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Impacts of trade-in program on duopoly competition with product quality differentiation and secondhand market

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Abstract: Considering the existence of the secondhand market and the implementation of trade-in program, the competition models between two manufacturers who produce the same products at various qualities are developed by the Nash game, and the impacts of the trade-in program from the perspectives of the demands, profits, marginal profits of manufacturers and the net costs of consumers are investigated. It finds that the trade-in program has different impacts when it is implemented by different manufacturers. When the low-quality manufacturer implements the program, it is always beneficial to himself and consumers but harmful to the high-quality manufacturer. However, when the program is implemented by the high-quality manufacturer, it can be beneficial to the low-quality manufacturer as well as to the implementer but harmful to consumers if the transaction cost of the consumer selling the used product in the secondhand market is low enough. Furthermore, with the increase in transaction cost, it also becomes harmful to the low-quality manufacturer and beneficial to consumers, which is the same as in the case that the low-quality manufacturer implements the trade-in program. The impacts of related parameters on the demands, marginal profits of manufacturers and the net costs of consumers are also analyzed.

Key words: trade-in program; quality differentiation; duopoly competition; Nash game

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Product upgrading accelerates greatly due to the advance in technology in many industries (e. g., mobile phones and PCs), which makes the market increasingly saturated. Many manufacturers have started to offer the trade-in program in order to encourage consumers to repeat purchasing. Under this program, consumers can get rebates when buying the new products and return the used ones. For example, the recent trade-in program that Apple provides is "Apple Trade In". Other manufacturers, such as Huawei, Samsung and Xiaomi, have offered their own trade-in programs. At the same time, the secondhand market, especially the online market (e. g., eBay, Xianyu), grows rapidly due to the development of electronic commerce and the express industry. It becomes more convenient for consumers to sell their used products in hand through the secondhand market. Thus, when a manufacturer decides whether to implement the trade-in program, he/she should consider not only the threats from opponents' trade-ins but also the impacts of secondhand markets. Trade-in operations therefore become more challenging.

With trade-in programs widely implemented, researchers are paying more attention to them. van Ackere and Reyniers[1] compared the effects of trade-in rebates and introductory offers on marketing durable and consumable products. Ray et al. [2] studied three pricing schemes when a monopoly manufacturer implements the trade-in program. Rao et al. [3] explored the role that trade-ins play and the motivation which drives the seller to set up a channel to facilitate trade-ins in durable goods markets. Based on two-period dynamic models with strategic consumers, Yin et al. [4–5] explored the optimal pricing decisions and characterized the conditions under which the trade-in program is beneficial without/with the up-front fee. Miao et al. [6] studied three kinds of closed-loop supply chain structures with trade-ins and analyzed the condition under which the trade-in program is beneficial to the environment. Liu et al. [7–8] investigated the optimal pricing strategy and product rollover strategy considering product innovation and strategic consumers with the trade-in program. As remanufacturing is a sustainable way to treat the collected products, the remanufacturing decision under the trade-in program is also a hot topic[9–13]. All the aforementioned studies are conducted in monopoly settings. However, only little literature focused on duopoly competition with trade-in programs, which are most related to our research. Heese et al. [14] studied the competitive advantage from taking back used products in a duopoly competition in a single period setting. Zhu et al. [15] analyzed the effect of implementing the trade-in program on the duopoly competition in a two-period setting. Both studies[14–15] did not consider product quality differentiation and they assumed that the used product has a constant salvage value for the manufacturers.

Unlike the existing research, we study the effects of the

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trade-in program on duopoly competition considering products quality differentiation and the secondhand market. Furthermore, the price of the used products in the secondhand market is not constant. Under the above context, we will explore the following three problems: 1) What are the impacts of trade-in programs on manufacturers? 2) What are the impacts of trade-in programs on consumers? 3) Is there any difference between the impacts when the trade-in program is implemented by different manufacturers? In order to answer these questions, we develop a game framework and analyze the impacts of the trade-in program. We find that the program shows different impacts when it is implemented by different manufacturers.

1 Problem Description and Assumptions

In the new product market, there are two manufacturers: M_{h} who produces high-quality product x_{h} priced at p_{h}, and M_{l} who produces low-quality product x_{l} priced at p_{l}. Each consumer in the new product market has a used product in hand. When purchasing a new product, the consumer will trade in the used product through manufacturers or sell it in a secondhand market. We consider that each manufacturer may or may not implement the trade-in program in the new product market. If a manufacturer implements the trade-in program, he/she will also sell the recycled used product in the same secondhand market. In our study, we will focus on four market competition scenarios: 1) No manufacturer implements the trade-in program; 2) Only M_{h} implements it; 3) Only M_{l} implements it; 4) Both manufacturers implement it. Under each scenario, the decision sequence is as follows: First, M_{h} and M_{l} decide the prices of their products simultaneously, which can be seen as the Nash game; then, consumers decide whether to buy a new product (x_{h} or x_{l}) and trade in/sell the used product, or continue to use the used one in hand.

We make the following assumptions to describe the research problem.

Assumption 1 The size of the new product market is 1. Consumers' willingness to pay for x_{h} is θ and for x_{l} is $\beta\theta$ $(0<\beta<1)$, where θ is uniformly distributed over [0, 1] and β is the value discount coefficient of the low-quality product. The marginal production costs of both products are 0.

Assumption 2 The used products of consumers in the new product market are of the same quality and each has the same perceived residual value of v $(0<v<\beta)$ for its owner.

Assumption 3 The secondhand market is independent of the new product market, and the market-clearing price of used product p_{o} takes the form as $p_{\mathrm{o}}=(1-q_{\mathrm{o}})v$, where q_{o} denotes the total supply of used products, similar to the assumptions in Refs. [13, 16]. This price function implies that the resale price of the used product decreases in its supply and increases in residual value. This function also excludes the case that consumers just sell their used products and leave the market, because the net utility of consumers who just sells the used product is below 0. For example, consumers will not sell their smart phone unless they buy a new one.

Assumption 4 The consumer will incur a transaction cost c when a used product is sold through the secondhand market. This cost can also be thought as the hassle cost (e. g., time cost, delivery cost). For the economies of scale, we assume that the transaction cost for manufacturers to sell a used product is 0.

Assumption 5 For the existence of the transaction cost, the consumer prefers to trade in the used product when the consumer buys a new one if the manufacturer provides the trade-in program.

2 Model

In this paper, $k\in\{1,2,3,4\}$ denotes four market competition scenarios. Consumers in the new product market have three options: to buy x_{h}, buy x_{l} or continue to use the used product. The utility of consumers buying x_{h} is

$$U_{\mathrm{h}}^{k}=\begin{cases}\theta-p_{\mathrm{h}}^{k}+p_{\mathrm{o}}^{k}-c & \text{if } k=1,3\\ \theta-p_{\mathrm{h}}^{k} & \text{if } k=2,4\end{cases} \tag{1}$$

The utility of consumers buying x_{l} is

$$U_{\mathrm{l}}^{k}=\begin{cases}\beta\theta-p_{\mathrm{l}}^{k}+p_{\mathrm{o}}^{k}-c & \text{if } k=1,2\\ \beta\theta-p_{\mathrm{l}}^{k} & \text{if } k=3,4\end{cases} \tag{2}$$

The utility of consumers who continue to use the used product is $U_{\mathrm{o}}^{k}=v$ for $k=1,2,3,4$. Using consumer rationality in their purchasing decisions, we can easily obtain the expressions of the demands of both products $\{q_{\mathrm{h}}^{k}, q_{\mathrm{l}}^{k}\}$ under each scenario.

Thus, the profits of M_{h} and M_{l} are

$$\Pi_{\mathrm{h}}^{k}(p_{\mathrm{h}}^{k})=\begin{cases}q_{\mathrm{h}}^{k}p_{\mathrm{h}}^{k} & \text{if } k=1,3\\ q_{\mathrm{h}}^{k}(p_{\mathrm{h}}^{k}+p_{\mathrm{o}}^{k}) & \text{if } k=2,4\end{cases} \tag{3}$$

and

$$\Pi_{\mathrm{l}}^{k}(p_{\mathrm{l}}^{k})=\begin{cases}q_{\mathrm{l}}^{k}p_{\mathrm{l}}^{k} & \text{if } k=1,2\\ q_{\mathrm{l}}^{k}(p_{\mathrm{l}}^{k}+p_{\mathrm{o}}^{k}) & \text{if } k=3,4\end{cases} \tag{4}$$

3 Decisions and Impacts of Trade-In Program

As each consumer in the new product market has one used product in hand, we can obtain the market-clearing price of used product p_{o}^{k} in the secondhand market by substituting q_{h}^{k} and q_{l}^{k} into $p_{\mathrm{o}}=(1-q_{\mathrm{o}})v$, where $q_{\mathrm{o}}^{k}=q_{\mathrm{h}}^{k}+q_{\mathrm{l}}^{k}$. Then, from Eq. (3) and Eq. (4), we have the following theorem.

Theorem 1 There exist unique equilibrium prices for M_{h} and M_{l} under the four scenarios. The expressions of the optimal prices, demands and manufacturers' profits are given in Tab. 1 and Tab. 2.

Tab. 1 The equilibrium prices

Scenarios	p_h^*	p_l^*
1	$\frac{(2-c+v)(1-\beta)}{4+3v-\beta}$	$\frac{(1-\beta)(\beta-2c-v)}{4+3v-\beta}$
2	$\frac{(2+c-2\beta)\beta+v(2-c-3\beta+\beta^2)-3v^2-v^3}{(4+v-\beta)(v+\beta)}$	$\frac{(\beta-v)(1-\beta)-c(2+v-\beta)}{4+v-\beta}$
3	$\frac{(2+v)(1-\beta)-c(2+v-\beta)}{4+3v-\beta}$	$\frac{(1+c-\beta)\beta^2-v\beta(1-c-\beta)-v^2(4-\beta)-3v^3}{(4+3v-\beta)(v+\beta)}$
4	$\frac{2(1-\beta)\beta+v(2-3\beta+\beta^2)-3v^2-v^3}{4v+v^2+(4-\beta)\beta}$	$\frac{(1-\beta)\beta^2-v(1-\beta)\beta-v^2(4-\beta)-v^3}{4v+v^2+(4-\beta)\beta}$

Tab. 2 Product demands and manufacturers' profits

Scenarios	q_h^*	q_l^*	Π_h^*	Π_l^*
1	$\frac{2-c+v}{4+3v-\beta}$	$\frac{(1+v)(\beta-2c-v)}{(4+3v-\beta)(v+\beta)}$	$\frac{(2-c+v)^2(1-\beta)}{(4+3v-\beta)^2}$	$\frac{(1+v)(2c+v-\beta)^2(1-\beta)}{(4+3v-\beta)^2(v+\beta)}$
2	$\frac{2+c-2\beta}{4+v-5\beta-v\beta+\beta^2}$	$\frac{(\beta-v)(1-\beta)-c(2+v-\beta)}{(4+v-\beta)(1-\beta)(v+\beta)}$	$\frac{(2+c-2\beta)^2}{(4+v-\beta)^2(1-\beta)}$	$\frac{((\beta-v)(1-\beta)-c(2+v-\beta))^2}{(4+v-\beta)^2(1-\beta)(v+\beta)}$
3	$\frac{(2+v)(1-\beta)-c(2+v-\beta)}{(1-\beta)(4+3v-\beta)}$	$\frac{(1+v)((1+c-\beta)\beta-v(1-c-\beta))}{(1-\beta)(4+3v-\beta)(v+\beta)}$	$\frac{((2+v)(1-\beta)-c(2+v-\beta))^2}{(1-\beta)(4+3v-\beta)^2}$	$\frac{(1+v)((1+c-\beta)\beta-v(1-c-\beta))^2}{(1-\beta)(4+3v-\beta)^2(v+\beta)}$
4	$\frac{2}{4+v-\beta}$	$\frac{\beta-v}{(4+v-\beta)(v+\beta)}$	$\frac{4(1-\beta)}{(4+v-\beta)^2}$	$\frac{(\beta-v)^2(1-\beta)}{(4+v-\beta)^2(v+\beta)}$

According to Heese et al. [14], we also investigate the impacts of trade-in programs from the following aspects: product demands, unit product profit margins, consumers' net costs and manufacturers' profits. We use $m_i^k(i\in\{\mathrm{h},\mathrm{l}\})$ to denote the unit profit margin of manufacturer M_i under scenario k. When M_i implements the trade in program, he/she can obtain revenue from selling the new product and the recycled used product and $m_i^{k*}=p_i^{k*}+p_o^{k*}$; otherwise, $m_i^{k*}=p_i^{k*}$ when M_i does not implement it. We use n_i^k to denote the net costs of the consumer buying x_i under scenario k. We have $n_i^k=p_i^k$ when M_i implements the trade-in program; otherwise, $n_i^k=p_i^k-p_o^k+c$ when M_i does not implement it.

Next, we assume that $c<\min\left\{\frac{(\beta-v)(1-\beta)}{2+v-\beta}, \frac{v(3v+3v^2+\beta-\beta^2)}{2v^2+(4-\beta)\beta+v(4+\beta)}\right\}=\bar{c}_s$, which ensures that unit profit margin and product quantity are always positive, and also guarantees that the transaction fee in the second-hand market is always below the price of the used product.

Proposition 1 The impacts of the trade-in program on product demands are: 1) $q_h^{3*}<q_h^{1*}<q_h^{4*}<q_h^{2*}$; 2) $q_l^{2*}<q_l^{4*}<q_l^{1*}<q_l^{3*}$ if $0<c<\frac{v(2+v-\beta)(\beta-v)}{2(1+v)(4+v-\beta)}$, $q_l^{2*}<q_l^{1*}<q_l^{4*}<q_l^{3*}$ if $\frac{v(2+v-\beta)(\beta-v)}{2(1+v)(4+v-\beta)}<c<\bar{c}_s$.

The demand of M_h always increases when M_h implements trade-ins; and it decreases when M_l implements trade-ins. The impacts on demand of a high-quality product are similar to the results in Ref. [14]. However, the impacts on demand of a low-quality product are different. We find that the demand of x_l in scenario 4 is smaller than that in scenario 1 when c is small. The reasons are as follows. First, if c is small, the saving of transaction fee will not greatly stimulate the consumption of x_l when M_l implements trade-ins. When they both implement trade-in programs, M_h and M_l control the whole supply of the secondhand market since consumers prefer to trade in their used products. Since the quality of x_l is lower than that of x_h, M_h obtains more power than M_l to affect the second-hand market. This makes M_l become more disadvantaged in competition with M_h. Thus, if c is small, the demand of x_l decreases when both manufacturers implement trade-in programs. However, when c is large, the saving of transaction fee greatly stimulates the consumption of new products due to the implementation of trade-in programs, which leads to the increase of the demand of x_l in scenario 4.

Proposition 2 The impacts of the trade-in program on marginal profits of manufacturers are as follows:

1) $m_h^{3*}<m_h^{1*}<m_h^{4*}<m_h^{2*}$;

2) If $0<c<\frac{v(\beta-v)(1-\beta)}{4+7v+2v^2-\beta-2v\beta}$, $m_l^{1*}<m_l^{3*}<m_l^{2*}<m_l^{4*}$;

If $\frac{v(\beta-v)(1-\beta)}{4+7v+2v^2-\beta-2v\beta}<c<\frac{2v(\beta-v)(1-\beta)}{8v+3v^2+4\beta-2v\beta-\beta^2}$, $m_l^{1*}<m_l^{2*}<m_l^{3*}<m_l^{4*}$;

If $\frac{2v(\beta-v)(1-\beta)}{8v+3v^2+4\beta-2v\beta-\beta^2}<c<\frac{2v(\beta-v)(1-\beta)}{4v+v^2+4\beta-\beta^2}$, $m_l^{2*}<m_l^{1*}<m_l^{3*}<m_l^{4*}$;

If $\frac{2v(\beta-v)(1-\beta)}{4v+v^2+4\beta-\beta^2}<c<\bar{c}_s$, $m_l^{2*}<m_l^{1*}<m_l^{4*}<m_l^{3*}$.

The marginal profit of M_h always increases when he/

she implements trade-ins and decreases when his/her rival implements trade-ins, which is similar to the result in Ref. [14]. However, for the low-quality product, we find that the unit profit margin of M_l increases when M_h implements the trade-in program if c is small, which is because the total supply of used product in the secondhand market decreases and the price of the used product increases. Under this background, when M_l does not implement trade-ins, he/she can set higher new product price as consumers can get more revenue from selling their used products; when M_l implements trade-ins, he/she can also get higher margin from selling the used products in the secondhand market. However, with the increase in c, the total supply of used product increases due to the implementation of the trade in program by M_h. Then, the used product price and the unit profit margin of M_l decrease.

Proposition 3 The impacts of the trade-in program on net costs of consumers are as follows:

1) If $0 < c < \dfrac{v(1-\beta)(v-\beta)^2}{3(4-\beta)\beta + v^2(1+2\beta) + 2v(2+5\beta-\beta^2)}$, $n_h^{3*} < n_h^{1*} < n_h^{4*} < n_h^{2*}$;

If $\dfrac{v(1-\beta)(v-\beta)^2}{3(4-\beta)\beta + v^2(1+2\beta) + 2v(2+5\beta-\beta^2)} < c < \dfrac{v(1-\beta)(v-\beta)^2}{2(4-\beta)\beta + 2v^2(2+\beta) + v(8+6\beta-2\beta^2)}$, $n_h^{3*} < n_h^{4*} < n_h^{1*} < n_h^{2*}$;

If $\dfrac{v(1-\beta)(v-\beta)^2}{2(4-\beta)\beta + 2v^2(2+\beta) + v(8+6\beta-2\beta^2)} < c < \dfrac{v(1-\beta)(v-\beta)^2}{(2+v)(4v+v^2+4\beta-\beta^2)}$, $n_h^{3*} < n_h^{4*} < n_h^{2*} < n_h^{1*}$;

$\dfrac{v(1-\beta)(v-\beta)^2}{(2+v)(4v+v^2+4\beta-\beta^2)} < c < \dfrac{v(1-\beta)(v-\beta)^2}{9v^2+v^3+(4-\beta)\beta+v(12-\beta^2)}$, $n_h^{4*} < n_h^{3*} < n_h^{2*} < n_h^{1*}$;

If $\dfrac{v(1-\beta)(v-\beta)^2}{9v^2+v^3+(4-\beta)\beta+v(12-\beta^2)} < c < \bar{c}_s$, $n_h^{4*} < n_h^{2*} < n_h^{3*} < n_h^{1*}$;

2) If $0 < c < \dfrac{2v(\beta-v)(1-\beta)}{8+3v^2+2v(7-\beta)+2\beta-\beta^2}$, $n_l^{3*} < n_l^{1*} < nv_l^{4*} < n_l^{2*}$.

If $\dfrac{2v(\beta-v)(1-\beta)}{8+3v^2+2v(7-\beta)+2\beta-\beta^2} < c < \dfrac{2v(\beta-v)(1-\beta)}{3v^2+2v(4-\beta)+(4-\beta)\beta}$, $n_l^{3*} < n_l^{4*} < n_l^{1*} < n_l^{2*}$;

If $\dfrac{2v(\beta-v)(1-\beta)}{3v^2+2v(4-\beta)+(4-\beta)\beta} < c < \dfrac{2v(\beta-v)(1-\beta)}{4v+v^2+(4-\beta)\beta}$, $n_l^{3*} < n_l^{4*} < n_l^{2*} < n_l^{1*}$;

If $\dfrac{2v(\beta-v)(1-\beta)}{4v+v^2+(4-\beta)\beta} < c < \bar{c}_s$, $n_l^{4*} < n_l^{3*} < n_l^{2*} < n_l^{1*}$.

Proposition 3 shows that when M_l implements trade-ins all consumers' net costs decrease, which is similar to the result in Ref. [14]. However, all consumers' net costs increase when M_h implements trade-ins if c is small. The reasons are as follows. When c is small, implementing the trade-in program by M_h makes M_h have the power to affect the secondhand market since consumers prefer to trade in their used product. When M_h has more power, consumers will be more disadvantaged, and their net costs increase. With the increase in c, the saving of the transaction cost dominates the variation of consumers' net costs and all consumers' net costs decrease when M_h implements trade-ins. When M_l implements the trade-in program, the power he obtains to affect the secondhand market is lower than that of M_h; thus, consumers' net costs always decrease from saving the transaction cost.

Proposition 4 The impacts of the trade-in program on manufacturers' profits are as follows:

1) $\Pi_h^{3*} < \Pi_h^{1*} < \Pi_h^{4*} < \Pi_h^{2*}$.

2) $\Pi_l^{1*} < \Pi_l^{3*}$; $\Pi_l^{1*} < \Pi_l^{4*}$; $\Pi_l^{2*} < \Pi_l^{4*}$; $\exists c_1 \in \left(0, \dfrac{(\beta-v)(1-\beta)}{2+v-\beta}\right)$, if $0 < c < c_1$, $\Pi_l^{1*} < \Pi_l^{2*}$; otherwise, $\Pi_l^{1*} > \Pi_l^{2*}$; $\exists c_2 \in \left(0, \dfrac{(\beta-v)(1-\beta)}{2+v-\beta}\right)$, if $0 < c < c_2$, $\Pi_l^{3*} < \Pi_l^{2*}$; otherwise, $\Pi_l^{3*} > \Pi_l^{2*}$; $\exists c_3 \in \left(0, \dfrac{(\beta-v)(1-\beta)}{2+v-\beta}\right)$, if $0 < c < c_3$, $\Pi_l^{3*} < \Pi_l^{4*}$; otherwise, $\Pi_l^{3*} > \Pi_l^{4*}$.

Proof For the comparison between Π_l^{1*} and Π_l^{2*}, let $f(c) = \Pi_l^{1*}(c) - \Pi_l^{2*}(c)$. Since $f(c)$ is quadratic about c, we have $f(c \mid c=0) < 0$ and $f\left(c \mid c = \dfrac{(\beta-v)(1-\beta)}{2+v-\beta}\right) > 0$. Thus, there exists unique c_1 which satisfies $f(c \mid c = c_1) = 0$. Then, we have the result 2) of Proposition 4. Similarly, we can compare $\{\Pi_l^{3*}, \Pi_l^{2*}\}$ and $\{\Pi_l^{3*}, \Pi_l^{4*}\}$. We omit the proofs of other results because they can be obtained by straight computation.

From Proposition 4, the profit of M_h increases when M_h implements the trade-in program; it decreases when M_l implements the program. However, the profit of M_l increases when M_h implements the trade in program if c is small. From Proposition 2, we know that the unit profit margin of M_l will increase when M_h implements trade-ins. Although the demand of x_l decreases when M_h implements the trade in program, the increase of profit margin leads to the increase of the profit of M_l when c is small.

Proposition 5 For $\forall k \in \{1, 2, 3, 4\}$ and $\forall i \in \{l, h\}$,

1) $\dfrac{\partial m_i^{k*}}{\partial v} < 0$; $\dfrac{\partial m_i^{1*}}{\partial c}, \dfrac{\partial m_h^{3*}}{\partial c}, \dfrac{\partial m_l^{2*}}{\partial c} < 0$; $\dfrac{\partial m_h^{2*}}{\partial c}, \dfrac{\partial m_l^{3*}}{\partial c} > 0$.

2) $\dfrac{\partial q_i^{k*}}{\partial v} < 0$; $\dfrac{\partial q_i^{1*}}{\partial c}, \dfrac{\partial q_h^{3*}}{\partial c}, \dfrac{\partial q_l^{2*}}{\partial c} < 0$; $\dfrac{\partial q_h^{2*}}{\partial c}, \dfrac{\partial q_l^{3*}}{\partial c} > 0$.

3) $\dfrac{\partial n_i^{k*}}{\partial v} < 0$; $\dfrac{\partial n_i^{1*}}{\partial c}, \dfrac{\partial n_i^{2*}}{\partial c}, \dfrac{\partial n_i^{3*}}{\partial c} > 0$.

From Proposition 5, the unit product margins of both manufacturers decrease with the increase in the residual value of the used products. It is because manufacturers must lower their product prices in order to stimulate consumers to buy the new one when the used products still function well. We also find that the manufacturer's unit marginal profit increases in the transaction cost if he/she implements the trade-in program, otherwise decreases in it. That is because consumers save the transaction cost when he/she trades in the used product for a new one. Besides, the consumers' net cost decreases in the residual value of the used products since manufacturers set a lower new product price. We also find that consumers' net cost increases in the transaction cost although the consumer buys the new products from the manufacturer who offers a trade-in program. We choose scenario 2 as an example. With the increase in the transaction cost, x_h becomes more competitive in the competition because consumers of x_h save the transaction cost. Thus, M_h can set higher price, which leads to the increase in the net costs of consumers buying x_h.

4 Conclusion

In this paper, we investigate the impacts of the trade-in program on the duopoly competition considering the product quality differentiation and the existence of the second-hand market. For M_h, implementing the trade in program by M_h always benefits M_h; otherwise, implementing the trade in program by M_l always hurts the interest of M_h. However, for the low-quality manufacturer, implementing the trade-in program by M_l benefits M_l, but implementing the trade-in program by M_h can also be beneficial for M_l if the transaction cost is low enough. For the consumer, implementing the program by the low-quality manufacturer is always beneficial; however, the trade-in program implemented by the high-quality manufacturer will hurt the interest of consumers if the transaction cost is small. We also investigate the effects of the residual value and the transaction cost on the manufacturer and the consumer. The results show that the higher residual value makes the consumer incur lower net cost, but the manufacturer's unit profit margin will decrease. With the increase in the transaction cost, the consumer will incur a higher net cost but the manufacturer who implements the trade-in program will obtain a higher unit profit margin.

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考虑产品质量差异和二手市场时以旧换新对双寡头竞争的影响

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摘要：考虑二手市场的存在及以旧换新的实施，利用 Nash 博弈构建了生产不同质量产品的两制造商竞争模型，并从制造商利润、边际利润、产品需求以及消费者净成本 4 个方面研究了以旧换新的影响. 研究发现当以旧换新由不同的制造商实施时，其产生的影响是不同的. 当低质量产品制造商实施时，以旧换新总是有益于实施者和消费者，但有害于高质量制造商. 当高质量产品制造商实施以旧换新时，如果消费者在二手市场出售旧产品的交易费用较低时，以旧换新将有益于实施者和低质量制造商，但有害于消费者；随着交易费的升高，它变得同样有害于低质量制造商但有益于消费者. 此外，还分析了相关参数对制造商边际利润、产品需求及消费者净成本的影响.

关键词：以旧换新；质量差异；双寡头竞争；Nash 博弈

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