The Research on the Dual-Channel Supply Chain Coordination with Compensation Strategy When the Costs of Production Are Changing

Boya Weng(✉) and Cancan Zhao

School of Safety and Environmental Engineering, Capital University of Economics and Business, Beijing, China
bettyweng@126.com, zhaocann@cueb.edu.cn

Abstract. This paper studies a dual-channel supply chain model which contains a manufacturer and a retailer. By using the game theory, we analysis and comparison the dual-channel supply chain when the costs of production is changing. We investigate the optimal price of the supply chain under centralized decision and decentralized decision making. We also design a compensation strategy which considering changes in the costs of production in order to both manufacturer and retailer are in win-win situation. Finally, this paper use the example demonstrated the effectiveness of the compensation strategy for the dual-channel supply chain coordination.

Keywords: Dual channel · Supply chain · Changes in production costs · Compensation strategy

1 Introduction

The developments of electronic commerce bring the market a lot of opportunities. The ministry of commerce had predicted that the e-commerce transactions will be more than 18 trillion Yuan in China in 2015 [12]. As a result, the rapid development of dual channel supply chain has made it attractive for large number of brick and mortar firms, and there have been a lot of largest examples which run the dual-channel supply chain and succeeded [11], such as Nike Company in the United States. However, it's difficult for some manufacturers to coordinate the relationship between the traditional channels and electronic channels. The development of electronic channels makes the retailer's profits are exploited which lead to traditional retailers believe online direct marketing channels are becoming a competitor [10]. Such approach also creates the potential for channel conflicts. In the issue, coordinate the relationship between the electronic channels and traditional channels plays a significant role in the dual-channel supply chain coordination.

Dual-channel supply chain coordination has been broadly studied in the literature [1–6]. It's not hard to find existing research mainly focused on decision making about the price and quantity of the dual channel supply chain under the stable condition. Generally the literature does not consider the costs of production [1, 2], or suppose

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production costs does not change [3–6], such as Zhao and Xu [1] introduced a model when a manufacturer use electronic channel and traditional retail channel to sell products at same time, established a demand function from the perspective of consumer utility which demand change depend on price change. They also designed a contract that the wholesale price plus electronic channel price, in order to coordinate the channel conflict, and improve the revenue sharing contract. Ai et al. [2] introduce a two layers of the supply chain competition model in the case of considering environmental information factors, so as to provides the basic theory for further build the double channel cooperation and incentive mechanism. Yan et al. [3] established a dual-channel supply chain coordination stackelberg model under service-price sensitive demand conditions, study the two coordinate ways: the coordination between the upstream and downstream nodes and the coordination between the traditional channel and electronic channel. Yan et al. [4] compared the non integrated channels and the integration channels, points out that the channel integration strategy which share profits can make both online sale channels and traditional channels profitable.

Besides, there are a few literature takes the changes in production costs into consideration [7, 8]. But these studies did not analyzed and discussed the coordinate way to solve the channel conflicts problem. Huang et al. [7] analyzed when the demand and production costs are disrupted at same time, the influence on centralized and decentralized dual-channel supply chain pricing and production decisions. They found optimal pricing and optimal production decisions in different range of distribution, but article did not elaborate how to coordinate the dual-channel supply chain after distribution occurred. Wang [8] introduced pricing strategy of dual-channel supply chain when considering the manufacture costs increase and decrease, he analyzed the range of manufacturing costs which affect the production plan. But the paper didn't mention how to coordinate the influence.

Our paper addresses these limitations by studying the compensation strategy when the costs of production are changing in the supply chain. Our objective in this paper is to design a compensation mechanism to make decentralized decision profits and centralized decision profits equal. And ensure that both manufacturer and retailer can obtain a benefit, realize the pareto optimality.

2 Problem Statement

Our basic model includes one manufacturer and one retailer, the hypotheses are as follow:

(1) Both sides of the decisions are rational;
(2) The two sides share same information;
(3) The two sides follow the master-slave game. The manufacturer is leader, the retailer is follower. First of all, the manufacturer decide the wholesale prices and the sales price of electronic channel, then according to the price declares by the manufacturer, the retailer set the sales price of traditional channel.

Preliminaries:

w: the wholesale price;
c: the unit production cost of the manufacturer;
P_e: The sales price of electronic channel;
P_r: The sales price of traditional channel;
d_r: Traditional channel demand;
d_e: Electronic channel demand;
a: total market demand, $a > 0$;
b: the substitution effect coefficient between electronic channel sales product and traditional channel sales product, $0 < b < 1$;
f: the market demand at traditional channel, $0 < f < 1$;
1-f: the market demand at electronic channel.

According to the literature of Ai et al. [2] and Chen [9], the demand functions for the traditional and electronic channel, respectively, can be expressed as:

Traditional channel demand:

$$d_r = fa - P_r + b(P_e - P_r). \quad (1)$$

Electronic channel demand:

$$d_e = (1 - f)a - P_e + b(P_r - P_e). \quad (2)$$

3 Model Structure

3.1 The Centralized Decision-Making

When the production costs reduced, the manufacturer will not produce fewer products, and this phenomenon may touch off oversupply, resulting in a decline in sales price. The manufacturer cannot sell all the products, and incur the processing costs. Similarly, when the production costs increases, the manufacturer will not produce more products, and this phenomenon may touch off demand exceeds supply, resulting in a sale prices rise. The manufacturer cannot meet all the requirements, and incur the shortage costs [13]. As a result, changes in the costs of production will affect the sale price, and then change the best decision in the whole supply chain.

When the costs of production are changing, the total profit is:

$$\begin{aligned}\pi_1^c = {} & (P_r - c - \Delta c)[fa - P_r + b(P_e - P_r)] + (P_e - c - \Delta c)[(1 - f)a - P_e \\ & + b(P_r - P_e)] - \mu_1(d_e + d_r - d_e^* - d_r^*)^+ - \mu_2(d_e^* + d_r^* - d_e - d_r)^+ \end{aligned}.$$

Among them, the third is when manufacturer produce more products may incur the processing cost. The fourth is when manufacturer produce fewer products may incur the shortage costs. And both costs can’t exist at the same time.

μ_1: Unit producing costs caused by the manufacturer producing one more products.

μ_2: Unit shortage costs caused by the manufacturer producing one less products, $\max\{\mu_1, \mu_2\} < c$.

The Production Costs Reduce Under the Centralized Decision-Making. The dual-channel supply chain's optimal profit is:

$$\pi_1^c = (P_r - c - \Delta c)[fa - P_r + b(P_e - P_r)] + (P_e - c - \Delta c)[(1-f)a - P_e + b(P_r - P_e)] - \mu_1(d_e + d_r - d_e^* - d_r^*)^+. \tag{3}$$

We obtain the optimal solution by solving the first-order condition, $\frac{\partial \pi_1^c}{\partial p} = 0$. Thus, the optimal sales price of electronic channel is: $P_e = \frac{2bc + 2b\Delta c + 2b\mu_1 + a - fa + c + \Delta c + \mu_1 + ab}{4b+2}$, the optimal sales price of traditional channel is:

$$P_r = \frac{ab + c + 2bc + fa + \Delta c + 2b\Delta c + \mu_1 + 2b\mu_1}{4b+2}. \tag{4}$$

Considering when the costs of production reduce, the electronic channel and traditional channel total demand cannot less than the total demand when the costs of production constant, we can get: $\Delta c \le -\mu_1$.

The Production Costs Increase Under the Centralized Decision-Making. The dual-channel supply chain's optimal profit is: $\pi_1^c = (P_r - c - \Delta c)[fa - P_r + b(P_e - P_r)] + (P_e - c - \Delta c)[(1-f)a - P_e + b(P_r - P_e)] - \mu_2(d_e^* + d_r^* - d_e - d_r)^+$, similar to the reduction of cost, we calculate and obtain the optimal sales price of electronic channel is: $P_e = \frac{2bc + 2b\Delta c - 2b\mu_2 + a - fa + c + \Delta c - \mu_2 + ab}{4b+2}$, the optimal sales price of traditional channel is:

$$P_r = \frac{ab + c + 2bc + fa + \Delta c + 2b\Delta c - \mu_2 - 2b\mu_2}{4b+2}. \tag{5}$$

Considering when the costs of production increase, the electronic channel and traditional channel total demand cannot exceeds the total demand when the costs of production constant, we can get: $\Delta c \ge \mu_2$.

Thus, the total profit of the dual-channel supply chain under the centralized decision-making is:

$$\pi_1^c = \begin{cases} \dfrac{\begin{array}{c} -4ab\Delta c + 8\Delta cb\mu_1 + 4b\Delta c^2 + 8cb\Delta c + 4b\mu_1{}^2 - 4abc + a^2b + 4bc^2 + 4c\Delta c \\ 2\mu_1{}^2 + 2c^2 + a^2 - 2ac - 2fa^2 + 2\Delta c^2 + 2f^2a^2 - 2a\Delta c + 4\Delta c\mu_1 \end{array}}{4+8b}, \Delta c \le -\mu_1 \\ \dfrac{4bc^2 - 4abc + a^2b - 2a^2f + 2a^2f^2 + 2c^2 + a^2 - 2ac}{8b+4}, -\mu_1 < \Delta c < \mu_2 \\ \dfrac{\begin{array}{c} -4ab\Delta c - 8\Delta cb\mu_2 + 4b\Delta c^2 + 8cb\Delta c + 4b\mu_2{}^2 - 4abc + a^2b + 4bc^2 \\ + 4c\Delta c + 2\mu_2{}^2 + 2c^2 + a^2 - 2ac - 2fa^2 + 2\Delta c^2 + 2f^2a^2 - 2a\Delta c - 4\Delta c\mu_2 \end{array}}{4+8b}, \Delta c \ge \mu_2 \end{cases} \quad (6)$$

3.2 Decentralized Decision-Making

We assume that all the loss caused by the changes in the cost of production undertakes by the manufacturer alone. The manufacturer's profit is:

$$\pi_2^c = (w - c - \Delta c)[fa - P_r + b(P_e - P_r)] + (P_e - c - \Delta c)[(1-f)a - P_e + b(P_r - P_e)] - \mu_1(d_e + d_r - d_e^* - d_r^*)^+ - \mu_2(d_e^* + d_r^* - d_e - d_r)^+. \quad (7)$$

The retailer's profit is:

$$\pi_3^c = [fa - P_r + b(P_e - P_r)](P_r - w). \quad (8)$$

The Production Costs Reduce Under the Decentralized Decision-Making. The manufacturer's profit is:

$$\pi_2^c = (w - c - \Delta c)[fa - P_r + b(P_e - P_r)] + (P_e - c - \Delta c)[(1-f)a - P_e + b(P_r - P_e)] - \mu_1(d_e + d_r - d_e^* - d_r^*)^+ \quad (9)$$

We obtain the optimal solution by solving the second-order dynamic game on Eqs. (8) and (9), the optimal sales price of electronic channel is:

$$P_e^* = \frac{\begin{array}{c} 2\mu_1 + 2a - 4fab - 2fab^2 + 8\Delta cb + 10\Delta cb^2 + 2\Delta c - 2fa + 8bc + 6ab + 10cb^2 + 6ab^2 + 2c \\ + 8\mu_1 b + 4cb^3 + 2ab^3 + 10\mu_1 b^2 + 4\mu_1 b^3 + 4\Delta cb^3 \end{array}}{20b^2 + 8b^3 + 16b + 4}. \quad (10)$$

The optimal wholesale price is:

$$w^* = \frac{\mu_1 + fab + 3\Delta cb + 2\Delta cb^2 + \Delta c + fa + 3bc + ab + 2cb^2 + ab^2 + c + 3\mu_1 b + 2\mu_1 b^2}{4b^2 + 6b + 2}. \tag{11}$$

The optimal sales price of traditional channel is:

$$P_r^* = \frac{4\Delta cb^2 + 4cb^2 + 2ab^2 + 4\mu_1 b^2 + 2ab + 4fab + 4bc + 4\mu_1 b + 4\Delta cb + \mu_1 + \Delta c + 3fa + c}{4 + 12b + 8b^2}. \tag{12}$$

Considering when the costs of production reduce, the electronic channel and traditional channel total demand cannot less than the total demand when the costs of production constant, we can get: $\Delta c \leq -\mu_1$.

The Production Costs Increase Under the Decentralized Decision-Making. The manufacturer's profit is:

$$\pi_2^c = (w - c - \Delta c)[fa - P_r + b(P_e - P_r)] + (P_e - c - \Delta c)[(1 - f)a - P_e + b(P_r - P_e)] - \mu_2(d_e^* + d_r^* - d_e - d_r)^+. \tag{13}$$

Similar to the reduction of cost above, we calculate and obtain the optimal wholesale price is:

$$w^* = \frac{-\mu_2 + fab + 3\Delta cb + 2\Delta cb^2 + \Delta c + fa + 3bc + ab + 2cb^2 + ab^2 + c - 3\mu_2 b - 2\mu_2 b^2}{4b^2 + 6b + 2}. \tag{14}$$

The optimal sales price of electronic channel is:

$$P_e^* = \frac{-2\mu_2 + 2a - 4fab - 2fab^2 + 8\Delta cb + 10\Delta cb^2 + 2\Delta c - 2fa + 8bc + 6ab + 10cb^2 + 6ab^2 + 2c - 8\mu_2 b + 4cb^3 + 2ab^3 - 10\mu_2 b^2 - 4\mu_2 b^3 + 4\Delta cb^3}{20b^2 + 8b^3 + 16b + 4}. \tag{15}$$

The optimal sales price of traditional channel is:

$$P_r^* = \frac{4b^2c + 2ab^2 - 4\mu_2 b^2 + 4\Delta cb^2 + 4bc + 2ab - 4\mu_2 b + 4fab + 4\Delta cb + c + \Delta c - \mu_2 + 3fa}{8b^2 + 12b + 4}. \tag{16}$$

Considering when the costs of production increase, the electronic channel and traditional channel total demand cannot more than the total demand when the costs of production constant, we can get: $\Delta c \geq \mu_2$.

Thus, the total profit of the dual-channel supply chain under the decentralized decision-making is:

$$\pi_4^c = \begin{cases} \dfrac{\begin{matrix} 4fabc + 4fab\Delta c - 4fab\mu_1 + 22bc^2 + 16c^2b^2 + 7c^2 + 22\mu_1{}^2 b + 16\mu_1{}^2 b^2 + 8a^2b + 4a^2 - 8a\Delta c - 8fa^2 - 8ac \\ + 4a^2b^2 - 16ab^2\Delta c + 4bc\mu_1 + 2fac + 2\Delta cfa + 32\Delta cb^2\mu_1 + 32\Delta cb^2c + 44\Delta cb\mu_1 + 44\Delta cbc - 2\mu_1 fa - 8a^2bf \\ + 6f^2a^2b + 2\mu_1 c + 14\mu_1\Delta c + 22\Delta c^2 b - 16ab^2c - 24ab\Delta c - 24abc + 16\Delta c^2b^2 + 14\Delta cc + 7\Delta c^2 + 7f^2a^2 + 7\mu_1{}^2 \end{matrix}}{16 + 48b + 32b^2}, & \Delta c \leq -\mu_1 \\ \dfrac{\begin{matrix} -16ab^2c + 16c^2b^2 + 4a^2b^2 + 8a^2b + 22bc^2 - 24abc + 4fabc + 6f^2a^2b - 8a^2bf \\ 2fac - 8fa^2 - 8ca + 7c^2 + 4a^2 + 7f^2a^2 \end{matrix}}{48b + 32b^2 + 16}, & -\mu_1 < \Delta c < \mu_2 \\ \dfrac{\begin{matrix} 2fac - 4bc\mu_2 + 2\mu_2 fa + 6f^2a^2b - 2\mu_2 c - 8a^2bf + 4fabc + 4fab\Delta c - 14\mu_2\Delta c + 7\mu_2{}^2 + 22\Delta c^2 b + 16\Delta c^2b^2 \\ + 14\Delta cc + 7\Delta c^2 + 7f^2a^2 + 16\mu_2{}^2b^2 + 44\Delta cbc - 44\Delta cb\mu_2 + 32\Delta cb^2c - 32\Delta cb^2\mu_2 + 2\Delta cfa - 24abc - 24ab\Delta c \\ - 16ab^2c - 16ab^2\Delta c - 8ca + 8a^2b + 22bc^2 + 16c^2b^2 + 7c^2 + 22\mu_2{}^2 b + 4a^2 - 8a\Delta c - 8fa^2 + 4a^2b^2 + 4fab\mu_2 \end{matrix}}{32b^2 + 48b + 16}, & \Delta c \geq \mu_2 \end{cases} \tag{17}$$

From the Eqs. (6) and (17), we can find that if fa > c, the centralized decision-making total profits is always greater than the decentralized decision-making total profits. According to the Eqs. (12), (4) and (16), (5), we can find that if fa > c, the optimal sales price of traditional channel under decentralized decision-making is always greater than the optimal sales price of traditional channel under centralized decision-making. Thus, the retailer is not willing to accept the profit allocation scheme under centralized decision-making, because retailer can gain more under decentralized decision-making.

4 The Compensation Strategy

In order to solve the conflict put forward in Chap. 3, we set a compensation strategy: the manufacturer supply certain proportion electronic channel order to the retailer as compensation (increased demand for traditional channel). At the same time, the manufacturer requires a certain order transfer fee to ensure its profit. And we also realized that the order transfer fee can not hinder the retailer's optimal pricing.

The proportion of the order that the manufacturer supply the retailer set as $\theta(0 < \theta < 1)$. The order transfer fee is: $e = (P_r - w)d_r + (P_e - w)\theta d_e - E(E \geq 0)$, E is bigger than zero which ensures that e cannot exceed the retailer's optimal pricing.

The retailer's profit is:

$$\pi_5 = (P_r - w)d_r + (P_e - w)\theta d_e - e. \tag{18}$$

Substituting (1) and (2) into (18), we obtain the reaction function by solving the first-order condition, $\frac{\partial \pi_5}{\partial P_r} = 0$. The reaction function is: $P_r = \frac{fa + bP_e + w(1+b) + \theta b(P_e - w)}{2+2b}$, and we can get demand function:

$$d_r = \frac{fa + bfa + bP_e - w - 2wb - \theta bP_e + \theta bw + b^2P_e - wb^2 - \theta b^2P_e + \theta b^2 w}{2+2b},$$

$$d_e = \frac{2a + 2ba - 2fa - bfa - 2P_e - 4bP_e - b^2P_e + wb + wb^2 + \theta b^2P_e - \theta b^2 w}{2+2b}.$$

4.1 The Optimal Pricing of Electronic and Traditional Channel Under the Costs of Production Changes

According to the Δc to choose the manufacturer's profit function, then substituting the manufacturer's profit function into the demand function and solve two equations simultaneous. We can get the optimal sales price of traditional and electronic channel, the optimal wholesale price and the optimal demand of traditional and electronic channel. We can find that the retailer's optimal sale price under compensation strategy is the same as the retailer's optimal sale price under centralized decision-making. In light of the actual situation, the wholesale price which retailer purchase products must less than the electronic channel sales price. Thus $P_e > w$, the constraint is: $2bc - ab + c + fa - a < -(2b+1)(\Delta c - \mu_2)$.

4.2 The Total Profits of Dual-Channel Supply Chain When Meet the Constraint

Base on the result in Sect. 4.1, we can get the total profits of dual-channel supply chain:

$$\pi_1^c = \begin{cases} \dfrac{\begin{matrix}-4ab\Delta c + 8\Delta cb\mu_1 + 4b\Delta c^2 + 8cb\Delta c + 4b\mu_1{}^2 - 4abc + a^2b + 4bc^2 \\ 4c\Delta c + 2\mu_1{}^2 + 2c^2 + a^2 - 2ac - 2fa^2 + 2\Delta c^2 + 2f^2a^2 - 2a\Delta c + 4\Delta c\mu_1\end{matrix}}{4+8b}, & \Delta c \le -\mu_1 \\ \dfrac{4bc^2 - 4abc + a^2b - 2a^2f + 2a^2f^2 + 2c^2 + a^2 - 2ac}{8b+4}, & -\mu_1 < \Delta c < \mu_2 \\ \dfrac{\begin{matrix}-4ab\Delta c - 8\Delta cb\mu_2 + 4b\Delta c^2 + 8cb\Delta c + 4b\mu_2{}^2 - 4abc + a^2b + 4bc^2 \\ + 4c\Delta c + 2\mu_2{}^2 + 2c^2 + a^2 - 2ac - 2fa^2 + 2\Delta c^2 + 2f^2a^2 - 2a\Delta c - 4\Delta c\mu_2\end{matrix}}{4+8b}, & \Delta c \ge \mu_2 \end{cases}. \tag{19}$$

According to the Eqs. (6) and (19), both total profits under the compensation strategy and under the centralized decision-making are equal. The result shows that the compensation strategy realizes the pareto optimality.

4.3 The Order Transfer Fee When Meet the Constraint

In order to satisfy the actual conditions, the manufacturer and retailer have to ensure its own profits under the compensation strategy more than the profits under the decentralized decision-making. We can get the order transfer fee condition: (the specific expressions of A,B,C,D,E,F,G,H,I,J,K…etc., see the appendix.)

$$\begin{cases} \dfrac{(Aa+Ba^2+C)\theta+D}{8(2b+1)(-1-b+\theta b)(2b^2+3b+1)} \le e \le \dfrac{(Ga^2+Ha+F)\theta^2+(Ja^2+Ka+I)\theta+E}{16(2b+1)^2(2\theta b^2+\theta b-1-2b^2-3b)^2(b+1)}, \Delta c \le -\mu_1 \\ \dfrac{(A_2a+B_2a^2+C_2)\theta+D_2}{8(2b+1)(-1-b+\theta b)(2b^2+3b+1)} \le e \le \dfrac{(G_2a^2+H_2a+F_2)\theta^2+(J_2a^2+K_2a+I_2)\theta+E_2}{16(2b+1)^2(2\theta b^2+\theta b-1-2b^2-3b)^2(b+1)(1+3b+2b^2)}, \Delta c \ge \mu_2 \\ \dfrac{(A_3a^2+B_3a+C_3)\theta^2+(D_3a^2+E_3a+F_3)\theta+G_3}{8(2b+1)^2(-1-b+\theta b)^2(1+b)} \le e \le \dfrac{(H_3a^2+I_3a+J_3)\theta^2+(K_3a^2+L_3a+M_3)\theta+N_3}{16(2b+1)^2(-1-b+\theta b)^2(b+1)}, -\mu_1 < \Delta c < \mu_2 \end{cases} \quad (20)$$

5 Numerical Example

In this section our objective is to illustrate our results with the help of a selected numerical example. The parameters are a = 1000, f = 0.3, b = 0.5, c = 20 Yuan, $\mu_1 = 1$ Yuan, $\mu_2 = 2$ Yuan. When the proportion of the order that the manufacturer supply the retailer set as: $\theta = 0.4$, we can obtain (Table 1):

Table 1. Order transfer fee under compensation strategy

Changes in the costs of production	Order transfer fee is more than	Order transfer fee is less than
−5	41654.76923	45062.10256
−4	41487.82692	44871.53526
−3	41321.25641	44681.42308
−2	41155.05769	44491.76603
−1	40989.23077	44302.5641
0	41036	44303
1	41036	44303
2	41129.23077	44302.5641
3	40963.77564	44113.81731
4	40798.69231	43925.52564
5	40633.98077	43737.6891

When we choose the order transfer fee as 42000 Yuan, we can get:

Table 2. The profits of manufacturer and retailer under compensation strategy

Changes in the costs of production	The manufacturer profits under decentralized decision-making	The retailer profits under decentralized decision-making	Order transfer fee	The manufacturer profits under compensation strategy	The retailer profits under compensation strategy
−5	120840	3360.67	42000	121185.23	6422.77
−4	120403.75	3337.04	42000	120915.92	6208.58
−3	119968.33	3313.5	42000	120647.08	5994.92
−2	119533.75	3290.04	42000	120378.69	5781.81
−1	119100	3266.67	42000	120110.77	5569.23
0	118670	3266.7	42000	119630.77	5569.23
1	118670	3266.7	42000	119630.77	5569.23
2	117800	3266.67	42000	118670.77	5569.23
3	117367.08	3243.38	42000	118403.31	5357.19
4	116935	3220.17	42000	118136.31	5145.69
5	116503.75	3197.04	42000	117869.77	4934.73

The Table 2 shows that the manufacturer and retailer profits under the compensation strategy were higher than the profits under decentralized decision-making. And we realized that the manufacturer and retailer profits are changed with the order transfer fee. The more order transfer fee has to pay, the fewer profits retailer can get. So it is important for the manufacturer have a discussion with the retailer, to draw up a satisfied order transfer fee, so as to arrange the distribution of profits reasonable.

6 Conclusions

Base on the dual-channel supply chain model which manufacturer is leader, by comparing when the costs of production is changing the dual-channel supply chain profits under centralized decision-making and the dual-channel supply chain profits under decentralized decision-making, we figure out when fa > c, the traditional channel profits under decentralized decision-making is higher than the profit under centralized decision-making. In order to coordinate the conflicts and find the optimal total profit, we introduced a compensation strategy: the manufacturer supply certain proportion electronic channel order to the retailer as compensation. At the same time, the manufacturer requires a certain order transfer fee to ensure its profit. Through this compensation strategy, both sides profit are not damaged, and can achieve the total profits optimal.

In this paper, we design conditions are completely rational, so in practical application, it's inevitably encounter loopholes. There are still a lot of problems that need to be studied. For example how to coordinate the dual-channel supply chain when the customers demand present exponential function distribution.

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Appendix

1. When $\Delta c \leq -\mu_1$: $A = -2(2b+1)^2[(fb-2b-2+2f)(c+\Delta c)+2\mu_1(b-1)(f-1)]$

$B = (2b+1)(-2b^2+2f^2b^2+f^2b-4b+4bf-2-2f^2+4f)$

$C = -(2b+1)^2[6\Delta cb(c+\mu_1)+4(bc\mu_1+c\Delta c+\mu_1\Delta c)+(3b+2)({\mu_1}^2+c^2+\Delta c^2)]$

$D = -(2b+1)^2(b+1)(2c\Delta c+2\mu_1\Delta c+c^2+4\mu_1 c-$
$4\mu_1 fa-2fac+f^2a^2-2\Delta cfa+\Delta c^2+{\mu_1}^2)$

$E = 3(b+1)^2(2b+1)^4(-fa+c+\Delta c+\mu_1)^2$

$F = -b(5b+4)(2b+1)^4(\mu_1+\Delta c+c)^2$

$G = 49152b^{11}c+16(3f^2-2)b^6+16(4f+6f^2-7)b^5+8(20f+5f^2-19)b^4$
$+4(-6f^2+36f-25)b^3+(56f-21f^2-32)b^2+4(2f-f^2-1)b$

$H = [32(4-3f)(\Delta c+c)-96\mu_1 f]b^6+[384(\Delta c+\mu_1)-320f(c+\Delta c+\mu_1)]b^5+$
$16(28-25f)(c+\Delta c+\mu_1)b^4+16(16-15f)(\mu_1+\Delta c+c)b^3$
$+2(36-35f)(\mu_1+\Delta c+c)b^2+8(1-f)(\Delta c+c+\mu_1)b$

$I = (146b^2+160b^5)(c^2+\Delta c^2)+38\Delta c^2 b+288{\mu_1}^2b^3+8c\Delta c$

$J = 32(-3f^2+1)b^6+16(9-18f^2-4f)b^5+$
$8(-38f^2+33-28f)b^4+4(-28f^2+63-76f)b^3+2(66+9f^2-100f)b^2+$
$2(16-32f+11f^2)b+2(f-1)^2$

$K = (\Delta c+c+\mu_1)[64(3f-2)b^6+64(11f-8)b^5+32(33f-26)b^4$
$+64(13f-11)b^3+4(91f-82)b^2+4(21f-20)b+8(f-1)]$

2. When $\Delta c \geq \mu_2$: $A_2 = 2(2b+1)^2[(2b-fb-2f+2)(\Delta c+c)+2\mu_2(b+1)(f-1)]$

$B_2 = (2b+1)(-2b^2+2f^2b^2+f^2b-4b+4bf-2-2f^2+4f)$

$C_2 = (2b+1)^2[6b\Delta c(c-\mu_2)-4(bc\mu_2+\mu_2\Delta c+\mu_2 c+$
$c\Delta c)+(2+3b)(\Delta c^2+{\mu_2}^2+c^2)$

$D_2 = -(b+1)(2b+1)^2[4\mu_2(fa-c)-2(fa\Delta c-c\Delta c+\mu_2\Delta c+cfa)$
$+(f^2a^2+{\mu_2}^2+\Delta c^2+c^2)]$

$E_2 = 3(b+1)^3(2b+1)^5(fa-\Delta c+\mu_2-c)^2$

$F_2 = -b(\Delta c-\mu_2+c)^2(b+1)(5b+4)(2b+1)^5$

$G_2 = 32(3f^2-2)b^8+16(-20+8f+21f^2)b^7+32(16f+13f^2-31)b^6$
$+8(-96+104f+21f^2)b^5+2(-258+352f-37f^2)b^4+(-95f^2+328f-204)b^3$
$+(-33f^2-44+80f)b^2-2(f-1)^2b$

$H_2 = -2b(b+1)(2b+1)^5(\Delta c - \mu_2 - c)(3bf - 4b - 4 + 4f)$
$I_2 = \left(\Delta C^2 + {\mu_2}^2 + C^2\right)\left(64b^8 + 416b^7 + 1120b^6 + 1648b^5 + 1460b^4 + 802b^3 + 268b^2\right.$
$\left. + 50b + 4\right) + (\Delta cc - \mu_2\Delta c - \mu_2 c)(128b^8 + 832b^7 + 2240b^6 + 3296b^5 + 2920b^4$
$+ 1604b^3 + 536b^2 + 100b + 8)$
$J_2 = 64\left(1 - 3f^2\right)b^8 + 16\left(24 - 8f - 54f^2\right)b^7 + 32\left(31 - 20f - 49f^2\right)b^6$
$+ 16\left(90 - 89f^2 - 84f\right)b^5 + 4\left(-384f - 151f^2 + 321\right)b^4 + 2\left(-7f^2 + 360 - 516f\right)b^3$
$+ 4\left(62 + 23f^2 - 102f\right)b^2 + 2\left(24 + 17f^2 - 44f\right)b + 2(f-1)^2$
$K_2 = 4(b+1)^2(2b+1)^5(\Delta c - \mu_2 + c)(-2b + 3bf - 2 + 2f)$
3. When $-\mu_1 < \Delta c < \mu_2$: $A_3 = b(2b+1)(2f^2b^2 - 2b^2 + 4fb + f^2b - 4b - 2 - 2f^2$
$+ 4f)$
$B_3 = -2bc(2b+1)^2(-2b + fb - 2 + 2f);$
$C_3 = -bc^2(3b+2)(2b+1)^2$
$D_3 = -2(2b+1)(b+1)^2(2f^2b - b + 2f - 1 - f^2)$
$E_3 = 4c(b+1)^2(2b+1)^2(f-1)$
$F_3 = 2c^2(b+1)^2(2b+1)^2$
$G_3 = \left(4a^2b^4 + 12a^2b^3 + 13a^2b^2 + 6a^2b + a^2\right)f^2$
$\left(-24ab^3c - 12abc + 26ab^2c - 8ab^4c - 2ca\right)f + 4b^4c^2 + c^2 + 6bc^2 + 12b^3c^2 + 13b^2c^2$
$H_3 = b(2b+1)(6f^2b^2 - 4b^2 + 3f^2b - 8b + 8bf - 4f^2 - 4 + 8f)$
$I_3 = -2bc(2b+1)^2(3bf - 4b - 4 + 4f)$
$J_3 = -bc^2(5b+4)(2b+1)^2$
$K_3 = -2\left(-2b^2 + 6f^2b^2 + 3f^2b - 4b + 4bf - 2 - 2f^2 + 4f\right)(b+1)(2b+1)$
$L_3 = 4c(b+1)(2b+1)^2(3bf - 2b + 2f + 2)$
$M_3 = 2c^2(b+2)(b+1)(2b+1)^2$
$N_3 = 3\left(4fab^2 + 3fab + fa - c - 3bc - 2b^2c\right)(-c - 3bc - 2b^2c + fa + 3fab)$

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