Research on Product Quality Improvement Strategy of Supply Chain Considering Consumers' Double Preference

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ABSTRACT
This paper aim is to improve the product quality of manufacturer, under considering the dual preference of consumer channel and quality. Our conclusions show that the manufacturer's profit and quality improvement boundary are uncorrelated with channel preference, under decentralized decision-making; manufacturer profit and quality improvement boundary are correlative to preference channel. Therefore, the manufacturer can reduce the cost of quality improvement through upgrading production technology, implementing quality management and other means. Moreover, at the same time, the manufacturer can improve consumers' recognition of high-quality products through advertising and other means.
Keywords: *quality preference, channel preference, product quality improvement*

1. INTRODUCTION

With the development of e-commerce, the business strategy of manufacturing enterprises has shifted from the traditional single channel to the dual channels, while the focus of consumers is mainly on the reliability of the quality of online goods and the convenience of shopping channels. Therefore, many scholars have studied dual-channel supply chain from different fields.

Early studies mainly focused on the realization of supply chain balance and coordination, by adjusting competitive factors such as service level and product quality. Such as, Banker [1] studied the equilibrium level of product quality in different competitive environments, and then analyzed the relationship between the intensity of competition and product quality. Hall etal. [2] considered multi-stage sales with capacity limitation, and then analyzed the positive correlation between product quality level and fierce market competition. Kranton etal. [3] studied that the product quality of different enterprises was affected by consumers' purchasing experience and preference.

Recent years, some scholars studied product quality problems from the perspective of internal operation of supply chain management. Li etal. [4] discussed how to adopt appropriate quality control strategies under the condition of bilateral moral hazard. Lu and Zhu, Chen et al. Introduced the influence of product quality on supply chain balance and performance [5-8], Xiao [9] studied such as composed of two suppliers and one manufacturer in supply chain system, under the effect of quality competition and price competition at the same time, the members of the supply chain coordination strategy. Li etal. [10] basing on the game theory, studied the influence of quality improvement on the coordination of sales channels, price, sales volume and total profits of the system, under the three modes of pure retail, pure direct selling and dual-channel coexistence. Li etal. [11] considered that both suppliers and manufacturers have equity concerns, and analyzed the impact of equity concerns and supply chain game structure on product quality and retail pricing optimization decision. Wang etal. [12] established a network equilibrium model of service supply chain that takes into account fairness concern and quality, and analyzed the influence of fairness concern behavior and lower limit of service quality standard on its trading volume, quality and utility, as well as the equilibrium decision-making of the whole network.

Subsequent scholars introduced consumers' channel preferences. Such as, Lin [13] Analyzed manufacturer' product quality and pricing decisions under different channel choice level. Sun etal. [14] differentiated consumers' channel preference, and then sought the optimal emission reduction boundary of low-carbon supply chain through comparison of different decision-making modes and analysis of numerical examples. Zuo [15] analyzed the dual-channel pricing strategy of retail enterprises based on the channel preference of consumers.

To sum up, the improvement of product quality mainly realizes controlling material quality and strengthening the internal operation of supply chain. Under the consideration of consumer channels, the research only discusses product pricing through different channels, without considering the channel preference that commodity quality will affect consumption. Therefore, this paper considers the manufacturer's quality improvement strategy under the condition that consumers have both quality and channel preferences. In order to simplify the research, this paper uses the reduction degree of commodity quality complaints to express the manufacturer's product quality improvement degree. The boundary conditions of quality improvement of dual-channel supply chain under different decision-making modes are further studied.

2. BASIC MODEL AND ASSUMPTIONS

In this paper, we consider a two-level supply chain composed of a manufacturer and a retailer, the manufacturer

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and the retailer make independent decisions, and with the goal of maximizing their own interests in the decision-making process. According to the Stackelberg game decision order, the supplier first sets the wholesale price and quality improvement degree, and then the retailer decides the retail price and order quantity, according to the manufacturer's decision and the market demand. We made the following assumptions:

(1) The manufacturer and the retailer about market information are symmetric and complete, and the market can be completely cleared. The market capacity of the product is d , θ represents the channel preference of consumers.

(2) When the manufacturer does not carry out quality improvement, the complaint rate of consumers to the product quality isv_0, after the manufacturer improves the product quality, the complaint rate isv_1, we order that $\varepsilon = (v_0 - v_1)/v_0$ ($0 < \varepsilon \leq 1$) represents the improvement degree of the manufacturer to the product quality improvement rate (hereinafter referred to as the quality improvement degree).

(3) The initial production cost of the manufacturer is c,$c_1 = \varepsilon^{-n}c$ it represents the cost that the manufacturer reduces the complaint rate by improving quality, and $n(n > 0)$ represents the sensitivity of cost to quality improvement. $f(f > 0)$ Represents the sensitivity coefficient of consumers to the degree of product quality, and ε^f represents the influence factor of demand. n/f Represents the impact ratio of reduced quality complaint rate on quality cost-demand.

(4) Consumers pay attention to the rate of complaints about product quality, and are willing to pay higher prices for high-quality products. The demand of selling products will be influenced by consumers' channel preference, quality preference, and product price and quality complaint rate.

Table 1 Notations

Parameter	Definition
d	market capacity
θ	network channel preference
ε	quality complaint rate improvement
n	cost sensitivity to quality improvement
α	price to cost ratio
c	manufacturer's initial cost
w	wholesale price
p	sales price
f	consumer sensitivity to quality

In order to distinguish the profit function of manufacturers, retailers and the whole supply chain, we use m , r and sc as subscripts.

The demand function of manufacturer and retailer can be written as:

$$q_m = \theta d - \varepsilon^f p \quad (1)$$

$$q_r = (1-\theta)d - \varepsilon^f p \quad (2)$$

The manufacturer, retailer, and supply chain profit models can be written as:

$$\pi_m = (w - \varepsilon^{-n}c)\left[(1-\theta)d - \varepsilon^f p\right] + (p - \varepsilon^{-n}c)(\theta d - \varepsilon^f p) \quad (3)$$

$$\pi_r = (p - w)\left[(1-\theta)d - \varepsilon^f p\right] \quad (4)$$

$$\pi_{sc} = (p - \varepsilon^{-n}c)(d - 2\varepsilon^f p) \quad (5)$$

3. MODEL ANALYSIS

3.1. When the Manufacturer does not Take Quality Improvement Measures ($\varepsilon = 1$)

3.1.1. Centralized Decision Situation

The overall profit function of the supply chain is:

$$\pi_{sc} = (p - c)(d - 2p)$$

Solve it can be available:

$$p = \frac{c}{2} + \frac{d}{4}, \quad q = \frac{d}{2} - c, \quad \pi_{sc} = \frac{(d\text{-}2c)^2}{8}, \quad \alpha_1 = \frac{p}{c} = \frac{1}{2} + \frac{d}{4c}$$

3.1.2. Decentralized Decision Situation

Joint equations (3) and (4) can be obtained as follows:

$$p = \frac{2c + (3-2\theta)d}{6}, \quad q_m = \frac{(8\theta - 3)d - 2c}{6}, \quad q_r = \frac{(3-4\theta)d - 2c}{6}$$

The Profits of manufacturers, retailers and the entire supply chain are:

$$\pi_m = -\frac{2d^2\theta^2}{3} + \frac{d(3d-2c)}{3}\theta - \frac{d^2}{4} + \frac{1}{3}c^2$$

$$\pi_r = \frac{4d^2\theta^2}{9} - \frac{2d(3d-2c)}{9}\theta + \frac{d^2}{4} - \frac{dc}{3} + \frac{1}{9}c^2$$

$$\pi_{sc} = -\frac{2d^2}{9}\left(\theta - \frac{3d-2c}{4d}\right)^2 + \frac{(d-2c)^2}{8}$$

$$\alpha_2 = \frac{wq_r + pq_m}{q_r + q_m} = h(\theta) = \frac{1}{2} + \frac{\theta d}{2c} - \frac{3\left(\theta - \frac{1}{2}\right)^2 d^2}{2c(\theta d - c)} \quad \left(1 < h(\theta) < \frac{1}{2} + \frac{\theta d}{2c}\right)$$

According to the formula of manufacturer's price-cost ratio, α is affected by d 、 c and θ.

3.2. When the Manufacturer Takes Quality Improvement Measures ($\varepsilon \neq 1$)

3.2.1. Centralized Decision Situation

According to equation (5), we can be obtained p 、 q then, Bring those into formula (5), obtains the supply chain profit:

$$p = \frac{2c\varepsilon^{f-n} + d}{4\varepsilon^f} = \frac{c}{2}\varepsilon^{-n} + \frac{d}{4}\varepsilon^{-f}, \quad q = q_m + q_r = d - 2\varepsilon^f p = \frac{d}{2} - c\varepsilon^{f-n}$$

$$\pi_{sc} = \frac{d^2}{8}\varepsilon^{-f} + \frac{c^2}{2}\varepsilon^{f-2n} - \frac{dc}{2}\varepsilon^{-n}, \quad \alpha_2 = \frac{p}{c} = \frac{\varepsilon^{-n}}{2} + \frac{d}{4c}\varepsilon^{-f}$$

Proposition 1: $n/f = 1/2 + d/4c$ the manufacturer does not take corrective action against quality complaints

Proving Course: According to the condition, n/f represents the impact ratio of reducing quality complaint rate on quality cost-demand, α is the profit ratio of a manufacturer's unit product. When manufacturers do not adopt quality improvement strategies ($\varepsilon = 1$), and then $p = c/2 + d/4$

If $n/f > \alpha$, it means that the cost of improving the quality of goods is higher than the benefit without improvement, and the total utility will reduce. As a rational decision maker, manufacturer will choose not to improve the strategy. Therefore, $n/f = 1/2 + d/4c$ the manufacturer does not take corrective action against quality complaints.

Proposition 2: $0 < n/f < 1/2 + d/4c$, manufacturers will adopt quality improvement strategies and there is an optimal degree of improvement.

Proving Course: $0 < n/f < 1/2 + d/4c$, it means that the cost of improving the quality of goods is lower than the income without improving, the total income will increase, and the manufacturer adopts the improvement strategy.

According to equation (6), ε can be solved as follows:

$$\frac{\partial \pi_{sc}}{\partial \varepsilon} = \frac{c^2(f-2n)}{2}\varepsilon^{f-2n-1} - \frac{fd^2}{8\varepsilon^{f+1}} + \frac{dcn}{2\varepsilon^{n+1}} = \frac{\varepsilon^{-f-1}}{2}\left(c(f-2n)\varepsilon^{f-n} + \frac{fd}{2}\right)\left(c\varepsilon^{f-n} - \frac{d}{2}\right) \quad (7)$$

It satisfies the conditions: $\begin{cases} p > w > c\varepsilon^{-n} \\ (1-\theta)d > \varepsilon^f p > c\varepsilon^{f-n} \\ \theta d > \varepsilon^f p \end{cases}$

Set: $g(x) = \left(c(f-2n)x + \frac{fd}{2}\right)\left(cx - \frac{d}{2}\right)$

($x = \varepsilon^{f-n}$)

When: $g(x) = 0$, $x_1 = \frac{fd}{2c(2n-f)}, x_2 = \frac{d}{2c}$

1) when $0 < n/f < 1/2$, $0 < x < 1$, as figure 1:

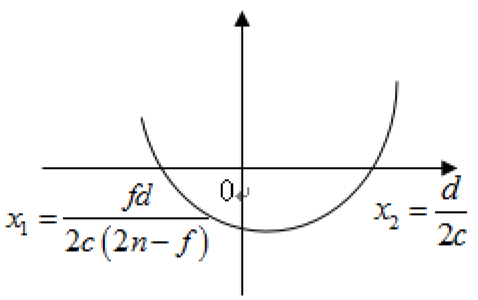

Figure 2 The Function graph of $g(x)$

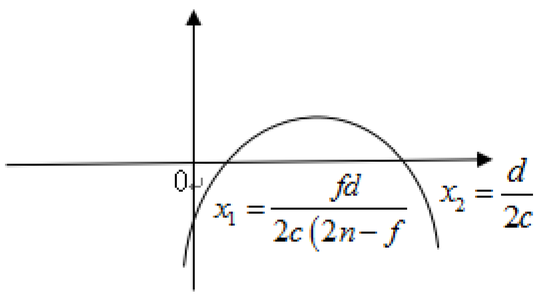

Figure 3 The Function graph of $g(x)$

when $(0 < n/f < 0.5)$ when $0.5 < n/f < 1$

As shown in the figure 1: $x_1 < 0$, $g(0) = -fd^2/4 < 0$. $x_2 > 1$, $1/2 + d/4c > 1$

So, when $0 < x < 1$, $g(x) < 0$, that means, π_{sc} is a minus function of ε, and the manufacturer will continue to make quality improvement.

2) when $0.5 < n/f < 1$, $0 < x < 1$, as figure 2

As shown in the figure 2: $g(0) = -fd^2/4 < 0$; if $x_1 < 1$, then $x_2 < 1$, it contradicts the conditions $x_2 > 1$, so $x_1 > 1$. That means, π_{sc} is a minus function of ε, and the manufacturer will continue to make quality improvement, when $0 < x < 1$.

3) when $1 < n/f < 1/2 + d/4c$, $x > 1$, as figure 3

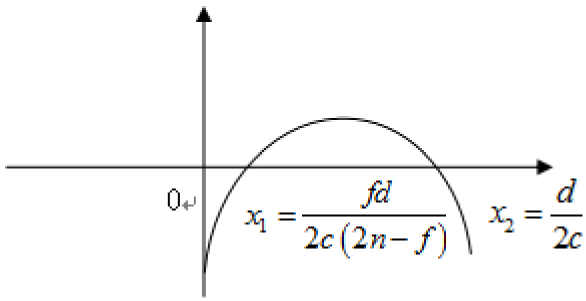

Figure 4 The Function graph of $g(x)$ when $(1 < n/f)$

As shown in the figure 2 and 3: $x_1 > 1$, $g(0) = -fd^2/4 < 0$. $x_2 > 1$, So, when $1/2 + d/4c > 1$, π_{sc} Is a minus function of ε, when $x \in (1, x_1)$, and manufacturer will continue to make quality improvement. π_{sc} Is an increasing function of ε; when $x \in (x_1, x_2)$, from the above analysis, it can be seen that the manufacturer's quality improvement strategy has an optimal degree of improvement.

The solution to equation (7) can be obtained:

$$\varepsilon^* = \left[\frac{fd}{2c(2n-f)}\right]^{\frac{1}{f-n}}, \quad p^* = \left[\frac{nd}{2(2n-f)}\right]\varepsilon^{*-f},$$

$$\pi_{sc} = \frac{\varepsilon^{*-f}}{2}\left(\frac{d}{2} - c\varepsilon^{*-n}\right)^2$$

3.2.2. Decentralized Decision Situation

The solution to equation (4), it obtains:

$$p = \frac{(1-\theta)d + w\varepsilon^f}{2\varepsilon^f}$$

bring p into equation (3), it can get

$$\pi_m(w) = \frac{1}{2}\left(w - c\varepsilon^{-n}\right)\left[(1-\theta)d - \varepsilon^f w\right] + \left[\frac{w}{2} + \frac{(1-\theta)d\varepsilon^{-f}}{2} - c\varepsilon^{-n}\right]\left[\frac{\varepsilon^f w}{2} - \frac{\varepsilon^{f-n} c}{2} ... \right]$$

$$\frac{\partial \pi_m}{\partial w} = -\frac{3}{2}\varepsilon^f w + c\varepsilon^{f-n} + \frac{\theta d}{2}$$

we can be obtaining:

$$w = \frac{\theta d}{3}\varepsilon^{-f} + \frac{2c}{3}\varepsilon^{-n}, \quad q_m = \frac{(8\theta-3)d}{6} - \frac{c}{3}\varepsilon^{f-n},$$

$$q_r = \frac{(3-4\theta)d}{6} - \frac{c}{3}\varepsilon^{f-n}$$

And then,

$$\alpha_3 = \frac{\left[\left(3\theta - 2\theta^2 - \frac{3}{4}\right)d^2 - c^2\varepsilon^{2f-2n}\right]\varepsilon^{-f}}{2d\theta - 2c\varepsilon^{f-n}}$$

Proposition 3: When the cost-demand ratio of improving quality by reducing complaint rate is different, manufacturers will adopt different quality improvement strategies.

1) Manufacturers will choose not to improve the strategy for the cost of reducing the complaint rate is higher than the benefit, when $n/f > h(\theta)$.

2) Manufacturers will take corresponding measures to reduce the complaint rate, there is an optimal degree of improvement, when $1 < n/f < h(\theta)$.

Proving:1) $n/f > \alpha = h(\theta)$, According to the proof process of proposition 1, since the cost of reducing the complaint rate is higher than the benefit, the manufacturer will choose not to improve the strategy. And then ε=1

2) bring p, w into equation (3), And solving equations about ε:

$$\frac{\partial \pi_{dm}}{\partial \varepsilon} = \frac{c^2}{3}(f-2n)\varepsilon^{f-2n-1} + \frac{2\theta cdn}{3}\varepsilon^{-n-1} - \frac{12\theta - 8\theta^2 - 3}{12}fd^2\varepsilon$$

$$\varepsilon = \left[\frac{\theta dn}{c(2n-f)} \pm \frac{1}{c}\sqrt{\frac{B}{f-2n}}\right] \frac{(3\theta-1)d}{2},$$

$$\left(B = \frac{(nd\theta)^2}{(f-2n)} - \left(2\theta^2 - 3\theta + \frac{3}{4}\right)fd^2\right)$$

Then we can obtain:

$$\pi_m = \varepsilon^{-f}\left[\frac{1}{3}\left(c\varepsilon^{f-n} - \theta d\right)^2 - \left(\theta - \frac{1}{2}\right)^2 d^2\right]$$

$$\pi_r = \varepsilon^{-f}\left[\frac{d}{6}(3-4\theta) - \frac{c}{3}\varepsilon^{f-n}\right]^2$$

$$\pi_{sc} = \varepsilon^{-f}\left[\frac{(3-2\theta)d}{6} - \frac{2c}{3}\varepsilon^{f-n}\right]\left(\frac{2\theta d}{3} - \frac{2c}{3}\varepsilon^{f-n}\right)$$

3.3. Contrastive Analyses

According to the above analysis, the quality improvement degree boundary of the manufacturer is $\alpha_1 = 1/2 + d/4c$, under centralized decision-making .it has nothing to do with the channel preference. Under decentralized decision-making, the quality improvement degree boundary is α_2, according to the above equation, α_2 is the function of θ

$$\alpha_2 = \frac{1}{2} + \frac{\theta d}{2c} - \frac{3\left(\theta - \frac{1}{2}\right)^2 d^2}{2c(\theta d - c)}$$

Based on the given condition:

$$q_m = \frac{(8\theta - 3)d - 2c}{6} > 0$$

$$q_r = \frac{(3 - 4\theta)d - 2c}{6} > 0$$

We can conclude: $\frac{3}{8} + \frac{c}{4d} < \theta < \frac{3}{4} - \frac{c}{2d}$

We will contain: when $\theta = \frac{\sqrt{6}}{4} - \frac{\sqrt{6}c}{2d} + \frac{c}{d}$, α_2 has maximum.

Corollary 1

1) The quality improvement boundary increases with the increase of channel preference. When $\frac{3}{8} + \frac{c}{4d} < \theta < \frac{\sqrt{6}}{4} - \frac{\sqrt{6}c}{2d} + \frac{c}{d}$

2) The quality improvement boundary decreases with the increase of channel preference, when $\frac{\sqrt{6}}{4} - \frac{\sqrt{6}c}{2d} + \frac{c}{d} < \theta < \frac{3}{4} - \frac{c}{2d}$.

4. NUMERICAL SIMULATION

In order to further study, display and verify the conclusions in this paper, this section conducts simulation analysis on the assignment of relevant parameters, where the parameters are: $d = 60, c = 3, n = 5, f = 0.5$

(1) Under decentralized decision-making, channel preference has an impact on profits of all parties.

As can be seen from figure 4, in the absence of quality improvement, the profit of the manufacturer and the supply chain increases with the increase of θ, but there is a maximum point. The profit of retailers decreases with the increase θ, but there is a minimum point. This is because; Consumers choose more online channels to buy with the increase θ.

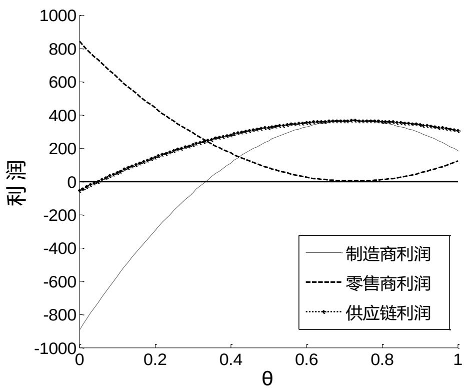

Figure 5 Influence of channel preference On profits of all parties

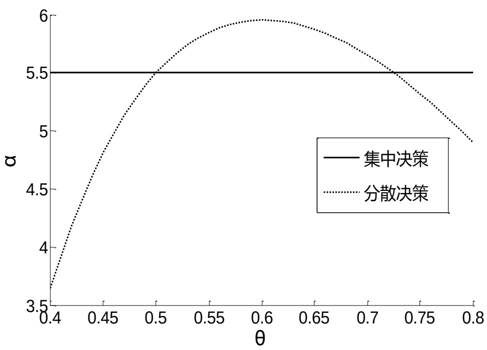

Figure 6 Influence of channel preference on quality improvement boundary

(2) Influence of channel preference on quality improvement boundary

As can be seen from figure 5, the boundary of manufacturer's quality improvement is fixed under centralized decision-making. Under decentralized decision-making, the quality improvement boundary increases first and then decrease with the increase of channel preference. When $0 < \theta < 0.5$, the improved boundary of centralized decision is larger than decentralized decision; when $\theta = 0.5$, the improved boundary of the two decision modes is the same; when $0.5 < \theta < 0.745$, the improved boundary of decentralized decision is larger than that of centralized decision. This is consistent with the analysis of the quality improvement boundary in section 3.3.

(3) The influence of channel preference on the optimal improvement degree

As can be seen from figure 6, under centralized decision-making, the optimal improvement degree is independent of channel preference, but only affected by the cost-demand ratio. Under decentralized decision-making, the optimal improvement degree ε decreases first and then increases with the increase of θ .Therefore, the increase of channel preference can bring higher profits to manufacturers. However, when the θ further increase will cause ε increase, this is detrimental to the quality improvement of the supply chain. Therefore, there is an optimal channel preference point.

At the same time, Depending on the value of n, f, we found that ε increases as n/f increases. Therefore, manufacturers can make consumers prefer high-quality products by producing better quality products or through external publicity, to achieve a reduction in n/f, thereby reducing the optimal improvement degree ε .

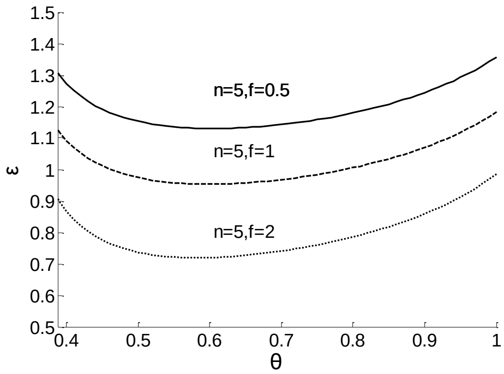

Figure 7 Influence of channel preference on the optimal improvement degree

5. CONCLUSION

In the dual channel supply chain quality improvement, the manufacturer price - cost ratio is the key parameter of quality improvement strategy, the parameters to affect the quality improvement further. Manufacturers will improve the quality of the border by consumer channels the dual effects of preferences and price - cost ratio. Under centralized decision-making, the manufacturer's profits and degree of quality improvement is not affected by channel preference; under decentralized decision making, the profits of manufacturers and quality improvement boundary are affected by the preference of channel. When consumer’s network channel preference is low, centralized decision making greater improvement; when consumer web channel preference is higher, higher degree of improvement of decentralized decision making; Existence preference points make two patterns the same degree of improvement.

The paper only considers double preference under linear demand function of the general strategy, not considering the random demand of quality improvement strategies, at the same time, also can further study when manufacturers have fairness concerns the psychological, its quality improvement strategy selection problem.

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