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Consider strategic consumers and trade-in product dynamic pricing strategy research

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Abstract. This paper analyzes the choice behavior of strategic consumers and the impact of trade-in on product pricing path, compares the equilibrium deviation between different pricing decision-making methods, and discusses the optimal product pricing strategy under different situations. It is found that strategic consumers tend to buy low quality products with lower price if the degree of strategy is higher. The higher the level of quality investment, the stronger the willingness of strategic consumers to buy new products. Compared with centralized decision-making, decentralized decision-making is more conducive to the two enterprises to improve their own profit level. The relevant conclusions of the research can provide forward-looking basis for enterprises in the launch timing of new and old products, pricing decisions and trade-in strategies, which has certain theoretical significance and practical value.

Keywords: Strategic Consumers; Trade-in; Dynamic Pricing; Quality Difference.

1. Introduction

With the rapid development of science and technology, enterprises are constantly improving the marketization speed of new products, and the differences between products of the same consumption grade in quality, price and even marketing strategies are becoming less and less [1]. In order to protect the existing market share and further tap the consumption potential, many enterprises have adopted the strategy tool of "trade-in for new" to motivate consumers to purchase and experience new products. Apple, millet and companies such as HUAWEI, for example, the club's official website opened to old change new channels, by to help consumers evaluate the product to determine its price deduction, if consumers choose to old change new, so pay only after the deduction of the price of the new product can be completed the purchase process, greatly improves the consumer's buying experience, then achieve the purpose of mining market demand. However, in the context of e-commerce, product-related information is increasingly public. In order to improve their own utility in the process of purchase, consumers tend to compare the price and quality of similar products with the known information. Such consumers are generally called strategic consumers in the field of operation management [2]. Although studies have shown that differentiation strategy can effectively alleviate the adverse impact of strategic consumers' delayed purchase on enterprise product operation [3], how can enterprises adjust the quality and price of products sold to strategic consumers to encourage consumers to trade in old products for new ones? What kind of pricing method is more suitable for enterprises to adopt the old for new strategy? These are the practical problems that enterprises need to solve.

The trade-in model has excellent performance in product sales, resource reuse, environmental governance and other aspects [4-6], which has been regarded by some enterprises as a necessary operation means to achieve long-term market development. Therefore, many scholars have incorporated it into the analysis framework of operation management to discuss relevant decisions of enterprises. Although the above studies discussed the implementation conditions of the trade-in strategy from the perspective of enterprises and consumers respectively, they ignored the situation of strategic consumers in the market demand side. Unlike short-term consumer, strategic consumers pay more attention to product quality and price in the process of shopping attributes such as factors affect its utility, and the effectiveness of its focus is not only the current product price, on a sales or the next issue of the product price, and competitors' products prices are strategic consumers weigh the own effectiveness is an important part [7-12]. A potential condition of the trade-in strategy is

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that the consumers who hold the old products can buy the new products, and there is a certain difference between the old and new products [13,14]. Obviously, under the condition of trade-in, strategic consumers who hold old products will decide whether to trade in or not, depending on whether the new products can bring greater utility to them, which will have an important impact on the market demand estimation of enterprises and the price adjustment strategy of new and old products.

In the case of strategic consumers on the market demand side, the new products sold by the enterprise in the second stage will be considered. By analyzing the strategic consumer behavior and introducing the old for new strategy into the demand function, the dynamic pricing decision model is established. By analyzing the optimal product price path, this paper discusses the influence of the main parameters on corporate profits and pricing model selection, and tries to answer the relevant questions mentioned above.

2. Model

Strategic Consumers. It is assumed that strategic consumers in the market do not have the situation of repeated purchase, that is, each consumer can only buy one unit of product at most. This assumption has been widely used in relevant researches in the field of strategic consumer behavior operation, and its scientificity has been verified by many scholars [15]. In the second stage, strategic consumers are more sensitive to product price due to the higher quality of the new product. After the end of this stage, all consumers can purchase a unit of product, that is, consumer surplus is not less than zero. In addition, it is assumed that the cost variation of consumer search and waiting time caused by purchase is not considered in the purchase process. Accordingly, the number of strategic consumers in the market can be U, and the valuation of the required products is v, and follows [0, v^+] the uniform distribution.

Product. It is assumed that the unit production cost of products A and B is $c_w > 0$, and to make the model more consistent with economic practice, it is assumed that the unit production cost of the new product is not lower than that of products A and B, $c_n \geq c_w > 0$. The two enterprises will decide the product quality input and sales price according to the actual demand, and both take the pursuit of profit maximization as the action goal.

Scenario 1. The unit product quality input of the two enterprises in the first stage are q_A and q_B, the price are p_{A1} and p_{B1}, and $c_w > q_A > q_B$, product A has relatively higher quality and price. In the second stage, considering the quality loss caused by product advancement over time (i.e. relative to new products, old products in use function and durability decreases over time), consumers' overall evaluation of the product will also decline. At this point, the product price is respectively, and the discount coefficient are p_{A2} and p_{B2}. The higher the consumer's strategic degree is $\alpha \in (0,1)$. In addition, since product quality input is a key factor affecting consumers' purchase, enterprises producing low-quality products have the motivation to narrow the difference between high-quality products and high-quality products. It can be assumed $0 < \alpha < q_B / q_A \leq 1$, that this means that the smaller the quality difference between products, the lower the valuation loss of products in the second phase. It reflects the view that high-quality products can alleviate the waiting behavior of strategic consumers [16].

Situation 2. The first stage is similar to scenario 1. But in the second stage, the two companies sell new products AN and BN to tap market demand. The price of the new product is p_{AN} and p_{BN}, and the unit quality input is q_{AN} and q_{BN}. This kind of product is mainly sold to consumers who have not purchased the product in the first stage. In addition, consumers who have already purchased a product in the first stage can exchange for a new product in the second stage based on the recovered price and the recovered price spot. The recovery price are p_{A0} and p_{B0}.The profit that the two

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enterprises can obtain from recycling products is s [17], which meets the conditions $0 < p_{A0}, p_{B0} \le s$. This indicates that the unit income obtained by the old product is not less than the recycling price, which is the profitable condition for the enterprise under the trade-in strategy.

3. The decision-making process of strategic consumers

Not selling new products. In this scenario, the products that strategic consumers can choose in the first stage include A and B, and the valuation function $v_A^1=\beta_a v$ and $v_B^1=\beta_b v$. Where, $\beta_a,\beta_b \in (0,1)$ is the quality sensitivity coefficient of consumers on products A and B, is the function of product quality input and production cost, and the expression are $\beta_a = q_A / c_w$ and $\beta_b = q_B / c_w$. This reflects that the degree of quality difference between products is the key factor affecting consumers' evaluation of products, and the unit product quality input is not higher than the production cost, that is, relative to the production cost, the higher the product quality input, the higher the consumer's evaluation of products. In the second stage, products A and B will be sold at discounted prices as time goes by, and the valuation function $v_A^2=\alpha\beta_a v$ and $v_B^2=\alpha\beta_b v$. The consumer surplus functions at different stages are $S_A^1=v_A^1-p_{A1}$, $S_A^2=v_A^2-p_{A2}$, $S_B^1=v_B^1-p_{B1}$ and $S_B^2=v_B^2-p_{B2}$ respectively.

When strategic consumers purchase product A or product B in the first stage, conditions $S_A^1 \ge \max\{S_B^1,S_A^2,S_B^2\}$ and $S_B^1 \ge \max\{S_A^1,S_A^2,S_B^2\}$ shall be met respectively. In the second stage, consumers who have not purchased products in the early stage will purchase as long as the consumer surplus is greater than zero. Otherwise, the waiting behavior in the previous stage is meaningless. So if you buy product A or product B, conditions $S_A^2 \ge \max\{S_B^2,0\}$ and $S_B^2 \ge \max\{S_A^2,0\}$ are met, respectively. Enterprises determine the final sales price based on the product selection of strategic consumers in different sales stages. When the product quality is high and consumers have a high evaluation, the purchase behavior will be triggered. According to relevant assumptions, the order of product purchase of consumers can be known. The market share of strategic consumers purchasing different products in each stage is as follows:

$$\begin{cases} D_A^1=\dfrac{U}{v^+}\left[v^+-\dfrac{c_w\left(p_{A1}-p_{B1}\right)}{q_A-q_B}\right];\ D_B^1=\dfrac{U}{v^+}\left[\dfrac{c_w\left(p_{A1}-p_{B1}\right)}{q_A-q_B}-\dfrac{c_w\left(p_{B1}-p_{A2}\right)}{q_B-\alpha q_A}\right] \\ D_A^2=\dfrac{U}{v^+}\left[\dfrac{c_w\left(p_{B1}-p_{A2}\right)}{q_B-\alpha q_A}-\dfrac{c_w\left(p_{A2}-p_{B2}\right)}{\alpha\left(q_A-q_B\right)}\right];\ D_B^2=\dfrac{U}{v^+}\left[\dfrac{c_w\left(p_{A2}-p_{B2}\right)}{\alpha\left(q_A-q_B\right)}-\dfrac{c_w p_{B2}}{\alpha q_B}\right] \end{cases} \tag{1}$$

Selling new products. Strategic consumers value products A and B as $v_A^1=\beta_a v$ and $v_B^1=\beta_b v$ in the first stage. In the second stage, since the two enterprises sell new products AN and BN, depreciation or valuation loss is

not considered, and the consumer valuation function is $v_A^N=\beta_{an} v$ and $v_B^N=\beta_{bn} v$ respectively. Where, $\beta_{an},\beta_{bn} \in (0,1)$ respectively are the quality sensitivity coefficients of consumers for new products, and are functions of quality and production cost, with expressions $\beta_{an}=q_{AN}/c_n$ and $\beta_{bn}=q_{BN}/c_n$ respectively. The consumer surplus functions at different stages are $S_A^1=v_A^1-p_{A1}$, $S_A^N=v_A^N-p_{AN}$, $S_B^1=v_B^1-p_{B1}$ and $S_B^N=v_B^N-p_{BN}$ respectively.

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According to the assumptions, conditions $S^1_A \geq \max\{S^1_B, 0\}$ and $S^1_B \geq \max\{S^1_A, 0\}$ must be met to trigger strategic consumers to purchase products in the first stage. In the second stage, strategic consumers need to satisfy conditions $S^N_A \geq \max\{S^N_B, 0\}$ and $S^N_B \geq \max\{S^N_A, 0\}$ to purchase products. It is worth noting that in the first stage, consumers who have already purchased products can exchange them for new products at the corresponding recovery price, so the evaluation functions of consumers participating in the trade-in strategy for new products are $v^n_A = \beta v_{an} + p_{A0}$ and $v^n_B = \beta v_{bn} + p_{B0}$ respectively. Accordingly, the consumer surplus functions are $S^n_A = v^n_A - p_{AN}$ and $S^n_B = v^n_B - p_{BN}$. Therefore, conditions $S^n_A \geq 0$ and $S^n_B \geq 0$ must be met to trigger strategic consumers to trade in old ones for new ones. According to the above analysis, it can be concluded that the market shares of strategic consumers in purchasing and exchanging products at various stages are as follows:

$$\begin{cases} D^{1n}_A = \frac{U}{v^+}\left[v^+ - \frac{c_w(p_{A1}-p_{B1})}{q_A-q_B}\right]; D^{1n}_B = \frac{U}{v^+}\left[\frac{c_w(p_{A1}-p_{B1})}{q_A-q_B} - \frac{c_w p_{B1}}{q_B}\right] \\ D^N_A = \frac{U}{v^+}\left[\frac{c_w p_{B1}}{q_B} - \frac{c_n(p_{AN}-p_{BN})}{q_{AN}-q_{BN}}\right]; D^N_B = \frac{U}{v^+}\left[\frac{c_n(p_{AN}-p_{BN})}{q_{AN}-q_{BN}} - \frac{c_n p_{BN}}{q_{BN}}\right] \\ D^{2n}_A = \frac{U}{v^+}\left[\frac{c_w(p_{A1}-p_{B1})}{q_A-q_B} - \frac{c_n(p_{AN}-p_{A0})}{q_{AN}}\right]; D^{2n}_B = \frac{U}{v^+}\left[\frac{c_w p_{B1}}{q_B} - \frac{c_n(p_{BN}-p_{B0})}{q_{BN}}\right] \end{cases} \quad (2)$$

4. The optimal price path for the product

Scenario 1. The product optimal pricing mechanism of enterprises is to enable strategic consumers with high valuation to purchase products at the highest price in the corresponding sales stage so as to maximize profits. According to Formula (1), the expected profit function of the two enterprises at different stages are as follows:

$$\left\{\pi^1_A = D^1_A(p_{A1}-c_w); \pi^1_B = D^1_B(p_{B1}-c_w); \pi^2_A = D^2_A(p_{A2}-c_w); \pi^2_B = D^2_B(p_{B2}-c_w)\right. \quad (3)$$

By constructing KKT condition, the first order condition of expected profit function is used to solve the optimal product price under decentralized decision and centralized decision conditions respectively. The optimal price under decentralized decision can be obtained as follows:

$$\left\{p^*_{A1} = \frac{\Delta\varphi_3 + \varphi_2\varphi_4 + \varphi_2}{2\Delta c_w}; p^*_{B1} = \frac{\varphi_1\varphi_4 + \varphi_2}{2\Delta c_w}; p^*_{A2} = \frac{q_A(2\varphi_5\varphi_6 + \varphi_7)}{2\Delta c_w}; p^*_{B2} = \frac{q_B\varphi_5\varphi_6 - \varphi_8 + \varphi_4\varphi_8}{2\Delta c_w}\right. \quad (4)$$

These are implicit as follows, $\Delta = q_B(4q_A - 3\alpha q_A - q_B)^2 - 4\alpha q_A(q_A - q_B)^2$, $\varphi_2 = 2q_A(q_A - q_B)(3q_B - 2\alpha q_A - \alpha q_B)c^2_w$, $\varphi_1 = (q_A - q_B)(q_B - \alpha q_A)v^+_A + (2q_A - 3\alpha q_A + q_B)c^2_w$, $\varphi_3 = (q_A - q_B)v^+ + c^2_w$, $\varphi_4 = q_B(4q_A - 3\alpha q_A - q_B)$, $\varphi_5 = 2\alpha q_A(q_A - q_B)^2 c^2_w$, $\varphi_6 = \alpha(q_A - q_B)$, $\varphi_7 = (4q_A - 3\alpha q_A - q_B)(3q_B - \alpha q_B - 2\alpha q_A)c^2_w$, $\varphi_8 = (1-\alpha)(q_B + 2q_A)c^2_w$.

The optimal price under centralized decision are as follows:

$$\left\{p^{**}_{A1} = \frac{q_A v^+ + c^2_w}{2c_w}; p^{**}_{B1} = \frac{q_B v^+ + c^2_w}{2c_w}; p^{**}_{A2} = \frac{\alpha q_A v^+ + c^2_w}{2c_w}; p^{**}_{B2} = \frac{\alpha q_B v^+ + c^2_w}{2c_w}\right. \quad (5)$$

Scenario 2. In this case, the products of the two companies are sold out in the first phase and they plan to launch new products in the second phase. Strategic consumers who purchased the products in the first phase can exchange their old ones for new ones in the second phase. When determining the optimal product price of an enterprise, the optimal product price can be determined according to the expected profit of the two sales periods, and then the optimal recovery price can be solved by combining the expected profit function under the trade-in condition. According to Formula (2), the

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expected profit function of the two enterprises selling products A and B in the first phase and products AN and BN in the second phase is as follows:

$$\left\{\pi_A^{1n} = D_A^{1n}\left(p_{A1} - c_w\right);\ \pi_B^{1n} = D_B^{1n}\left(p_{B1} - c_w\right);\ \pi_A^N = D_A^N\left(p_{AN} - c_n\right);\ \pi_B^N = D_B^N\left(p_{BN} - c_n\right)\right. \tag{6}$$

Further, based on relevant assumptions, the expected profit function of the two enterprises when they adopt the trade-in is determined as follows:

$$\left\{\pi_A^{2n} = D_A^{2n}\left(p_{AN} - c_n + s - p_{A0}\right);\ \pi_B^{2n} = D_B^{2n}\left(p_{BN} - c_n + s - p_{B0}\right)\right. \tag{7}$$

According to the second-order condition of Equation (7), it can be known that this equation is a strictly concave function of the recovery price, and has a maximum value. The first order condition of expected profit function can be used to solve the optimal product price. The optimal price of finished products and the optimal recovery price under decentralized decision are as follows:

$$\begin{cases} p_{A1}^{*} = \dfrac{q_A\xi_0}{c_w\left(4q_A - q_B\right)};\ p_{B1}^{*} = \dfrac{q_B\xi_0}{c_w\left(4q_A - q_B\right)};\ p_{AN}^{*} = \dfrac{q_{AN}\left[2\left(q_{AN} - q_{BN}\right)\xi_2 + 3\nabla c_n^2\right]}{c_n\nabla\left(4q_{AN} - q_{BN}\right)} \\ p_{BN}^{*} = \dfrac{q_{BN}\left[\xi_1\xi_2 + \nabla\left(q_{BN} + 2q_{AN}\right)c_n^2\right]}{c_n\nabla\left(4q_{AN} - q_{BN}\right)};\ p_{A0}^{*} = p_{AN}^{*} - \dfrac{\left(c_n - s\right)}{2} - \dfrac{q_B q_{AN}\left[\left(2q_A - q_B\right)v^+ + c_w^2\right]}{2c_n\nabla};\ p_{B0}^{*} = p_{BN}^{*} - \dfrac{\left(c_n - s\right)}{2} - \dfrac{q_{BN}\xi_2}{2c_n\nabla} \end{cases} \tag{8}$$

$\nabla = q_B\left(4q_A - q_B\right)$, $\xi_0 = 2\left(q_A - q_B\right)v^+ + 3c_w^2$, $\xi_1 = q_{BN}\left(q_{AN} - q_{BN}\right)$, $\xi_2 = q_B\left(q_A - q_B\right)v^+ + \left(2q_A + q_B\right)c_w^2$. Similarly, the optimal product price and optimal recovery price under centralized decision can be obtained as follows:

$$\begin{cases} p_{A1}^{**} = \dfrac{2c_n q_B\left[2q_A v^+ + c_w\left(2c_w + 3c_n\right)\right] - c_w q_{AN}\left(q_A - q_B\right)v^+}{2c_w\left(4c_n q_B - c_w q_{AN}\right)};\ p_{AN}^{**} = \dfrac{q_B\left(q_{AN}v^+ + 2c_n^2\right) + c_w q_{AN}\left(c_w + c_n\right)}{4c_n q_B - c_w q_{AN}} \\ p_{B1}^{**} = \dfrac{c_n q_B\left[2q_B v^+ + c_w\left(2c_w + 3c_n\right)\right]}{c_w\left(4c_n q_B - c_w q_{AN}\right)};\ p_{BN}^{**} = \dfrac{2q_B\left(q_{BN}v^+ + 2c_n^2\right) + c_w\left[q_{BN}\left(3c_w + 2c_n\right) - c_n q_{AN}\right]}{2\left(4c_n q_B - c_w q_{AN}\right)} \\ p_{A0}^{**} = p_{AN}^{**} - \dfrac{c_n - s}{2} - \dfrac{q_{AN}v^+}{4c_n};\ p_{B0}^{**} = \dfrac{c_w q_{BN}\left(c_w - c_n\right)}{2\left(4c_n q_B - c_w q_{AN}\right)} + \dfrac{s}{2} \end{cases} \tag{9}$$

5. Numerical analysis

The influence of discount coefficient on pricing mode of enterprises. Based on relevant assumptions, $U=100, v^+=20, c_w=10, q_A=8, q_B=7$ can be made. It can be known that the domain of discount coefficient is $\alpha\in(0,\ 0.875)$, and the pricing decision-making mode of enterprises can be discussed by describing the relationship between discount coefficient and total expected profit.

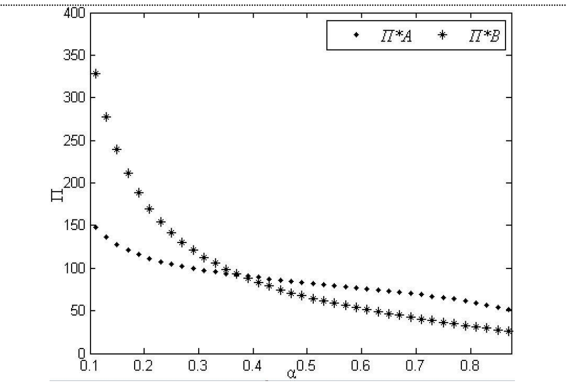

Figure 1. The effect of discount coefficient on enterprise expected profit under decentralized decision making.

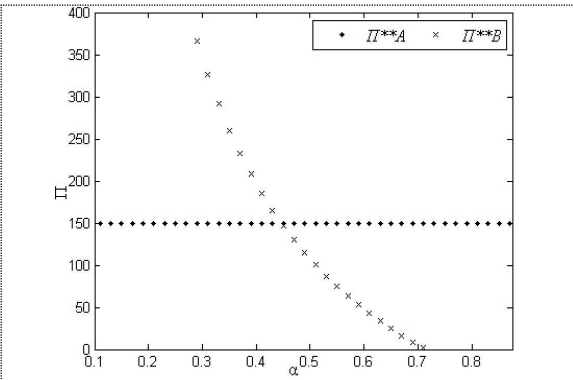

Figure 2. The effect of discount coefficient on enterprise expected profit under centralized decision making.

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According to Figure 1 and Figure 2, under the decentralized decision, with the increase of the discount coefficient, the total expected profit of the two enterprises decreases, and the condition $0.4 < \alpha < 0.875$ is met. The relationship between the total expected profit is $\Pi^*_A > \Pi^*_B$. This indicates that the lower the strategic degree of strategic consumers is, the higher the profit of enterprise A will be, whereas the profit difference between the two enterprises will be reduced. When the discount coefficient meets the condition $0 < \alpha < 0.4$, the profit of enterprise B is higher than that of enterprise A, that is, when the difference in product quality is small, most strategic consumers will choose to buy products with relatively low prices. Under centralized decision, the discount coefficient has A negative effect on the total expected profit of enterprise B, but has no effect on the total expected profit of enterprise A. This indicates that the level of strategic consumer strategy in this decision-making mode has no influence on the profits of enterprises producing high-quality products. Only when the level of strategic consumer strategy is high, enterprises producing low-quality products can obtain profits. Obviously, this decision-making mode is unstable.

The influence of new product quality input on enterprise pricing. Figure 3 and figure 4 depict the relationship between new product quality input and expected profit of enterprise B.

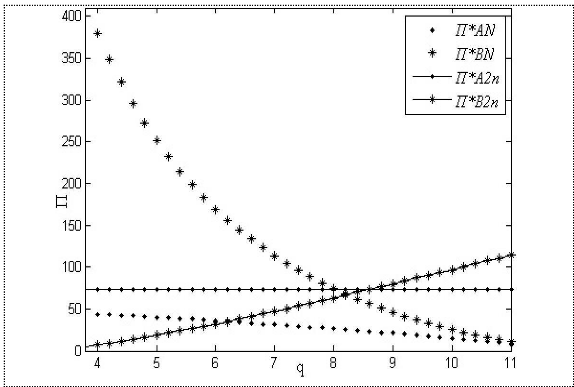

Figure 3. The effect of quality input of new product of firm B on expected profit under decentralized decision making.

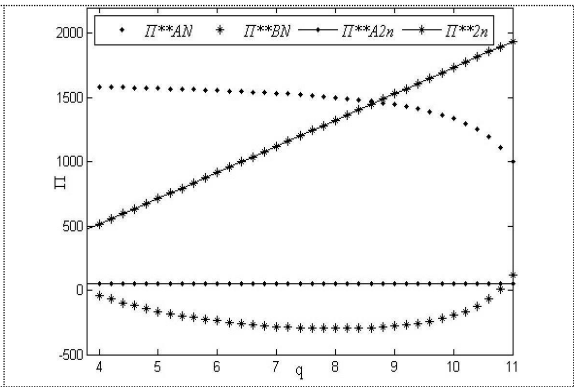

Figure 4. The effect of quality input of new product of enterprise B on expected profit under centralized decision.

Figure 3 and Figure 4 show that under decentralized decision making, the quality input of BN of new product is positively correlated with its own product price and negatively correlated with profit. Meanwhile, consumers who have bought old products can be encouraged to trade in old products for new ones, thus improving the profit level. Under centralized decision making, the investment level of new product quality can restrain the profit of competitive enterprises, but they will also be in a dilemma of no profit. Especially when two enterprises launch new products to the market, the strategy of trade-in for new is the main profit source of enterprises producing low-quality products. This means that even if enterprise B gains some profits by implementing the new strategy, it is at the expense of all profits of the enterprise in the second stage, so the centralized decision is not applicable to enterprise B. In addition, according to the assumption of recovery price and unit revenue of recovered products, the recovery price of enterprise A under centralized decision-making mode is contrary to it, so it further proves that this decision-making mode is not the first choice of enterprise A.

6. Conclusion

In scenario 1, the strategic degree of consumer strategy directly affects the profit gap between competing enterprises. With the continuous narrowing of the quality investment difference, the profit difference between the two enterprises becomes smaller and smaller. Under centralized

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decision-making, enterprises that produce low quality products improve quality investment, and enterprises that produce high quality products can obtain relatively stable profits. However, the profits of enterprises producing low-quality products are more sensitive to the strategic degree of consumers, resulting in unstable pricing decision patterns.

In scenario 2, decentralized decision making method is helpful for low quality products manufacturing enterprises in the second stage by scrappage obtain more profits, at the same time improve the quality of investment no significant negative effects on the new product price, but to promote the recycling price increases, in improving the quality of products at the same time, ensure the overall profitability of enterprises. In the case of centralized decision-making, it is difficult for enterprises producing low-quality products to make profits, and the recovery price of enterprises producing high-quality products is higher than the unit revenue, resulting in negative profits under the implementation of the old for new strategy, which deviates from the ultimate goal of enterprises. Therefore, this decision-making method does not apply to both enterprises.

In the case of trade-in, improving the quality input level of new products under decentralized decision-making can motivate strategic consumers to trade in old products to improve the profit level, and restrain the sales price and profit of competitors' new products. Under centralized decision to old change new become low quality products manufacturing enterprises the main profit source, and it is difficult to through direct sales in the second stage of new product profit, and at the same time because of the competitive enterprise back prices are relatively high, its by scrappage can only get very low profits, so the two companies were not adopt centralized decision-making power.

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