta = 0$. And, the retailer get the least profit when $\delta = -0.33$.

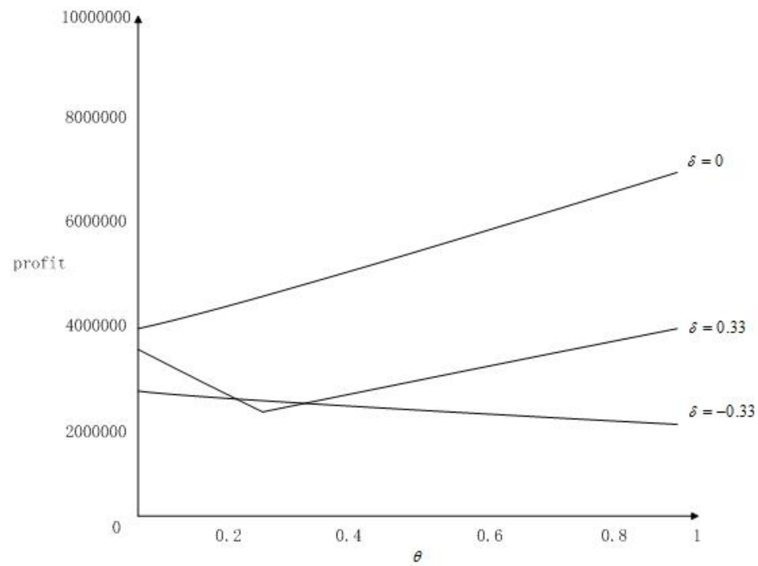

Figure.4 the Relationship between θ and the Profit of Manufacturer on Traditional Channel

From fugure.4, we can see that the profits of manufacturer on traditional channel are all straight lines when $\delta = 0$ and $\delta = -0.33$. When $\delta = 0.33$, it is a broken line which decreases first then increases with the increasing θ . Manufacturer can get the most profit when $\delta = 0$.

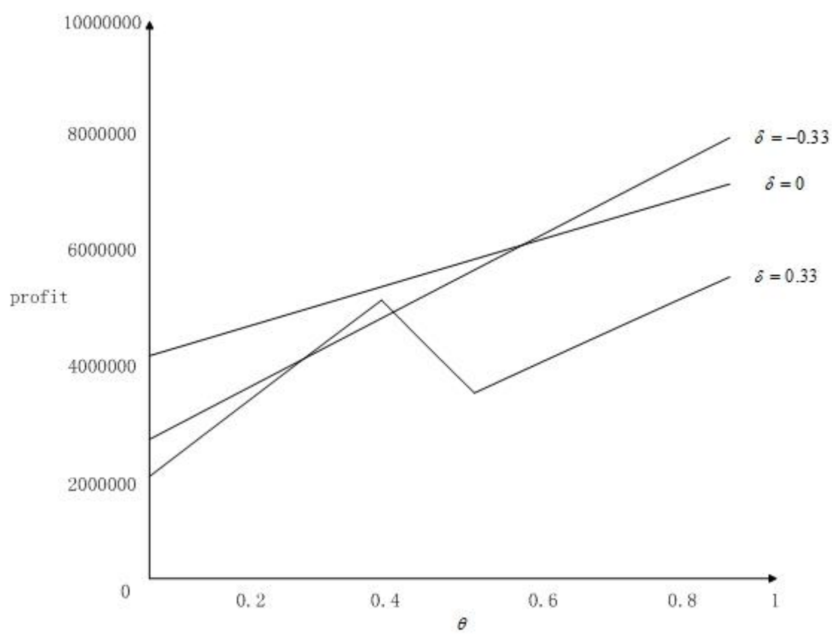

Figure.5 The Relationship between θ and the Profit of Direct Channel

From fugure.5, we can see that the profits of manufacturer on traditional channel are all straight lines when $\delta = 0$ and $\delta = -0.33$. When $\delta = 0.33$, it is a broken line. At the interval $[0, 0.4]$, the line increases with the increasing θ . At the interval $[0.4, 0.5]$, the line decreases with the increasing θ . At the interval $[0.5, 1]$, the line increases with the increasing θ . Manufacturer can get the most profit when $\delta = 0$ at the interval $[0, 0.6]$. And at the interval $[0.6, 1]$, manufacturer can get the most profit when $\delta = -0.33$

4. Conclusion

Internet has changed customers' consumption patterns a lot. And it also has changed the manufactures' sale model. These phenomena bring us reformation and challenge. In this paper, we research the lead time and profit in centralized dual-channel supply chain. In this paper, we establish an analytical framework. This framework analyzes the impact on the lead time and the profit in centralized dual channel. The study of this problem will offer a decision aid for manufacturer and retailer. We have done the below work: (1) we construct a new dual-channel supply chain model including quoted lead time; (2) we analyze the centralized dual-channel supply chain; (3) we make the numerical analysis to study the relationship about the lead time, profit and θ . This is very helpful to manufacturers and retailers.

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