Durable goods with secondary markets

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ABSTRACT
This article captures the effects of secondary markets on the durable goods with game theory technology. Firstly, under monopoly in production, secondary markets both improve the producer’s profits and extend the market size. Secondly, to improve the profits, the producer launches the secondary markets although he/she undertakes a loss in the secondary markets. Thirdly, under large preference (wealth) difference, the producer prices as a type of luxury. Finally, the conditions about the producer pricing are identified. In summary, this article establishes the general framework of durable goods. The wealth difference is considered to analyze the effects of wealth on the demand of both the new product market and the secondary markets. The producer’s optimal decisions depend on the number of all types of consumers. Both the wealth difference and the number of all types of consumers jointly determine the price of new and used goods.

1. Introduction

The used goods are very popular for housing, home appliance industry, car markets and so on. For instance, Goolsbee (1998) found that the major of Boeing 707 aircrafts changed owners. Because of the new house availability, the deal of second-hand houses in China covered almost half of all house market in the centers of big cities (Xu & Li, 2021). From 1991 to 2003 of Hong kong, at least 23% of the private flats were repeat sales (Chau, Wong, Yiu, & Leung, 2005; Nie, Chen, & Wang, 2021). Bond and Iizuka (2014) pointed out that the secondary markets for textbook are very active. Moreover, second-hand market also exists for cloth industry (Kim, Lauren, Woo, & Ramkumar, 2021). Turunen, Cervellon, and Carey (2020) pointed the second-hand market of luxury.

Actually, the secondary markets have important effects of new goods, including price, outputs, innovations and merger (Cho & Koo, 2012; Chen, Nie, & Wang, 2015; Chen, Wen, & Luo, 2016; Chen, Nie, & Huang, 2017; Chen, Zheng, Xu, Liu, & Wang, 2018; Dargaud, and Jacques, 2015; Liberali, Gruca, & Nique, 2011; Nie, 2018; Nie, Wang, Chen, & Yang, 2018; Nie, Wang, Chen, & Chen, 2018; Nie, Wang, & Yang, 2019; Mehrjoo & Pasek, 2016 Nie, 2014; Todeschini, Cortimiglia, Callegaro-de-Menezes, & Ghezzi, 2017; Wang & Nie, 2018; Yang, Nie, Liu, & Shen, 2018). On one hand, secondary markets may
do harm to producers. Chen, Esteban, and Shum (2013) examined that secondary markets hurt firms’ profits with data from U.S. automobile industry. On the other hand, under special situations, firms benefit from secondary markets. Hendel and Lizzeri (Hendel & Lizzeri, 1999) discussed the effects of used goods and concluded that the manufacturer earns from the secondary market. Furthermore, Chen et al. (2013) also pointed out that firms benefit from secondary markets if the number of firms decreases.

Since the secondary markets affect the producers, Hendel and Lizzeri (1999) investigated that producers interfere the secondary markets by various ways, including rents, maintenance restriction and so on. Burgess and Steenkamp (2006) discussed the effects of secondary markets on the price and other firms’ strategies.

Some researchers focus on some special industries with secondary markets. Lee and Whang (2002) addressed the effects of secondary markets on the industry related to chain supply. Huang, Gu, Ching, and Siu (2014) further argued that secondary markets improve the total wholesale volume. Bond and Iizuka (2014) examined the effects of secondary markets for textbook industry. Second-hand houses are also highlighted and the price of the second-hand houses is extensively investigated. Wong, Yiu, and Chan (2012) focused on the real estate market taken second-hand houses into account.

Used car industry attracts much attention of researchers in recent years. Stolyarov (2002) considered the market of used cars and some interesting conclusions are uncovered. Surprisingly, Stolyarov (2002) found that trade volume is relatively low in the beginning and in the middle of cars’ life. Esteban and Shum (2008) developed a dynamic oligopoly game model and identified the parameters using data from the automobile industry over a 20-year period. Gavazza, Lizzeri, and Roketskiy (2014) further analyzed the used-car market and examined the effects of wealth on the quantity in the U.S. and French used-car markets.

Secondary markets affect the price of the producers (Chen, Chen, & Mishra, 2020; Nocke & Peitz, 2003). Moreover, the product quantity depends on the wealth allocation. It is therefore important to develop a theoretic framework taking the wealth and secondary markets into account.

This paper establishes the general framework of durable goods. On one hand, the wealth difference is considered to analyze the effects of wealth on the demand of both the new product market and the secondary markets. On the other hand, the producer’s optimal decisions depend on the number of all types of consumers. We show that both the wealth difference and the number of all types of consumers jointly determine the price of new and used goods.

This article contributes the theory about durable goods. By introducing secondary market, the price about durable goods is analyzed. The price of durable goods depends on the distribution of wealth. This article also contributes to wealth theory. The effects of wealth difference on luxury are captured.

Moreover, this article discusses various types of durable goods, including car market, house market and so on. The scope of this work is not limited to a certain goods.

The closest paper to this article is Hendel and Lizzeri (Hendel & Lizzeri, 1999). Hendel and Lizzeri (1999) assumed that the secondary market is perfectly competitive, while this article assumes that the monopolist can control and affect the secondary market. For example, in China, the maintenance market of cars is interfered by producers and almost all cars with big brand are required by producers to maintain in specific stores. Therefore,
on one hand, these firms play monopolization position because of the big brand. On the other hand, the second market is robustly controlled by the corresponding monopolist. These phenomena motivate this research.

The rest of this paper is organized as follows: The model is established in Section 2. To simplify we consider the life expectancy to be 2. The demand and the secondary markets are discussed in Section 3 and 4. Section 5 addresses the producer’ strategies. Some remarks are presented in Section 6.

2. Model

Taken the secondary markets into account, here we establish the model about durable goods. Assume that there is a unique producer and a unique firm to sell the used goods in some industry with storable products. Two firms launch Stackelberg competition and the producer plays the leading position while the firm with secondary markets in the following position.

Assume that these durable goods provide a useful service for the first $T$ periods. The good at the stage $t$, $t = 0, 1, 2, \ldots, T - 1$, has the flow of service (or the quality) equal to $x_t$, satisfies the relationship

$$0 < x_{t+1} < x_t, t = 0, 1, 2, \ldots, T - 2$$

(1)

Moreover, all goods become useless at stage $t$ for $t \geq T$. Or $x_t = 0$ for $t \geq T$. The quality at each stage meets

$$x_t = \max\{0, \frac{e^t - e^{-1}}{1 - e^{-1}}\}$$

(2)

Under (2), we have $0 < x_{t+1} < x_t, t = 0, 1, 2, \ldots, T - 2$ and $x_t = 0$ for $t \geq T$. Moreover, $x_0 = 1$. (2) represents that the discount of this durable good satisfies the exponent distribution related to the life expectancy.

Consumers Assume that there are $N$ possible buyers in this market with the random variable, related to marginal utility and observed the distribution with an atomless density $n(h)$. This paper always assumes the random variable $h \in H = \{h_1, h_2, h_3\}$ standing for the preference (or wealth) along with the corresponding probability $\eta = (\eta_1, \eta_2, \eta_3)$ where $h_1 > h_2 > 0$, $\eta_1 + \eta_2 + \eta_3 = 1$ and $\eta_i \geq 0$ for $i = 1, 2, 3$. Moreover, this assumption manifests that there exist three types of consumers with high, middle and low preference (or wealth) to this good. We further assume that $\eta_1 \geq \eta_2$ and $\eta_1 \geq \eta_3$. Given the quality $x_t$, the utility to a consumer with type $h$ is

$$u_h(x, c) = xh + c$$

(3)

where $c > 0$ is a constant, standing for the numeraire.

The model about the goods and the consumers resorts to the interesting one of Stolyarov (2002). The quality at each stage is induced by the interesting formulation in Nie (2012).

To simplify the problem, we assume that $T = 2$, in which the products in the secondary markets are identical.
Firms The first firm produces the new durable goods and sells them with price $p_0^k$ and the quantity to be $q_0^k$ in the stage $k$ for $k = 1, 2, \cdots, K$, where $K$ is the life expectancy of this industry. Denote the discount of the firms’ profits to be 1 and the marginal costs to be $c_0 > c > 0$. The profits of the producer are

$$
\pi_0 = \sum_{k=1}^{K} (p_0^k - c_0)q_0^k \quad (4)
$$

At stage $k$, assume the firm in the secondary market to buy the used goods with price $p_1^{k,1}$ and to sell with price $p_1^{k,2}$. The quantity in the secondary market is $q_1^k$ in the stage $k$. Denote $\tau$ to be the marginal transaction costs. The profits of the firm in the secondary market are

$$
\pi_1 = \sum_{k=2}^{K} (p_1^{k,2} - p_1^{k,1} - \tau)q_1^k \quad (5)
$$

To analyze, this paper launches the following assumption

**Assumption** (A) The types of consumers are known by firms and consumers.

(B) $h_1 > c_0 - c$, $h_2 > c_0 - c$ and $c_0 - c > h_3$.

(C) The utility is zero if the consumer does not buy the goods.

The assumptions $h_1 > c_0 - c$ and $h_2 > c_0 - c$ represent that the market is not empty. $c_0 - c > h_3$ manifests that some consumers have no intention (or ability) to buy the new goods. For convenience to analyze, we assume that $K$ is even. Moreover, for tractability, we assume that the producer prices consistently or the producer always prices identically in all periods.

The timing table of this game is (Figure 1): In each period, at the first stage, the producer prices. At the second stage, the firm in the secondary market determines $p_1^{k,1}$ and $p_1^{k,2}$.

**Producer pricing firm in secondary market prices**

**Stage 1** Stage 2

**Figure 1.** Timing table of this game.

3. Analysis of the producer pricing no higher than $h_2 + c$

We first outline the equilibrium if the preference difference $h_1 - h_2$ is small. In this case, the producer prices no higher than $h_2 + c$. Then, the equilibrium is analyzed and compared.

3.1. The equilibrium if $p_0^1 = p_0^2 = p_0^3 = \cdots = p_0 = h_2 + c$

Firstly, we consider the consistent price $p_0^1 = p_0^2 = p_0^3 = \cdots = p_0 = h_2 + c$. For the small $h_1 - h_2$, the producer prices $h_2 + c$ to attract the high and middle preference consumers. It is easy to prove that this is a Nash equilibrium under the small $h_1 - h_2$. The condition to price $p_0^1 = p_0^2 = p_0^3 = \cdots = p_0 = h_2 + c$ will be further discussed in Section 5.
We address the above model in two cases: \( h_2 - \frac{1 - e^{\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_1 + \tau < \frac{e^{\frac{1}{2}} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_3 \)
and \( h_2 - \frac{1 - e^{\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_1 + \tau > \frac{e^{\frac{1}{2}} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_3 \).

**Case 1** \( h_2 - \frac{1 - e^{\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_1 + \tau \leq \frac{e^{\frac{1}{2}} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_3 \)

identifies that the wealth difference is not large enough. For the demand function, by (1)–(5), we have

\[
q_0^{1,*1} = q_0^{3,*1} = q_0^{5,*1} = \cdots q_0^{K-1,*1} = N(\eta_1 + \eta_2), \quad q_0^{2,*1} = q_0^{6,*1} = \cdots q_0^{K,*1} = N\eta_1
\]

(6)

\[
q_1^{k,*1} = N\eta_1, \quad k = 2, 3, \cdots, K
\]

(7)

The equilibrium price is

\[
p_1^{k,1,*1} = c + h_2 - \frac{1 - e^{\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_1, \quad p_1^{k,2,*1} = \frac{e^{\frac{1}{2}} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_3 + c
\]

(8)

The profits of the producer are

\[
\pi_0^{1,*1} = N(h_2 + c - c_0) \frac{K(\eta_1 + \eta_2)}{2}
\]

(9)

\[
\pi_1^{*1} = N(K - 1)\eta_1 \left( \frac{e^{\frac{1}{2}} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_3 - h_2 + \frac{1 - e^{\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_1 - \tau \right)
\]

(10)

Based on the assumption (C), the social welfare is the sum of the consumer surplus and the firms’ profits.

\[
PS^{*1} = N(h_2 + c - c_0) \frac{K(\eta_1 + \eta_2)}{2} + N(K - 1)\eta_1 \left( \frac{e^{\frac{1}{2}} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_3 - h_2 + \frac{1 - e^{\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_1 - \tau \right)
\]

(11)

\[
CS^{*1} = \frac{N\eta_1}{2} (h_1 - h_2)
\]

(12)

\[
SW^{*1} = N(h_2 + c - c_0) \frac{K(\eta_1 + \eta_2)}{2} + N(K - 1)\eta_1 \left( \frac{e^{\frac{1}{2}} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_3 - h_2 + \frac{1 - e^{\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_1 - \tau \right)
\]

\[+ \frac{N\eta_1}{2} (h_1 - h_2)
\]

(13)

Moreover, under equilibrium, according to the types of consumers, consumers are divided into three groups: The first group (with \( h = h_1 \)) always uses the new goods, the second group uses the durable goods from new to old, and the third group (with \( h = h_3 \)) always uses the second-hand goods.

The above analysis is summarized as follows

**Proposition 1** The price of the new products increases in the degree of the middle wealth (or preference). The profits of the producer increase in the number of both the higher and the middle wealth (or preference) consumers.
Remarks: The profits of the producer strictly monotonically increase in the number of the high and middle wealth (or preference) consumers. Moreover, the producer benefits from the high degree of middle preference (wealth) consumers. From the equilibrium, we find that the profits and the price depend on the allocation of wealth.

Case 2 $h_2 - \frac{1-e^{-\frac{1}{\varepsilon}}}{1-e^{-\frac{1}{\varepsilon}}} h_1 + \tau > \frac{1}{1-e^{-\frac{1}{\varepsilon}}} h_3$

In this case, based on the analysis of case 1, the secondary market does not exist. The producer always prices identically. Or $p^1_0 = p^2_0 = p^3_0 = \cdots = p^*_0 = h_2 + c$. Moreover, $q^1_0 = q^2_0 = q^3_0 = \cdots = q^{K-1}_0 = N(\eta_1 + \eta_2), q^1_0 = q^2_0 = q^3_0 = \cdots = q^K_0 = 0$
The profits of the producer are

$$\pi^*_0 = N(h_2 + c - c_0) \frac{K(\eta_1 + \eta_2)}{2}$$
(14)

$$\pi^1_0 = 0$$
(15)

The social welfare is $SW^*_0 = N(h_2 + c - c_0) \frac{K(\eta_1 + \eta_2)}{2} + \frac{NK\eta_1}{2}(h_1 - h_2)$.

Without the secondary market, the equilibrium is achieved. We find that $h_2 - \frac{1-e^{-\frac{1}{\varepsilon}}}{1-e^{-\frac{1}{\varepsilon}}} h_1 + \tau > \frac{1}{1-e^{-\frac{1}{\varepsilon}}} h_3$ is the condition without the secondary market. The large wealth (preference) difference between the high and the low preference (or wealth) prevent from the secondary market.

Compared (12)--(13) with (9)--(11), we immediately have

$$\sum_{k=1}^{K} q^*_0 = \frac{K(2\eta_1 + \eta_2)}{2}$$
(16)

$$\sum_{k=1}^{K} q^{*+2}_0 = \frac{K(\eta_1 + \eta_2)}{2}$$
(17)

(16) and (17) manifest that the secondary market extends the market size of the new products. Similarly, for the profits and the social welfare, the similar conclusions hold. This analysis is summarized as follows.

Proposition 2 The secondary market promotes the market size of the new products.

The producer benefits from the secondary market if another firm sells the used goods. The social welfare is also promoted by the secondary market.

Remarks: Secondary markets support chances for the high preference (or wealth) to sell their used goods and to buy new goods. Therefore, the secondary market extends the market size and, improves the profits of the producer and the social welfare.

The above conclusion is consistent with the empirical results in Chen et al. (2013). Therefore, Proposition 1 supports a theoretic explanation about Chen et al. (2013).

Since the producer earns from the secondary markets, the producer has intention to interfere the secondary market in two cases. One is the producer acting as the monopolist in the secondary markets. The other is the producer launching the price competition with another firm in the secondary markets.
3.2. The producer to be the monopolist seller of secondary market

In this situation, we also consider by two cases. Under \( h_2 - \frac{1 - e^{-1}}{1 - e^{-1}} h_1 + \tau \leq \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 \), the equilibrium is the same as (6)–(11). The social welfare is also equal to that of (13). The profits of the producer are (9).

Here, we address the equilibrium under the formulation \( h_2 - \frac{1 - e^{-1}}{1 - e^{-1}} h_1 + \tau \leq \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 \). By the case 2 of Section 3, the firms quit the secondary market. We consider that the producer sells the used goods. In this case, the producer sells both the new and the used products. Further, the producer can choose the quantity of the used products. Or the producer can determine the market size of the secondary market.

If \((h_2 + c - c_0)K < -2(K - 1)(\frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-1}}{1 - e^{-1}} h_1 - \tau)\), we have the formulation

\[
PS^2 = N(h_2 + c - c_0) \frac{K(2\eta_1 + \eta_2)}{2} + N(K - 1)\eta_1 \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-1}}{1 - e^{-1}} h_1 - \tau
\]

\(< \pi_0^2 = N(h_2 + c - c_0) \frac{K(\eta_1 + \eta_2)}{2} \). This means that the loss to sell a used product is greater than the earnings to sell a new one. Therefore, the producer does not like to sell used goods.

If \((h_2 + c - c_0)K \geq -2(K - 1)(\frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-1}}{1 - e^{-1}} h_1 - \tau)\), we have the following formulation

\[
PS^2 = N(h_2 + c - c_0) \frac{K(2\eta_1 + \eta_2)}{2} + N(K - 1)\eta_1 \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-1}}{1 - e^{-1}} h_1 - \tau
\]

\(\geq \pi_0^2 = N(h_2 + c - c_0) \frac{K(\eta_1 + \eta_2)}{2} \). In this situation, the producer has the intention to sell the used goods as many as possible to extend the market size of the new goods.

Therefore, we focus on the situation under the relationship \((h_2 + c - c_0)K \geq -2(K - 1)(\frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-1}}{1 - e^{-1}} h_1 - \tau)\). The equilibrium is correspondingly determined by (6)–(8) and

\[
\pi_0^{*3} = N(h_2 + c - c_0) \frac{K(2\eta_1 + \eta_2)}{2} + N(K - 1)\eta_1 \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-1}}{1 - e^{-1}} h_1 - \tau
\]

(19)

In (19), under \( h_2 - \frac{1 - e^{-1}}{1 - e^{-1}} h_1 + \tau \leq \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 \), the term \(N(h_2 + c - c_0) \frac{K(2\eta_1 + \eta_2)}{2} \) is positive while the term \(N(K - 1)\eta_1 \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-1}}{1 - e^{-1}} h_1 - \tau \) is negative.

We have the following conclusion

**Proposition 3** Under the conditions \( h_2 - \frac{1 - e^{-1}}{1 - e^{-1}} h_1 + \tau \leq \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 \) and

\((h_2 + c - c_0)K \geq -2(K - 1)(\frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-1}}{1 - e^{-1}} h_1 - \tau)\), the producer also sells the used goods and benefits from the expansion of the market size.

**Remarks:** On one hand, the producer undertakes a loss in the secondary market. On the other hand, because of the secondary market, the market size of the new goods is promoted and the producer benefits from this expansion. The relationship \((h_2 + c - c_0)K \geq -2(K - 1)(\frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-1}}{1 - e^{-1}} h_1 - \tau)\) manifests the benefits are larger than the loss. Moreover, no firms (including the producer and other firms) will enter secondary markets if \((h_2 + c - c_0)K < -2(K - 1)(\frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-1}}{1 - e^{-1}} h_1 - \tau)\).
3.3. The duopoly competition in the secondary market

Then, we consider the secondary market with the producer and another firm. As we show that $h_2 - \frac{e^{\frac{1}{2}}}{1-e^{-\frac{1}{2}}} h_1 + \tau > \frac{e^{\frac{1}{2}}}{1-e^{-\frac{1}{2}}} h_3$ indicates other firms quitting the secondary markets. We highlights $h_2 - \frac{e^{\frac{1}{2}}}{1-e^{-\frac{1}{2}}} h_1 + \tau \leq \frac{e^{\frac{1}{2}}}{1-e^{-\frac{1}{2}}} h_3$ in this subsection. Under $h_2 - \frac{e^{\frac{1}{2}}}{1-e^{-\frac{1}{2}}} h_1 + \tau \leq \frac{e^{\frac{1}{2}}}{1-e^{-\frac{1}{2}}} h_3$, if the producer and another firm launch price competition in the secondary markets, the equilibrium is presented as follows: The demand is the same as (6)–-(7). The price and profits are

The equilibrium price is

$$p_i^{k,1+4} = c + h_2 - \frac{1 - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_1, \quad p_i^{k,2+4} = c + h_2 - \frac{1 - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_1 + \tau$$  \hspace{1cm} (20)

The profits of the producer are

$$\pi_o^{*+4} = N(h_2 + c - c_0) \frac{K(2\eta_1 + \eta_2)}{2}$$  \hspace{1cm} (21)

$$\pi_i^{*+4} = 0$$  \hspace{1cm} (22)

The consumer surplus is

$$CS^{*+4} = N\eta_1[(h_1 - h_2) + (K - 1)(h_1 - h_2 + \frac{1 - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} h_1)]$$  \hspace{1cm} (23)

The social welfare is

$$WS^{*+4} = N(h_2 + c - c_0) \frac{K(2\eta_1 + \eta_2)}{2} + CS^{*+4}$$  \hspace{1cm} (24)

We have that

**Proposition 4** Under $h_2 - \frac{e^{\frac{1}{2}}}{1-e^{-\frac{1}{2}}} h_1 + \tau \leq \frac{e^{\frac{1}{2}}}{1-e^{-\frac{1}{2}}} h_3$ and the price competition in the secondary market, compared with Case 1 in Section 3, the consumer surplus is improved.

**Remarks:** The price competition in the secondary markets improves the consumer surplus because the secondary markets play a Bertrand (or price) competition. As we known, the price competition improves the consumer surplus.

3.4. Producer pricing lower than $h_2 + c$

Here, we discuss the case if the producer pricing lower than $h_2 + c + h_3 + c < p_o^{k} < h_2 + c$. In this situation, the middle preference consumers have intention to sell the used goods. We have the following equilibrium.

$$p_o^{k} = p_o^{*,5} = c + h_2 \frac{1 - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}} + h_3 \frac{e^{-\frac{1}{2}} - e^{-1}}{1 - e^{-1}} - \tau$$  \hspace{1cm} (25)

$$p_i^{k,1} = p_i^{k,1+5} = c + h_3 \frac{e^{-\frac{1}{2}} - e^{-1}}{1 - e^{-1}} - \tau$$  \hspace{1cm} (26)
\[ p_{1}^{k,2} = p_{1}^{k,2+5} = c + h_{3} \frac{e^{\frac{h}{2}} - e^{-1}}{1 - e^{-1}} \] (27)

The profits of this producer are
\[ \pi_{0}^{*} = (c + h_{2} \frac{1 - e^{\frac{h}{2}}}{1 - e^{-1}} + h_{3} \frac{e^{\frac{h}{2}} - e^{-1}}{1 - e^{-1}} - \tau - c_{0}) K[(\eta_{1} + \eta_{2}) + \min\{\eta_{3}, \eta_{1} + \eta_{2}\}] \] (28)
\[ \pi_{1}^{*} = 0 \] (29)

If \( \eta_{3} \geq \eta_{1} + \eta_{2} \), the consumer surplus is
\[ CS^{*} = N\eta_{1}[h_{1} - (h_{2} \frac{1 - e^{\frac{h}{2}}}{1 - e^{-1}} + h_{3} \frac{e^{\frac{h}{2}} - e^{-1}}{1 - e^{-1}} - \tau - c_{0})] + N\eta_{2}[(h_{2} - h_{3}) \frac{e^{\frac{h}{2}} - e^{-1}}{1 - e^{-1}} + \tau + c_{0})] + N\eta_{1}(K - 1)[(h_{1} - h_{2}) \frac{1 - e^{\frac{h}{2}}}{1 - e^{-1}} + c_{0}] \] (30)

In this case, price is the lowest and the quantity is the highest in the above five cases. The producer’s price \( p_{0}^{k} = p_{0}^{*} = c + h_{2} \frac{1 - e^{\frac{h}{2}}}{1 - e^{-1}} + h_{3} \frac{e^{\frac{h}{2}} - e^{-1}}{1 - e^{-1}} - \tau \) is a trade-off between the price and the quantity.

4. Producer pricing as a luxury

Here, we address the case when the preference difference between the high and middle preference consumers is large enough. When the preference difference between the high and middle preference consumers is large enough, the producer prices higher than \( h_{2} + c \). We consider this in two cases. One is \( p_{0}^{k} = h_{1} + c \) and the other is \( h_{2} + c < p_{0}^{k} < h_{1} + c \).

If \( p_{0}^{k} = p_{0}^{*} = h_{1} + c \), the secondary market is vanished. The quantity is \( q_{0}^{*} = q_{0}^{3} = \cdots = q_{0}^{K-1} = N\eta_{1} \) and \( q_{0}^{*} = q_{0}^{*} = \cdots = q_{0}^{K} = 0 \). The profits of the producer are
\[ \pi_{0}^{*} = \frac{NK\eta_{1}(h_{1} + c - c_{0})}{2} \] (31)

The social welfare is
\[ SW^{*} = \frac{NK\eta_{1}(h_{1} + c - c_{0})}{2} \] (32)

Here we consider \( h_{2} + c < p_{0}^{k} < h_{1} + c \). The equilibrium is given by \( q_{0}^{*} = q_{1}^{*} = N\eta_{1} \). Moreover,
\[ p_{0}^{k} = p_{0}^{*} = c + h_{1} \frac{1 - e^{\frac{h}{2}}}{1 - e^{-1}} + h_{2} \frac{e^{\frac{h}{2}} - e^{-1}}{1 - e^{-1}} - \tau \] (33)
\[ p_{1}^{k,1} = p_{1}^{k,1*} = c + h_{2} \frac{e^{\frac{h}{2}} - e^{-1}}{1 - e^{-1}} - \tau \] (34)
\[ p_1^{k,2} = p_1^{k,2*} = c + h_2 \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} \]  

(35)

The profits of this producer and the firm in the secondary market are

\[ \pi_0^{*7} = (c + h_1 \frac{1 - e^{-\frac{1}{2}}}{1 - e^{-1}} + h_2 \frac{e^{-\frac{1}{2}} - e^{-1}}{1 - e^{-1}} - \tau - c_0)NK\eta_1, \pi_1^{*7} = 0 \]

(36)

The social welfare is

\[ CS^{*7} = (c + h_1 \frac{1 - e^{-\frac{1}{2}}}{1 - e^{-1}} + h_2 \frac{e^{-\frac{1}{2}} - e^{-1}}{1 - e^{-1}} - \tau - c_0)NK\eta_1 + \]

\[ NK\eta_1[(h_1 - h_2) \frac{e^{-\frac{1}{2}} - e^{-1}}{1 - e^{-1}} + \tau] + N(K - 1)\eta_1[(h_1 - h_2) \frac{e^{-\frac{1}{2}} - e^{-1}}{1 - e^{-1}} + \tau] \]

(37)

By comparison (31) with (36), we have

If \( h_1 \geq c - c_0 + 2(h_1 \frac{1 - e^{-\frac{1}{2}}}{1 - e^{-1}} + h_2 \frac{e^{-\frac{1}{2}} - e^{-1}}{1 - e^{-1}} - \tau) \), \( \pi_0^{*6} \geq \pi_0^{*7} \). Otherwise, \( \pi_0^{*6} < \pi_0^{*7} \). We also point out that \( h_1 \geq c - c_0 + 2(h_1 \frac{1 - e^{-\frac{1}{2}}}{1 - e^{-1}} + h_2 \frac{e^{-\frac{1}{2}} - e^{-1}}{1 - e^{-1}} - \tau) \) may hold if the transaction costs are large enough. When the transaction costs are not very large, the producer likes to price \( p_0^k = p_0^{*,7} = c + h_1 \frac{1 - e^{\frac{1}{2}}}{1 - e^{-1}} + h_2 \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} - \tau \).

5. Producer’s decision

Here, we consider the first stage of each period or the producer’s pricing decision. Taken the above seven cases into account, we have

(1) Under \( h_2 - \frac{1 - e^{\frac{1}{2}}}{1 - e^{-1}} h_1 + \tau \leq \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 \), we have \( p_0^1 = p_0^2 = p_0^3 = \cdots = p_0 = h_2 + c \) and

\[ \pi_0^{*1} = N(h_2 + c - c_0) \frac{K(2\eta_1 + \eta_2)}{2} \]

(2) Under \( h_2 - \frac{1 - e^{\frac{1}{2}}}{1 - e^{-1}} h_1 + \tau > \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3, p_0^1 = p_0^2 = p_0^3 = \cdots = p_0 = h_2 + c \) and \( (h_2 + c - c_0)K \geq -2(K - 1)(\frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-\frac{1}{2}}}{1 - e^{-1}} h_1 - \tau) \), we have

\[ \pi_0^{*3} = N(h_2 + c - c_0) \frac{K(2\eta_1 + \eta_2)}{2} + N(K - 1)\eta_1 \frac{e^{-\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-\frac{1}{2}}}{1 - e^{-1}} h_1 - \tau \]

(3) Under \( h_2 - \frac{1 - e^{\frac{1}{2}}}{1 - e^{-1}} h_1 + \tau > \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3, p_0^0 = p_0^2 = p_0^3 = \cdots = p_0 = h_2 + c \) and \( (h_2 + c - c_0)K \leq -2(K - 1)(\frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} h_3 - h_2 + \frac{1 - e^{-\frac{1}{2}}}{1 - e^{-1}} h_1 - \tau) \), we have

\[ \pi_0^{*3} = N(h_2 + c - c_0) \frac{K(\eta_1 + \eta_2)}{2} \]

(4) If \( p_0^k = p_0^{*,5} = c + h_2 \frac{1 - e^{\frac{1}{2}}}{1 - e^{-1}} + h_3 \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} - \tau \), we have

\[ \pi_0^{*5} = (c + h_2 \frac{1 - e^{\frac{1}{2}}}{1 - e^{-1}} + h_3 \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} - \tau - c_0)K[(\eta_1 + \eta_2) + \min\{\eta_3, \eta_1 + \eta_2\}] \]

(5) If \( h_1 \geq c - c_0 + 2(h_1 \frac{1 - e^{\frac{1}{2}}}{1 - e^{-1}} + h_2 \frac{e^{\frac{1}{2}} - e^{-1}}{1 - e^{-1}} - \tau) \) and \( p_0^k = p_0^{*,6} = h_1 + c \), we have
\[ \pi_0^6 = \frac{NK\eta_1(h_1 + c - c_0)}{2} \]

(6) If

\[ h_1 < c - c_0 + 2(h_1 \frac{1-e^{\frac{1}{2}}}{1-e^{-1}} + h_2 \frac{e^{\frac{1}{2}}-e^{-1}}{1-e^{-1}} - \tau) \text{and} p_0^k = p_0^{*,7} = c + h_1 \frac{1-e^{\frac{1}{2}}}{1-e^{-1}} + h_2 \frac{e^{\frac{1}{2}}-e^{-1}}{1-e^{-1}} - \tau, \]

we have \[ \pi_0^{*,7} = (c + h_1 \frac{1-e^{\frac{1}{2}}}{1-e^{-1}} + h_2 \frac{e^{\frac{1}{2}}-e^{-1}}{1-e^{-1}} - \tau - c_0)NK\eta_1 \]

Here we consider the first stage or the producer prices for small transaction costs. We analyze in two cases: One is that the high preference (wealth) degree is much larger than the middle preference (wealth). The other is that the high preference (wealth) degree is not much larger than the middle preference (wealth).

(A) If the high preference (wealth) degree is much larger than the middle preference (wealth), we have:

\[ h_2 - \frac{1-e^{\frac{1}{2}}}{1-e^{-1}} h_1 + \tau \leq \frac{e^{\frac{1}{2}}-e^{-1}}{1-e^{-1}} h_3 \text{ and } (h_2 + c - c_0)\eta_2 < 2(h_1 \frac{1-e^{\frac{1}{2}}}{1-e^{-1}} + h_2 \frac{e^{\frac{1}{2}}-e^{-1}}{1-e^{-1}} - \tau - h_2)\eta_1 \]

\[ \pi_0^{*,1} = N(h_2 + c - c_0)\frac{K(2\eta_1 + \eta_2)}{2} < \pi_0^{*,7} \]

\[ = (c + h_1 \frac{1-e^{\frac{1}{2}}}{1-e^{-1}} + h_2 \frac{e^{\frac{1}{2}}-e^{-1}}{1-e^{-1}} - \tau - c_0)NK\eta_1 \]

\[ h_2 - \frac{1-e^{\frac{1}{2}}}{1-e^{-1}} h_1 + \tau \leq \frac{e^{\frac{1}{2}}-e^{-1}}{1-e^{-1}} h_3 \text{ and } (h_2 + c - c_0)\eta_2 \geq 2(h_1 \frac{1-e^{\frac{1}{2}}}{1-e^{-1}} + h_2 \frac{e^{\frac{1}{2}}-e^{-1}}{1-e^{-1}} - \tau - h_2)\eta_1 \]

\[ \pi_0^{*,1} = N(h_2 + c - c_0)\frac{K(2\eta_1 + \eta_2)}{2} \geq \pi_0^{*,7} \]

\[ = (c + h_1 \frac{1-e^{\frac{1}{2}}}{1-e^{-1}} + h_2 \frac{e^{\frac{1}{2}}-e^{-1}}{1-e^{-1}} - \tau - c_0)NK\eta_1 \]

**Proposition 5** Under the high preference (wealth) degree being much larger than the middle preference (wealth), when the number of consumers with middle preference (wealth) is much larger than that of the low preference (wealth), we have \( p_0^1 = p_0^2 = \cdots = p_0 = h_2 + c \) and \( \pi_0^{*,1} = N(h_2 + c - c_0)\frac{K(2\eta_1 + \eta_2)}{2} \). Otherwise, this durable good prices as a luxury one.

Or, \( p_0^k = c + h_1 \frac{1-e^{\frac{1}{2}}}{1-e^{-1}} + h_2 \frac{e^{\frac{1}{2}}-e^{-1}}{1-e^{-1}} - \tau \) and \( \pi_0^{*,7} = (c + h_1 \frac{1-e^{\frac{1}{2}}}{1-e^{-1}} + h_2 \frac{e^{\frac{1}{2}}-e^{-1}}{1-e^{-1}} - \tau - c_0)NK\eta_1 \)

**Remarks:** The above Proposition gives a condition for luxury price. Further, if high preference (wealth) degree is much larger than the middle preference (wealth), and the number of consumers with middle preference (wealth) is not much larger than that of the low preference (wealth), this durable good is a luxury one. Actually, when the high preference (wealth) degree is much larger than the middle preference (wealth) and the number of middle wealth is not much larger than that of the high wealth consumers, the producer cares more about the high preference (wealth) consumers and prices as a luxury. Otherwise, the producer prices to sell new goods to high wealth consumers and used goods to middle wealth consumers.
(A) Here we discuss that the high preference (wealth) degree is not much larger than the middle preference (wealth). If the preference (wealth) difference between the middle and the low preference (wealth) consumers is much large, by the similar way, we have

Proposition 6 Under the high preference (wealth) degree being much larger than the middle preference (wealth), when the preference (wealth) difference between the middle and the low preference (wealth) consumers is not much large and the number of the low preference (wealth) is much large, the producer prices \( p_0^k = c + h_2 \frac{1-e^{-1}}{1-e^{-h_3}} + h_3 \frac{e^{z_{-1}}}{1-e^{-h_3}} - \tau \) and the producer’s profits are \( \pi_0^{\tau} = (c + h_2 \frac{1-e^{-1}}{1-e^{-h_3}} + h_3 \frac{e^{z_{-1}}}{1-e^{-h_3}} - \tau - c_0) K[(\eta_1 + \eta_2) + \min(\eta_1, \eta_1 + \eta_1)] \). Otherwise, the producer prices \( p_0^1 = p_0^2 = p_0^3 = \cdots = p_0 = h_2 + c \).

Remarks: Under the high preference (wealth) degree being not much larger than the middle preference (wealth), the preference (wealth) difference determines the price of the producer. When the preference (wealth) difference between the middle and the low preference (wealth) consumers is not much large and the number of the low preference (wealth) is much large, the producer prices lower than \( h_2 + c \) to extend the market size.

The price pattern depends on the wealth allocation. For example, in China, a high degree of income inequality exists, which is further more serious than that in U.S. (Kanbur & Zhang, 2005; Zamudio & Jewell, 2018). The wealth difference in China is much larger than that in U.S. Therefore, some popular durable goods in U.S. are priced luxury in China, such as Lee Jeans, Coach handbags and so on.

6. Concluding remarks

This paper firstly considers the monopolization producer and another monopolist in the secondary market. We find that the producer benefits from the secondary market. Moreover, the wealth (or preference) difference prevents the secondary market. When the producer acts as the market participation of the secondary market, under certain conditions, we argue that the producer benefit from the expansion of the market size of new goods although he undertakes a loss in the secondary market. The producer’s participation in the secondary markets improves the social welfare.

Moreover, the conditions for the producer pricing are presented. When the high preference (wealth) degree is much larger than the middle preference (wealth), the producer prices as a type of luxury. If the high preference (wealth) degree is not much larger than the middle preference (wealth), we also give the optimal price of the producer, which depends on the preference (wealth) difference between the middle and the lower preference (wealth).

This theoretic analysis about secondary market supports a good explanation of Chen et al. (2013). Moreover, the policy implication is to encourage the producer to participate the secondary market to improve the profits. Before 2012, China launched subsidies for “old for new” in the home appliance industry to extend the market size. This is an interesting example to support the conclusions in this work.
Following this paper, some further researching topics arise. Firstly, the effects of the incomplete information should be further addressed. Actually, the incomplete information deters the secondary markets, which is called as adverse selection. Wong, Yiu and Chan (Wong et al., 2012) examined that asymmetric information deters the transaction of second-hand houses in Hongkong. It is interesting to further develop the theory under asymmetric information. Secondly, the equilibrium under continuous preference (or wealth) distribution is interesting. Thirdly, this paper assumed that no difference exists for used goods. It is interesting to consider the multiple types of used goods. Under continuous distribution, the problem becomes more complicated. Finally, this paper addresses two-stage and it is interesting to extend to multiple stages for each period. Finally, the maintenance of durable goods may change the equilibrium in reality. These are our further researching topics.

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