Agricultural Issues Center
University of California

**April 2005**
**WORKING PAPER**

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**A Working Paper**

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Supported in part by the Agricultural Marketing Resource Center

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**Abstract**

Consumers may face a great fit risk when they purchase products. The fit uncertainty can be caused by possible discrepancies between idiosyncratic needs, expectations, and product attributes. This paper analyzes two post purchase mechanisms on reducing the fit risk: money back guarantee (MBG) and secondhand market (SHM). We identify key factors affecting the desirability of these two mechanisms from the perspective of retailers and consumers: (a) the perceived value difference between new and used products; (b) the transaction cost in a secondhand market; (c) return costs of an MBG option; and (d) the marginal production cost relative to the maximum product benefit. The lower the value difference, the higher the transaction cost, and/or the lower the relative marginal production cost, the lower the value of a secondhand market to retailers and consumers. Particularly, we find the following results: (a) A secondhand market increases both retail profits and consumer surplus if it has a sufficiently low transaction cost and/or retailers have a relative high marginal production cost; (b) Providing an MBG is more desirable from the perspective of retailers and consumers if a secondhand market has a sufficiently high transaction cost and the total return cost per unit of an MBG option is sufficiently low, or if the total return cost per unit equals to the transaction cost.

*Key words*: fit risk, product fit, money-back guarantee, secondhand market, secondhand product

## 1 Introduction

Consumers face a fit risk when they purchase products (Roselius, 1971; Heiman and Muller, 1996; Heiman *et al.*, 2001, 2002). That is, consumers may purchase a product at a reasonable price that performs properly and effectively but does not match their needs, lifestyle, or social feedbacks. For example, when purchasing clothes buyers are not completely sure whether the new clothes fit into their daily life and the rest of their wardrobe; parents who buy musical instruments while their children want to learn a different one; consumers may fact uncertainty when they buy treadmill for their "back to shape" campaign.

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Fit risk is reduced only by gaining personal experience with the product. The previous literature investigated several mechanisms against the fit risk, including money back guarantees (MBGs) (Davis *et al.*, 1995; Heiman *et al.*, 2001, 2002), product demonstrations in durable products and sampling for consumables (Smith and Swinyard, 1983; Heiman *et al.*, 2001; Dipak *et al.*, 1995). An MBG allows consumers to try the product in their own environment at a convenient time. If they find a misfit for whatever the reason, the buyer can return the product and receive a full price paid within a prespecified period. Product demonstrations, such as test drives and free sample for consumables, allow buyers to test products directly before purchases without any obligation.

In this paper, we discuss another mechanism against the fit risk, secondhand markets (SHMs). We model the tradeoff between MBG and SHM in reducing the fit risk. The interested readers could find an analysis of the tradeoff between demonstration and SHM in (Heiman *et al.*, 2005). The previous studies modeled SHM as a mechanism to improve market efficiency as it allows consumers to trade excess stock, or as a mechanism to allow high end consumers to sell low end consumers products that have been either obsolete or depreciated. We argue that a SHM has another role: prepurchase fit risk remedy. SHM provides an outlet to dispose of unwanted products that have been found not to meet needs. SHM has been studied in durable product categories, where used products preserve much of their original price, such as automobile (Purohit, 1992; Huang *et al.*, 2001). For example, Onsale (www.onsale.com) auctions off over $1 million a week of refurbished personal computers and other consumer electronics items (Luo, 2003). Amazon (www.amazon.com) concluded that the total used products increased up to 23% of North American unit sales in the last quarter of 2002 (Milliot, 2002). However, SHMs may also defectively reduce fit risk for non-durable goods. For example, one may want to sell a concert ticket in a SHM because of schedule conflicts even if the concert delivers an excellent performance.

A SHM has the following two effects on the primary market: (a) Insurance effect: a SHM increases consumers' willingness to buy since it provides a channel to salvage part of their initial purchase price by selling it in the SHM; and (b) Supply effect: used products provide another source of supply at a low cost and a possible low quality, which competes with the supply from retailers. The impacts of a SHM on market equilibrium and the welfare distribution depend on the trade-off between the insurance and supply effects. In comparison with a SHM, an MBG provides a more comprehensive risk insurance since an MBG option agrees to reimburse the full amount of purchase price which is likely higher than the used product price.[1] Thus, it is of retailers' interest to determine whether it is optimal to provide an MBG option to eliminate SHM. To summarize, we investigate the following research questions: (a) does and under what conditions a SHM increase the welfare of retailers and/or consumers and (b) does and under what conditions is it more profitable for retailers to provide an MBG than welcoming a SHM?

[1] We assume that an MBG agrees to reimburse the full amount of the purchase price. In reality, retailers may charge a penalty or provide a partial reimbursement. For example, the Good Guys charges customers a 15% "restocking" fee for open box returns.

This paper is organized as follows. We present the model in Section 2. In Section 3, we investigates the welfare impacts of SHM and MBG. We show that a SHM does not necessarily improve consumers' welfare, and retailers may benefit from a well functioning SHM with a low transaction cost. Under certain conditions, an MBG option is more desirable from the the perspective of retailers and consumers than a SHM. We present market evidences and managerial implications in Section 4 and offer concluding remarks and propose research extensions in Section 5.

## 2 The Model

To examine the impacts of MBG and SHM, we investigate purchase behaviors and return alternatives of the following three cases illustrated in Figure 1:[2]

- **Case 1, without MBG and SHM**: When both SHM and MBG are not available, consumers either buy new products or nothing. Buyers can only discard or scrap their unwanted products.
- **Case 2, with MBG only**: In this case, there are two possible scenarios: (a) a SHM does not exist, and retailers provide MBGs; and (b) retailers provide MBGs to kill off a SHM. The necessary conditions for an MBG to kill off a SHM are (a) an MBG has a sufficiently long return period for consumers to discover the possible misfit between the product and their idiosyncratic needs; and (b) consumers gain less if they sell the product in a SHM than return it to retailers. In this case, buyers return the product to retailers and get a refund of the purchase price if they find a misfit.
- **Case 3, with SHM only**: When a SHM exists but an MBG option is not available, consumers have three purchase alternatives: (a) not buy at all; (b) buy the new product from retailers; or (c) buy the used product in the SHM. Regardless whether consumers buy the new or used products, they sell the product in the SHM if they find a misfit.

The comparison between **Cases 1** and **3** examines the welfare impacts of a SHM; and the comparison between **Cases 2** and **3** demonstrates the substitutions between SHM and MBG in reducing the fit risk. We make the following assumptions:

- There are $N$ risk neutral consumers and each of them maximize the net monetary benefit. Consumers share an identical likelihood of product fit denoted by $q$. They receive a zero benefit if the product does not fit needs. However, if the product fits needs, consumers are differentiated by their valuation of the product. Let $x$ denote the monetary value an individual consumer perceives if the new product

[2] Realistically, there may exist a case where both an MBG option and a SHM are available. The reasons that we do not discuss this case are: (a) it is extremely hard to obtain analytic results; and (b) comparisons among the proposed three cases will provide sufficient insights to answer proposed research questions.

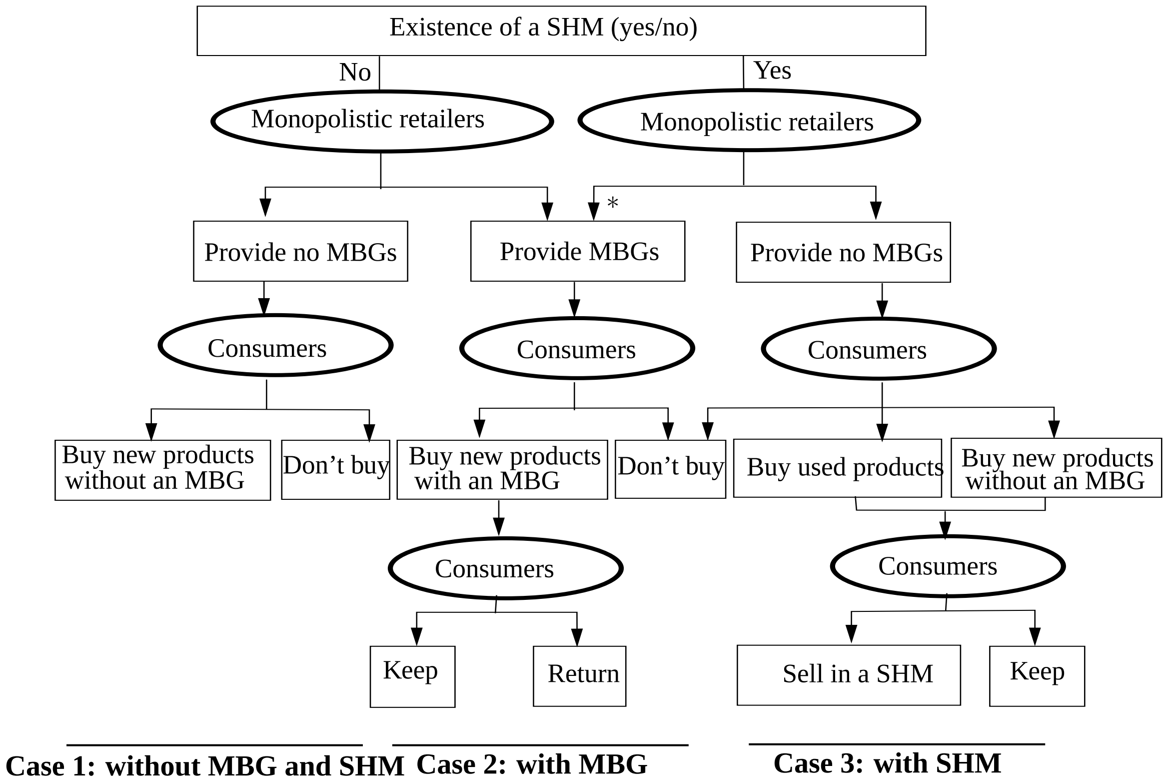



Figure 1: Choices of consumers and retailers under three cases (*: Retailers provide MBGs to kill off SHM.)

fits his/her needs. $x$ is a random variable ranging between the lower bound $\underline{x}$ and the upper bound $\overline{x}$, and has a density function $f(x)$ such that $\int_{\underline{x}}^{\overline{x}} f(x)\, dx = 1$. Thus, if consumers who buy the product on the margin have a product valuation $x'$, the amount of buyers is given by $N \int_{x'}^{\overline{x}} f(x)dx$.

- Consumers perceive a value difference between the new and used products. They place a relative low value on used products because of the following possible reasons: (a) A product may lose value to consumers simply because it is not new any more. For example, a brand new car loses its value at the moment it is sold; and (b) a used product may not be comparable with a new one even with a gentle use or few trials. Since our focus is on fit risk, the newness effect, i.e., consumer value the new products more because they are new, is an essential factor for the value different between new and used products. We assume that consumers perceive a value of $\beta x$ if the used product fits their needs, where $\beta \in [0, 1]$ is a valuation ratio of used products relative to new products and $(1 - \beta)$ is a depreciation ratio. $\beta = 1$ suggests that the new and used products give consumers the same benefit; and $\beta = 0$ implies that consumers will not buy secondhand products.[3]

[3]Used products are normally subject to physical use, which results in a perceptible process of deterioration. The value of $\beta$ is affected by product durability, the rate at which new products are introduced ($\beta$ decreases with a higher product turn over), related technological progress rate (personal computers have a low value of $\beta$, despite its relatively high reliability), and seasonality (used

- When retailers provide an MBG, consumers return the product if they find a misfit within a prespecified period. We define $RC$ and $R$ as the return cost to consumers and retailers, respectively. When a SHM exists, each transaction yields costs to buyers and sellers of used products. Define $T_b$ as buyers' search cost of finding price and characteristics of the used product and $T_s$ as sellers' resale cost. Both $T_b$ and $T_s$ represent time and efforts that consumers spend when they buy and sell the used products; they embody the value that consumers could get if they had perfect information about the SHM and full access to this market. The sum of $T_b$ and $T_s$ is the transaction cost $TT$.

- Retailers are monopolistic. They maximize their profits. Let $c$ denote a constant marginal production cost including the payment to manufacturers, marginal sale cost, etc.

In the rest of this section, we discuss consumer behaviors, pricing, and market equilibrium under three cases.

### Case 1: Without SHM and MBG

We first consider the benchmark case where both SHM and MBG are not available. Assuming that retailers sell the new product at $p_0$, an individual buyer will obtain a benefit of $x - p_0$ if it fits his/her idiosyncratic needs; and lose $p_0$ otherwise. Thus, an individual consumer with fit probability $q$ gains an expected net benefit $B_0(p_0)$ such that

$$B_0(p_0) = q(x - p_0) + (1 - q)(-p_0) = qx - p_0. \tag{1}$$

Consumers will buy the new product if and only if their expected product valuation is greater than the purchase price ($qx > p_0$). The critical value of product valuation above which consumers will buy the product is a function of $p_0$:

$$x_0(p_0) = \frac{p_0}{q}. \tag{2}$$

The corresponding demand thus is

$$D_0(p_0) = N \int_{x_0(p_0)}^{\overline{x}} f(x)dx. \tag{3}$$

Retailers will choose the optimal price to maximize profits. Assuming a zero fixed cost and a constant marginal production cost $c$, retailers' maximum profit is

$$\pi_0(p_0^*) = \max_{p_0} \left\{ (p_0 - c) D_0(p_0) \right\}, \tag{4}$$

costumes have a high $\beta$ as events such as Halloween are approaching). In this paper, we emphasize the fit risk. Consumers sell their unwanted product in the SHM because the product does not fit their needs. Thus, the physical depreciation of the product is not an issue, and secondhand products lost their value relative to the new product is mainly because they are not new any more.

where $p_0^*$ is the optimal price. $p_0^*$ is achieved when the marginal revenue $MR_0$ equals the marginal cost $c$,

$$MR_0 = p_0 + \frac{D_0(p_0)}{dD_0(p_0)/dp_0} = p_0 - \frac{q\int_{x_0(p_0)}^{\overline{x}} f(x)dx}{f(x_0(p_0))} = c. \tag{5}$$

The expected consumer surplus is written as

$$CS_0 = \int_{x_0(p_0^*)}^{\overline{x}} B_0(p_0^*)dx = \int_{x_0(p_0^*)}^{\overline{x}} (qx - p_0^*)f(x)dx = \underbrace{q\int_{x_0(p_0^*)}^{\overline{x}} xf(x)dx}_{Expected\ benefits} - \underbrace{p_0^* D_0(p_0^*)}_{Purchase\ costs}, \tag{6}$$

where $B_0(p_0^*)$ is the individual expected net benefit and $D_0(p_0^*)$ is the equilibrium quantity. Equation (6) shows that the aggregate expected consumer surplus is the total expected benefits net of the purchase cost.

### Case 2: with MBG only

If retailers sell a product with an MBG at price $p_1$, each buyer has a return option within a prespecified period. If the product fits their needs, buyers will keep the product and obtain a net benefit of $x - p_1$. Otherwise, they redeem the MBG option and obtain a refund of the purchase price. We assume that the return cost to consumers $RC$ is less than $p_1$. Otherwise, consumers will not return their unwanted products if $RC > p_1$.[4] An individual consumer with the fit probability $q$ obtains an expected net benefit of buying the product $B_1(p_1)$ such that

$$B_1(p_1) = q(x - p_1) + (1 - q)(-RC). \tag{7}$$

Consumers will buy the product if and only if $B_1(p_1) \geq 0$. The critical value of product valuation above which consumers will buy the product is a function of $p_1$,

$$x_1(p_1) = p_1 + \frac{1-q}{q} RC. \tag{8}$$

The initial demand hence is

$$D_1(p_1) = N\int_{x_1(p_1)}^{\overline{x}} f(x)\, dx, . \tag{9}$$

In this case, both consumers and retailers can recycle unwanted products. That is, consumers can return their unwanted products to the retailers, and their expected amount of returns is $(1-q)D_1(p_1)$. Retailers can resell the returned product or return it to manufacturers.[5] For each unit of initially sold products, retailers obtain a profit of $p_1 - c$ if it fits consumers' needs, and incur a constant return cost $R$ otherwise. Therefore,

[4]Some online computer parts shops deducts a substantial fixed portion from the guaranteed price. Thus, the return option is essentially valueless even though it is available.

[5]These returned products is not the focus of this study. They may be sold in a different market with some discount.

the expected profit per unit of initial sold product is $q(p_1 - c) - (1-q)R$, and retailers' maximum profit given a zero fixed cost is given below:

$$\pi_1(p_1^*) = \max_{p_1}\{[q(p_1 - c) - (1-q)R]\, D_1(p_1)\}, \tag{10}$$

where $p_1^*$ is the optimal product price. $p_1^*$ is achieved when the marginal revenue $MR_1$ equals the marginal cost $MC_1$. $MC_1$ consists of the marginal production cost and the adjusted return cost:

$$MR_1 = p_1 + \frac{D_1(p_1)}{dD_1(p_1)/dp_1} = p_1 - \frac{\int_{x_1(p_1)}^{\overline{x}} f(x)dx}{f(x_1(p_1))} = c + \frac{1-q}{q}R = MC_1. \tag{11}$$

The profitability of an MBG increases as the return cost declines $\left(\frac{d\pi(p_1)}{dR} < 0 \text{ and } \frac{d\pi(p_1)}{dRC} < 0\right)$ or the perceived fit probability goes up $\left(\frac{d\pi_1(p_1)}{dq} > 0\right)$.

The expected consumer surplus is

$$CS_1 = \int_{x_1(p_1^*)}^{\overline{x}} B_1(p_1^*)dx = \underbrace{q\int_{x_1(p_1^*)}^{\overline{x}} xf(x)dx}_{\substack{Expected\ product\\ valuation}} - \underbrace{qp_1^* D_1(p_1^*)}_{\substack{Expected\ purchase\\ costs}} - \underbrace{(1-q)D_1(p_1^*)RC}_{\substack{Expected\ return\\ costs}}. \tag{12}$$

Equation (12) shows that the expected consumer surplus is the total expected product valuation minus the sum of the expected purchase cost and the expected return costs.

### Case 3: With SHM only

A SHM provides consumers a cheaper substitute of the new product, and also an outlet for buyers to sell unwanted products. Let $p_2^n$ and $p_2^s$ denote the prices of new and used products, respectively. Figure 2 summarizes the corresponding payoffs of purchase alternatives (buy new products, used ones, or nothing).

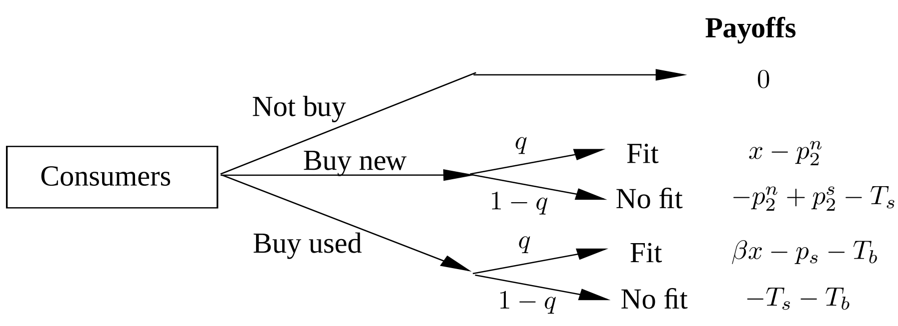



Figure 2: Consumers' purchase alternative and corresponding payoffs

Under the first purchase choice, consumers buy nothing and obtain a zero benefit. Under the second purchase choice, consumers buy the new product from retailers at $p_2^n$. If the product fits their personal needs, they obtain a benefit of $x - p_2^n$; otherwise, they discover a misfit and sell the unwanted product in the SHM at price $p_2^s$. The resale imposes a cost $T_s$ on the seller. Buyers of the new product will not sell their unwanted products if the sale price cannot cover the transaction cost. Thus, we assume that $p_s > T_s$. Hence, buyers of new products obtain a net benefit of $-p_2^n + p_2^s - T_s$ if the product does not fit their needs. Thus, the expected net benefit of buying the new product is

$$B_n(p_2^n, p_2^s) = q(x - p_2^n) + (1-q)(-p_2^n + p_2^s - T_s). \tag{13}$$

Solving $B_n(p_2^n, p_2^s) \geq 0$ yields the critical value of product valuation above which consumers realize a higher expected net benefit from buying the new product than not buying at all,

$$x_2^n(p_2^n, p_2^s) = \frac{p_2^n - (1-q)(p_2^s - T_s)}{q}. \tag{14}$$

Finally, under the third purchase alternative, consumers purchase the used product at $p_2^s$. They incur a search cost of obtaining information of product price and characteristics. Consumers will not buy used product if the sum of purchase cost and search cost is higher than the new product price. Hence, we assume that $p_2^s + T_b < p_2^n$. Buyers of used product obtain a value of $\beta x$ if the product fits their needs. If consumers discover a misfit, they sell the product in the SHM and receive the purchase price $p_2^s$, and their loss is the sum of the search cost $T_b$ and the resale cost $T_s$. Thus, the expected net benefit of buying a used product is

$$B_s(p_2^n, p_2^s) = q(\beta x - p_2^s - T_b) + (1-q)(-T_s - T_b). \tag{15}$$

Solving $B_s(p_2^n, p_2^s) \geq 0$ yields the critical value of product valuation above which consumers are better off buying the used product than not buying at all,

$$x_2^s(p_2^n, p_2^s) = \frac{qp_2^s + (1-q)T_s + T_b}{\beta q}. \tag{16}$$

All prospective consumers with $B_n(p_2^n, p_2^s) \geq B_s(p_2^n, p_2^s)$ would prefer buying the new product over the used one, which yields the critical value of product valuation above which consumers obtains a higher expected net benefit from buying the new product than the used one:

$$x_2^{ns}(p_2^n, p_2^s) = \frac{p_2^n - p_2^s - T_b}{(1-\beta)q}. \tag{17}$$

Figure 3 illustrates the range of product valuations of market segments. The horizontal intercepts determine the critical values of product valuation above which consumers obtain a non-negative net benefit: $x_2^n(p_2^n, p_2^s)$ for the new product and $x_2^s(p_2^n, p_2^s)$ for the used product. The market segments are characterized below: (a) those with high product valuations $x > x_2^{ns}(p_2^n, p_2^s)$ will buy the new product since two inequalities (14) and (17) are satisfied; (b) those with intermediate product valuations $x_2^s(p_2^n, p_2^s) < x < x_2^{ns}(p_2^n, p_2^s)$

will buy the used product since $B_2^s(p_2^n, p_2^s) > \max\{B_2^n(p_2^n, p_2^s), 0\}$; and (c) those with low product valuations $x < x_2^s(p_2^n, p_2^s)$ will buy nothing. To ensure that $x_2^s(p_2^n, p_2^s) < x_2^{ns}(p_2^n, p_2^s)$ holds, the valuation ratio of used products $\beta$ has to be greater than $\beta_{min}$,

$$\beta_{min} = \frac{p_2^s - (1-q)(p_2^s - T_s) + T_b}{p_2^n - (1-q)(p_2^s - T_s)}. \tag{18}$$

A low $\beta$ suggests a great value depreciation if consumers buy the used products. A sufficiently low $\beta$ will deter consumers from buying the used products, thereby killing off a SHM because of the lack of demand.

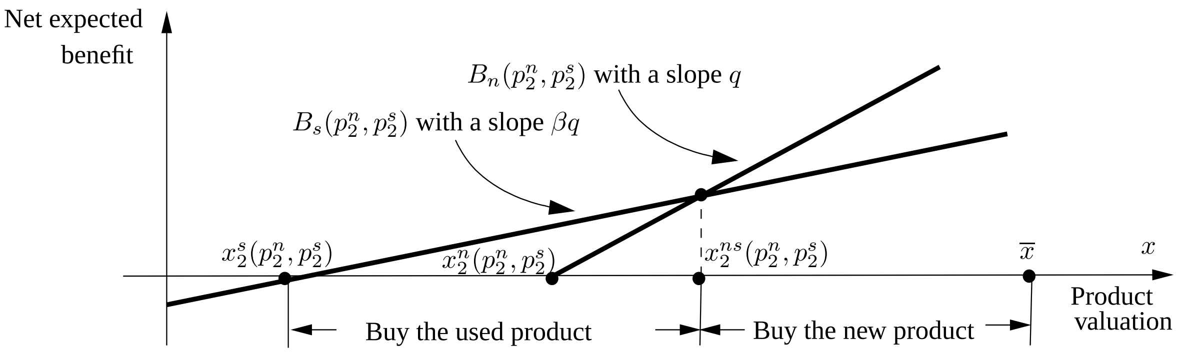



Figure 3: Market segments of new and used products when a secondary market exists

A SHM creates a market segmentation, and consumers self-select into the new and used product buyers according to their product valuations. The initial demand of the new and used products, $D_2^n(p_2^n, p_2^s)$ and $D_2^s(p_2^n, p_2^s)$, are given below:

$$D_2^n(p_2^n, p_2^s) = N \int_{x_2^{ns}(p_2^n, p_2^s)}^{\overline{x}} f(x)dx, \tag{19a}$$

$$D_2^s(p_2^n, p_2^s) = N \int_{x_2^{s}(p_2^n, p_2^s)}^{x_2^{ns}(p_2^n, p_2^s)} f(x)dx. \tag{19b}$$

A product can be resold in the SHM many times, and we assume it losses value only once that is the perceived value difference between the new and used product. Since buyers will sell the products in the SHM if they find a misfit, the supply of the used product $S_2(p_2^n, p_2^s)$ equals the expected resale among new and used product buyers,

$$S_2(p_2^n, p_2^s) = \underbrace{(1-q)D_2^n(p_2^n, p_2^s)}_{\substack{Expected\ resale\ among \\ new\ product\ buyers}} + \underbrace{(1-q)D_2^s(p_2^n, p_2^s)}_{\substack{Expected\ resale\ amomg \\ used\ product\ buyers}} = N(1-q) \underbrace{\int_{x_2^s(p_2^n, p_2^s)}^{\overline{x}} f(x)dx}_{\substack{Total\ demand\ of\ new \\ and\ used\ products}} . \tag{20}$$

Regardless whether consumers buy the new or used products, their fit probability is $q$. The actual amount of resale of both the new and used products is random, and quantity available in the SHM hence is a random variable. Thereafter, the market-clearing price varies instantaneously. We assume an *expected equilibrium* in the SHM, i.e., the used product price is achieved when the demand equals the *expected* supply:

$$S_2(p_2^n, p_2^s) = D_2^s(p_2^n, p_2^s) \Rightarrow (1-q)\int_{x_2^{ns}(p_2^n, p_2^s)}^{\overline{x}} f(x)dx = q\int_{x_2^s(p_2^n, p_2^s)}^{x_2^{ns}(p_2^n, p_2^s)} f(x)dx. \tag{21}$$

$p_2^{n*}$ and $p_2^{s*}$ hence are consistent with the *expected market equilibrium*. The actual prices may deviate from $p_2^{n*}$ and $p_2^{s*}$.

Differentiating Equation (21) with respect to $p_2^n$ and $p_2^s$ yields a price response function between the new and used products,

$$\frac{dp_2^s}{dp_2^n} = \frac{\beta f(x_{ns})}{(1-\beta)q^2 f(x_s) + \beta f(x_{ns})} = \frac{1}{1 + \frac{(1-\beta)q^2}{\beta}\frac{f(x_2^s)}{f(x_2^{ns})}}, \text{ and} \tag{22a}$$

$$\frac{dp_2^s}{dp_2^n} = \frac{\beta}{\lambda} \quad \text{if } x \text{ is uniformly distributed,} \tag{22b}$$

where $\lambda = \beta + (1-\beta)q^2$. Equation (22a) shows that the used product price responds to new product price, and the level of responsiveness depends on the valuation ratio $\beta$, fit probability $q$, and the probability of consumers at the margin, $f(x_2^{ns})$ and $f(x_2^s)$. For example, if $\beta = 1$, new and used products are perfect substitutes and have the same price. If product valuation is uniformly distributed, the probability of the marginal consumer group is the same $f(x_2^s) = f(x_2^{ns})$. Equation (22b) shows (a) if the used product price goes up by 1 unit, the new product price increases by $\left(1 + \frac{1-\beta}{\beta}q^2\right)$ units. Thus, the price difference between the new and used products increases by $\frac{1-\beta}{\beta}q^2$. This finding suggests that retailers may benefit from a SHM because of the price gain; and (b) the price responsiveness $\frac{\beta}{\lambda}$ monotonically increases with the product valuation ratio $\left(d\frac{dp_2^s}{dp_2^n}/d\beta > 0\right)$ and decreases with fit probability $\left(d\frac{dp_2^s}{dp_2^n}/dq < 0\right)$.

Retailers choose the new product price $p_2^n$ to maximize their profit, taking into account of the expected activity in the secondhand market. Hence, we need to incorporate the price responsiveness into the profit maximization. Retailers' profit is written as

$$\pi_2^n(p_2^{n*}, p_2^{s*}) = \max_{p_2^n}\{(p_2^n - c)\, D_2^n(p_2^n, p_2^s)\}, \tag{23}$$

where $p_2^{n*}$ and $p_2^{s*}$ are the optimal prices of the new and used products. $p_2^{n*}$ is achieved when the marginal revenue $MR_2$ equals the marginal cost $c$:

$$MR_2 = p_2^n + \frac{D_2^n(p_2^n, p_2^s)}{\frac{dD_2(p_2^n, p_2^s)}{dp_2^n}} = p_2^n - \frac{(1-\beta)q\int_{x_2^{ns}(p_2^n, p_2^s)}^{\overline{x}} f(x)dx}{\left(1 - \frac{dp_2^s}{dp_2^n}\right) f(x_{ns})} = c. \tag{24}$$

Equation (24) implies that the higher the responsiveness of the used product price to the new product price, the less likely retailers can charge a higher price. Substituting equation (22a) into equation (24) yields

$$p_2^{n*} - \int_{x_{ns}}^{\overline{x}} f(x)dx \left[\frac{(1-\beta)q}{f(x_{ns})} + \frac{\beta}{qf(x_s)}\right] = c. \tag{25}$$

Solving Equations (21) and (25) simultaneously yields the optimal prices of new and used products. Thereafter, we calculate the expected consumers surplus including the expected net benefits of consumers who buy new and used products,

$$CS_2 = \underbrace{\int_{x_2^{ns*}}^{\overline{x}} B_n(p_2^{n*}, p_2^{s*}) f(x) dx}_{\substack{Net\ expected\ benefit\ of \\ new\ product\ buyers}} + \underbrace{\int_{x_2^{s*}}^{x_2^{ns*}} B_s(p_2^{n*}, p_2^{s*}) f(x) dx}_{\substack{Net\ expected\ benefit\ of \\ used\ product\ buyers}}, \tag{26}$$

$$= \underbrace{q \int_{x_2^{ns*}}^{\overline{x}} x f(x) dx + \beta q \int_{x_2^{s*}}^{x_2^{ns*}} x f(x) dx}_{Expected\ product\ valuation} + \underbrace{(1-q)(p_2^{s*} - T_s)(D_2^{n*} + D_2^{s*})}_{Net\ expected\ resale\ benefits} - \underbrace{[p_2^{n*} D_2^{n*} + (p_2^{s*} + T_b) D_2^{s*}]}_{Purchase\ cost},$$

where $D_2^{n*} = D_2^n(p_2^{n*}, p_2^{s*})$ and $D_2^{s*} = D_2^s(p_2^{n*}, p_2^{s*})$ are the initial equilibrium quantity of new and used products, respectively. Buyers of the new product sell their unwanted products in the SHM, thereby receiving $p_2^{s*}$ at the cost of $T_s$. The resale results in a total expected resale benefit. Thus, the total expected consumer surplus consists of the expected product valuation and the net expected resale benefits subtracting the total purchase costs.

### 2.1 SHM versus MBGs

Both MBG and SHM provide an insurance against the fit risk. Redemptions of MBGs impose return costs on retailer and consumers. If the return cost is higher than the marginal production cost, it is less profitable for retailers to provide MBGs. Transactions in a SHM generate costs of selling unwanted products and the cost of collecting price and characteristic information of the product. A high resale cost decreases consumers' willingness to sell unwanted products. A high search cost discourages consumers from buying used product, thereby decreasing the used product price. Hence, retailers may have a low profit. A sufficiently high transaction cost results in a decrease in retail profits, or even eliminates a SHM.

Define the price difference $\Delta\pi = \pi_1(p_1^*) - \pi_2^n(p_2^{n*}, p_2^{s*}) = (p_1^* - c)D_0(p_1^*) - (p_2^{n*} - c)D_2^n(p_2^{n*}, p_2^{s*})$. The investigation on $\Delta\pi$ will provide insights of key factors affecting the desirability of MBG and SHM.

**Proposition 1** *The profit of an MBG relative to a SHM increases as the return cost of MBGs decreases* $\left(\frac{d\Delta\pi}{dRC} < 0 \text{ and } \frac{d\Delta\pi}{dR} < 0\right)$*; the transaction cost increases* $\left(\frac{d\Delta\pi}{dT_b} > 0 \text{ and } \frac{d\Delta\pi}{dT_s} > 0\right)$*; and/or the perceived value difference increases* $\left(\frac{d\Delta\pi}{d\beta} > 0 \text{ if } \beta > \frac{qp_2^{s*}+(1-q)T_s+T_b}{p_2^{n*}+(1-q)T_s}\right)$.

**Proof:** See Appendix A. ■

Proposition 1 suggests that retailers are more likely to provide an MBG to kill a SHM if the return cost is sufficiently low, the transaction cost is sufficiently high, and/or depreciation rate of used products is sufficiently low. This suggestion agree with our intuitions: (a) With a high return cost, only consumers with high product valuations will buy the product. Thus, the initial demand decreases, which may lead to a decrease in retailer profits.[6]; (b) A high transaction cost reduces the value of a SHM to retailers; and (c) When the product valuation ratio $\beta$ is high, some new product buyers may switch to the used products, which may lower retail profits. However, a high $\beta$ may increase the used product price, which likely results in an increase in the new product price and, hence, retail profits increase. If $\beta > \frac{qp_2^{s*}+(1-q)T_s+T_b}{p_2^{n*}+(1-q)T_s}$ is satisfied, an increase in $\beta$ will favor MBG in term of the profitability.

# 3 Impacts of Secondhand Market and MBG Option When Product Valuation is Uniformly Distributed

To obtain further insights about the impacts of MBG and SHM, we make one additional assumption that consumers' product valuation $x$ is uniformly distributed from $\underline{x}$ to $\overline{x}$. Table 1 presents the equilibria under three cases and shows that the difference of welfare distribution largely depends on the maximum social benefit per unit of product produced $M_i$, $i = 0, 1, 2$, where

$$M_0 = q\overline{x} - c, \tag{27a}$$

$$M_1 = \overline{x} - c - \frac{1-q}{q}(R + RC), \tag{27b}$$

$$M_2 = [q + \beta(1-q)]\overline{x} - \frac{1-q}{q}TT - c. \tag{27c}$$

As shown by the first term in Equation (27c), when a SHM exists, the expected maximum benefit is $q\overline{x}$ if the new product fits needs, and $\beta(1-q)\overline{x}$ if it does not fit needs and is sold in the SHM.

## 3.1 Outcomes when an MBG is provided and a SHM does not exist

Jin *et al.* (2005) investigate the welfare impacts of an MBG in great details, and one of their cases is that consumers share an identical fit probability but differ by their product valuation which is uniformly distributed. Proposition 2 summarizes the results of this special case.

**Proposition 2** *An MBG increases both retail profits and consumer surplus if the total return cost per unit is lower than the marginal production cost ($R + RC < c$). Otherwise, an MBG reduces both retail profits and consumer surplus if $R + RC > c$.*

**Proof:** Solving $\pi_1 > \pi_0$ and $CS_1 > CS_0$ shown in Table 1 yields the above results. ■

[6] We assume that consumers will return the product if they find a misfit. Therefore, the return rate is $1 - q$ as long as consumers' return cost is smaller than the product price. Thus, consumers' return cost will not directly affect the return rate.

Table 1: Summary of equilibria under different cases

| Cases | **Case 1** | **Case 2** | **Case 3** |
|---|---|---|---|
| SHM | absent | absent | exists |
| MBG | absent | provided | absent |
| New product price | $p_0^* = \frac{1}{2}(M_0 + 2c)$ | $p_1^* = \frac{1}{2}M_1 + c + \frac{1-q}{q}R$ | $p_2^{n*} = \frac{1}{2}(M_2 + 2c)$ |
| Used product price | / | / | $p_2^{s*} = \frac{\beta}{2\gamma}\left[c + (2\gamma - \beta - q + \beta q)\overline{x}\right]$ $- \frac{1}{2\gamma}\frac{1-q}{q}(2\gamma - \beta)TT - T_b$ |
| New product quantity | $D_0^* = \frac{1}{2(\overline{x}-\underline{x})q}M_0$ | $D_1^* = \frac{1}{2\Delta}M_1$ | $D_2^{n*} = \frac{q}{2(\overline{x}-\underline{x})\gamma}M_2$ |
| Used product quantity | / | / | $D_2^{s*} = \frac{1-q}{2(\overline{x}-\underline{x})\gamma}M_2$ |
| Expected retail profit | $\pi_0 = \frac{1}{4(\overline{x}-\underline{x})q}M_0^2$ | $\pi_1 = \frac{q}{4(\overline{x}-\underline{x})}M_1^2$ | $\pi_n = \frac{q}{4(\overline{x}-\underline{x})\gamma}M_2^2$ |
| Expected Consumer surplus | $CS_0 = \frac{1}{8(\overline{x}-\underline{x})q}M_0^2$ | $CS_1 = \frac{q}{8(\overline{x}-\underline{x})}M_1^2$ | $CS_2 = \frac{q}{8(\overline{x}-\underline{x})\gamma}M_2^2$ |
| Expected Social welfare | $SW_0 = \frac{3}{8(\overline{x}-\underline{x})q}M_0^2$ | $SW_1 = \frac{3q}{8(\overline{x}-\underline{x})}M_1^2$ | $SW_2 = \frac{3q}{8(\overline{x}-\underline{x})\gamma}M_2^2$ |

Proposition 2 shows that the privately optimal choice of an MBG is also socially optimal. An increase in the return cost and/or a decrease in the marginal product cost reduces the value of an MBG to retailers and society as well.

## 3.2 Outcomes when a SHM exists and an MBG is not available

A SHM will not exist if it lacks the demand or supply. On the demand side, consumers are less likely to buy the used product if they perceive a high value loss, and/or it is very costly to find used products. Therefore, $\beta > \beta_{min}$ has to be satisfied. On the supply side, buyers will not sell the product if the used product price is lower than the resale cost ($p_2^s < T_s$). Thus, the amount of transactions in the SHM may decline or even drop to zero with a sufficiently low valuation ratio and/or a sufficiently high transaction cost. To have both $\beta > \beta_{min}$ and $p_2^s > T_s$ hold, the transaction cost has to be low than $TT_0$ such that

$$TT_0 = \beta q\overline{x} + \frac{\beta q(q\overline{x} - c)}{2\lambda - \beta + \beta q}. \tag{28}$$

$\frac{c}{\overline{x}}$ is a ratio of the marginal production cost and the maximum product valuation. We call this ratio $\frac{c}{\overline{x}}$ as the relative marginal production cost in the rest of this paper.

**Proposition 3** *A SHM exists only if (a) the transaction cost is sufficiently low* $(0 < TT < TT_0)$*; and (b) the relative marginal production cost is sufficiently high* $\left(\frac{c}{\overline{x}} > \beta + q - \beta q - 2\lambda\right)$.

**Proof:** See Appendix B. ∎

A SHM recycles unwanted products. If the relative marginal production cost is sufficiently low, it may not worthwhile to recycle the products, and the value of a SHM declines. A sufficiently low $\frac{c}{\bar{x}}$ may eliminate the SHM. On the other hand, a sufficiently high transaction cost will kill off the SHM since it is not worthwhile to buy or sell the used products. Proposition 3 suggests that the ratio of the marginal production cost and maximum product valuation has to be sufficiently high and the transaction cost has to be sufficiently low to have a SHM.

Our intuition suggests the following impacts of a SHM: (a) A SHM may increase the new product demand by providing an insurance against the fit risk; and (b) Some new product buyers with low product valuations may switch to used products and, thus a SHM may decrease the demand. The impacts of a SHM depends on the transaction cost $TT$ and the marginal production relative to the maximum product valuation $\frac{c}{\bar{x}}$. A SHM saves the production cost since it recycles unwanted products. Thus, a high relative marginal production cost will increase the value of SHM to retailers. The transaction cost reduces the value of SHM to retailers because the insurance effect decreases with a high $T_s$, and also the value to consumers since they gain less to buy used products. We expect that a SHM may benefit retailers and consumers with a high relative marginal production cost and a low transaction cost. To obtain further insights, we discuss the impacts of a SHM on the price, equilibrium quantity, and retail profits and consumer surplus in Propositions 4, 5, and 6, respectively.

**Proposition 4** *A SHM increases the new product price. The difference in the new product price with and without a SHM increases as the transaction cost decreases* $\left(\frac{d\left(p_2^{n*}-p_0^*\right)}{dTT} < 0\right)$*, and/or the perceived depreciation ratio decreases* $\left(\frac{d\left(p_2^{n*}-p_0^*\right)}{d(1-\beta)} < 0\right)$.

**Proof:** See Appendix C. ■

According to equations (2) and (14), the new product price with and without a SHM are given

$$p_0 = qx_0, \qquad \text{without a SHM} \tag{29a}$$

$$p_2^n = qx_2^n + (1-q)(p_2^s - Ts), \qquad \text{with a SHM} \tag{29b}$$

where $x_0$ and $x_2^n$ are the production valuation of the marginal buyers who are indifferent to buying the new product or nothing. The second term in equation (29b) is the gain from a SHM because of the resale, which is positive. Thus, the price difference is $p_2^n - p_0 = q(x_2^n - x_0) + (1-q)(p_2^s - T_s)$. If a SHM decreases the new product quantity sold, $x_2^n > x_0$ and, thus, the new product price increases since $p_2^n > p_0$. If a SHM increases the new product quantity, $x_2^n < x_0$. Thus, whether the new product price increases depends on the tradeoff between $q(x_2^n - x_0)$ and the gain from a SHM. Proposition 4 suggests that regardless whether a SHM increase or decrease the quantity of the new product sold, the gain from a SHM dominates, and retailers always charge a higher price when a SHM exists.

Consumers demand more used products when they perceive a smaller valuation depreciation (a high $\beta$) and, thus, the used product price may go up. According to the price response function written in equation (22b), if the used product price increases by one unit, the new product price will increase by $\frac{\beta}{\beta+(1-\beta)q^2}$ units. Therefore, the price difference goes up by $\frac{(1-\beta)q^2}{\beta+(1-\beta)q^2}$ units, and retailers charge a much higher price $\left(\frac{d(p_2^{n*}-p_0^*)}{d\beta} > 0\right)$. If the SHM has a low transaction cost, consumers are willing to pay more, and retailers can charge a higher price $\left(\frac{d(p_2^{n*}-p_0^*)}{dTT} < 0\right)$.

**Proposition 5** *A SHM increases the total consumption of the product. When the relative marginal production cost is sufficiently small* $\left(\frac{c}{\overline{\overline{x}}} < \frac{q}{1+q}\right)$, *a SHM decreases the initial quantity of the new product* $D_2^{n*}$ *regardless of the transaction cost. However, a SHM increases* $D_2^{n*}$ *if* $\frac{c}{\overline{\overline{x}}} > \frac{q}{1+q}$ *and* $0 < TT < TT_q$, *where*

$$TT_q = \beta \left[ \frac{1+q}{q} c - \overline{x} \right]. \tag{30}$$

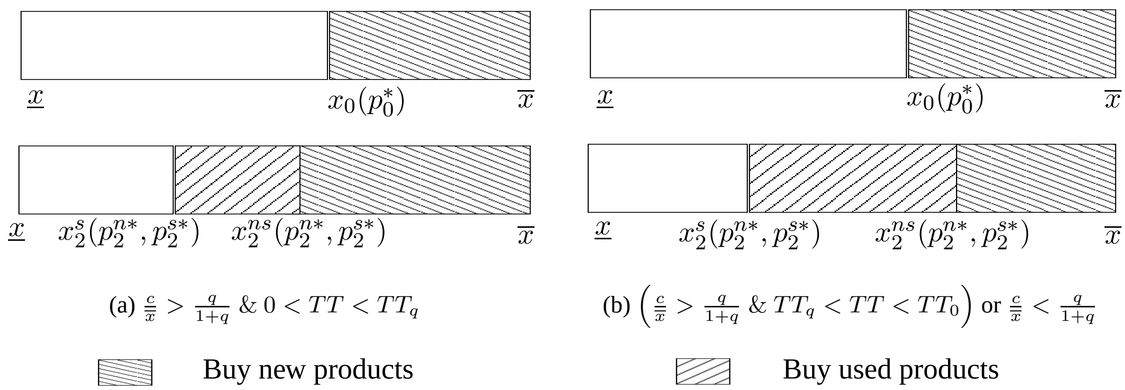
**Proof:** See Appendix D. ∎

Our intuition suggests the following changes on the initial quantity of the new product sold when a SHM exists: (a) Consumers who cannot afford the new product may purchase the used one at a lower price; (b) Those with relative low product valuations who would buy the new product may switch to the used product; and (c) Those who do not buy if there is no option to sell in the SHM may purchase the new product. These changes determine whether a secondary market increases the equilibrium quantity of the new product.

Figure 4 identifies the range of product valuations for market segments. The two upper plots show only consumers whose product valuation is higher than $x_0(p_0^*) = \frac{p_0^*}{q}$ will buy the product when a SHM does not exist. The two bottom plots shows that a SHM creates a market segmentation: consumers whose product valuation is greater than $x_{ns}(p_2^{n*}, p_2^{s*})$ will purchase the new product; those with intermediate product valuations $x_2^s(p_2^{n*}, p_2^{s*}) < x < x_2^{ns}(p_2^{n*}, p_2^{s*})$ will buy the used product; and the remaining consumers with low product valuations will not buy at all.

As shown in Figure 4, when the relative marginal production cost is sufficiently high $\left(\frac{c}{\overline{\overline{x}}} > \frac{q}{1+q}\right)$, retailers gain consumers with product valuations $x_2^{ns}(p_2^{n*}, p_2^{s*}) < x < x_0(p_0^*)$ if the transaction cost is low than $TT_q$ (the left pair in Figure 4). Consumers with low product valuations $x_2^s(p_2^{n*}, p_2^{s*}) < x < x_2^{ns}(p_2^{n*}, p_2^{s*})$ will buy the used product even though they do not buy if a SHM does not exist. As the transaction cost increases up to $TT_0 > TT > TT_q$, the new product buyers with product valuations $x_0(p_0^*) < x < x_2^{ns}(p_2^{n*}, p_2^{s*})$ switch to the used products (the right pair of Figure 4). Therefore, a SHM likely decreases the quantity of the new product sold with a low relative marginal production cost and/or a high transaction cost.

**Proposition 6** *When the relative marginal production cost is sufficiently low* $\left(\frac{c}{\overline{\overline{x}}} < q\left(1 - \frac{\beta(1-q)}{\sqrt{\lambda}-q}\right)\right)$, *a SHM decreases both retail profits and consumer surplus regardless of the transaction cost* $TT$. *However, a*




(a) $\frac{c}{\overline{x}} > \frac{q}{1+q}$ & $0 < TT < TT_q$

(b) $\left(\frac{c}{\overline{x}} > \frac{q}{1+q} \text{ \& } TT_q < TT < TT_0\right)$ or $\frac{c}{\overline{x}} < \frac{q}{1+q}$

Figure 4: Market segments with and without a SHM

*SHM benefits both retailers and consumers if* $\frac{c}{\overline{x}} > q\left(1 - \frac{\beta(1-q)}{\sqrt{\lambda}-q}\right)$ *and* $0 \leq TT < TT_\pi$*, where*

$$TT_\pi = \frac{1}{1-q}\left[(\beta + q - \beta q - \sqrt{\lambda})q\overline{x} + (\sqrt{\lambda} - q)c\right]. \tag{31}$$

**Proof:** See Appendix E. ■

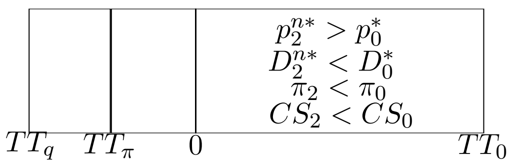
Intuitively, retailers may sell more and/or charge a higher price since a SHM provides an insurance. However, some buyers of the new product with relatively low product valuations may switch to used products at a lower price. Whether a SHM hurts retailers in the primary market depends upon these two effects. From the perspective of consumers, three groups of consumer may benefit from a SHM: those who afford used products but not the new ones; those who switch to used products; and those who sell their unwanted products. But buyers of new products may lose surplus since they may pay a higher price; buyers of the used product incur a search cost of price and product information; and new product buyers who find a misfit incur a cost to sell their unwanted products. Whether a SHM improves the welfare of consumers depends on the relative marginal production cost to the maximum product valuation $\frac{c}{\overline{x}}$ and the transaction cost $TT$. Proposition 6 suggests the following results: (a) A SHM with a high transaction cost, and/or retailers have a low marginal production cost relative to the maximum benefit, will hurt both retailers and consumers; and (b) A SHM increases both retail profits and consumer surplus if the marginal product cost relative to the maximum product valuation is sufficiently high, $\frac{c}{\overline{x}} > q\left(1 - \frac{\beta(1-q)}{\sqrt{\lambda}-q}\right)$, and the transaction cost is sufficiently low, $0 < TT < TT_\pi$.

Figure 5 provides a graphic summary about the impacts of a SHM on the equilibrium outcome presented in Propositions 4, 5, and 6. The main results are given below:

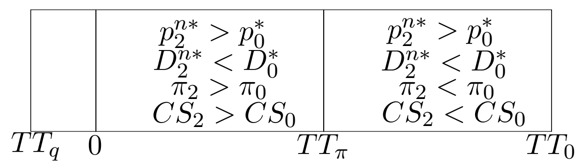
- *Low relative marginal production cost* $q\left(1 - \frac{\beta(1-q)}{\sqrt{\lambda}-q}\right) > \frac{c}{\overline{x}}$: A SHM increases the price and decreases the quantity of the new product. A SHM decreases both retail profits and consumer surplus.

- *Intermediate relative marginal production cost* $\frac{q}{1+q} > \frac{c}{x} > q\left(1 - \frac{\beta(1-q)}{\sqrt{\lambda}-q}\right)$: A SHM increases the price and decreases the quantity of the new product. Retailers and consumers gain from a SHM if $0 < TT < TT_\pi$. Otherwise, a SHM hurts both consumers and retailers.

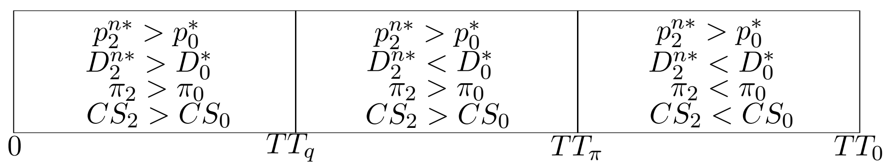
- *High relative marginal production cost* $\frac{c}{x} > \frac{q}{1+q}$: A SHM increases (a) the new product price; (b) the initial quantity of the new product if $0 \leq TT < TT_q$; and (c) both retailer profits and consumer surplus if $0 \leq TT < TT_\pi$.




(a) Low relative marginal production cost: $\frac{c}{x} < q\left(1 - \frac{\beta(1-q)}{\sqrt{\lambda}-q}\right)$




(b) Intermediate relative marginal production cost: $\frac{q}{1+q} > \frac{c}{x} > q\left(1 - \frac{\beta(1-q)}{\sqrt{\lambda}-q}\right)$




(c) High relative marginal production cost: $\frac{c}{x} > \frac{q}{1+q}$

Figure 5: Impacts of a SHM on the market equilibrium

Since it is not certain whether a SHM will hurt retailers, monopolistic retailers may have an incentive to restrain the competition from the SHM if it decreases retail profits, or to lower the transaction cost to facilitate the transaction in the SHM otherwise. The detailed discussion about retailers' strategies to facilitate transactions or interfere with the SHM is presented in Section 4.

### 3.3 Secondhand Market versus MBG Option

Both SHM and MBG play an important role in reducing the fit risk. Similarly, both mechanisms recycle unwanted products. That is, when retailers provide an MBG, consumers can return the product if they find a misfit and retailers resell the product or return it to manufacturers. Both redemptions of an MBG or transactions in the SHM generates costs: return costs to both consumers and retailers in the case of an MBG, and the search cost to buyers to buyers and resale cost to sellers of the used product. However, there is a key difference between MBG and SHM: retailers share redemption costs of an MBG, but do not explicitly share the transaction cost of the SHM. However, transaction costs in the SHM will affect the market equilibrium in the primary market and hence retail profits. We expect that an MBG is more profitable than a SHM if the return cost is sufficiently low and transaction cost is sufficiently high.

Figure 5 shows that a SHM hurts retailers if it has a high transaction cost, $TT > \max\{0, TT_\pi\}$. Thus, retailers may have an incentive to restrain the competition from the SHM by providing an MBG option. On the other hand, even if a SHM could benefit retailers when $\frac{c}{\overline{x}} > q\left(1 - \frac{\beta(1-q)}{\sqrt{\lambda}-q}\right)$ and $0 < TT < TT_\pi$ are satisfied (see Proposition 6). It is of retailers' interest to find out whether an MBG is more profitable. To make an MBG an effective tool to kill off the SHM, we make the following two assumptions: (a) An MBG option has a sufficiently long grace period for consumers to discover the possible misfit between the product and their idiosyncratic needs; (b) $p_1 - RC > p_2^s - T_s$ is satisfied, which implies that consumers have a higher gain if they return the product to retailers rather than sell the product in a SHM. Hence, consumers who experience a misfit will return the product to retailers. Comparing retail profits and consumer surplus under two cases where either an MBG option or a SHM is available yields the critical value of $TT$ above which an MBG option is more desirable:

$$TT_{MBG} = \frac{q}{1-q}[\overline{x}(\beta + q - \beta q - \sqrt{\lambda}) + c(\sqrt{\lambda} - 1)] + \sqrt{\lambda}(R + RC). \tag{32}$$

**Proposition 7** *The private choice of SHM and MBG is also socially optimal.*

- *Both retailers and consumers gain more from an MBG if the transaction cost is sufficiently high* $(\max\{0, TT_{MBG}\} < TT < TT_0)$ *and the total return cost per unit is lower than the marginal production cost* $(c > R + RC)$*, or the total return cost per unit equals the transaction cost.*

- *If the total return cost per unit and the transaction cost are sufficiently high,* $c < R + RC$ *and* $\max\{0, TT_\pi\} < TT < TT_0$*, the absence of both SHM and MBG is socially and privately optimal.*

**Proof:** See Appendix F ■

Proposition 7 suggests that under two conditions retailers have an incentive to provide an MBG to kill off a SHM:

- *When the transaction cost is high,* $\max\{0, TT_{MBG}\} < TT < TT_0$: Consumers are less willing to buy used products with a high search cost, and buyer are less willing to sell unwanted products with a high resale cost. The lack of the demand and supply of used products decreases the value of the SHM to retailers, and retailers may provide an MBG to kill off a SHM.

- *The total return cost per unit equals the transaction cost,* $R + RC = TT$: An MBG option refunds the total amount of the purchase price, while selling unwanted products in the SHM only partially recover the purchase price. If $TT = R + RC$, an MBG yields a higher equilibrium quantity and a higher price, which results in a higher retail profits.

Proposition 7 also suggests that the absence of both SHM and MBG is socially and privately desirable when the total return cost per unit and the transaction cost are both sufficiently high, $c < R + RC$ and $\max\{0, TT_{MBG}\} < TT < TT_0$. Intuitively, retailers and society gain the marginal production cost for each returned product but incur return costs. If the total return cost per unit is higher than the production cost, the gain in the welfare from providing an MBG is lower than redemption costs, thereby an MBG reduces the welfare of retailers and society. On the other hand, if a SHM has a high transaction cost, $\max\{0, TT_\pi\} < TT < TT_0$, both retailers and consumers lose their welfare. Therefore, if $c < R + RC$ and $\max\{0, TT_\pi\} < TT < TT_0$, it is privately and socially optimal to not have MBGs nor SHMs.

# 4 Market Evidence and Managerial Implications

We model both a SHM and an MBG option as mechanisms to reduce the fit risk. The welfare impacts of SHM and MBG depends on the following factors: (a) the transaction cost; (b) the perceived value difference between new and used products; (c) fit probability; and (d) the marginal production cost relative to the maximum product valuation. A well-functioning SHM with a low transaction cost increases retail profits. Retailer hence have an incentive to facilitate transactions in the SHM, engage in selling used products, create an electronic SHM, etc. However, if a SHM decreases retail profits, retailers will interfere with a SHM. For example, they may provide an MBG option to kill off a SHM if the total return cost per unit is sufficiently low. We discuss the possible strategies retailers can adopt when a SHM hurts or benefits retailers below.

### (a): Interfere with a SHM

We find that a SHM hurts retailers if the transaction cost is sufficiently high, and/or consumers perceive a small depreciation of used products. In this case, retailers may want to interfere with the secondary market, or take actions to make transactions in the SHM harder. Our results suggest that retailers may want to provide an MBG to eliminate the supply of used products and, hence kill off the SHM.

There are other alternative strategies retailers can use to interfere with a SHM. But these strategies may not work well for the fit risk. For example, retailers can (a) endogenously choose the built-in durability of the new product (Hendel and Lizzeri, 1999; Purohit, 1992); (b) introduce "planned obsolescence" by selling new products to make old units obsolete (Waldman, 1993, 1996; Choi, 1994; Miller, 1974). Automobile manufacturers have a history of introducing annual style changes into their new model car (Waldman, 1993); textbooks have yearly edition changes (Miller, 1974); and (c) design the optimal contracts of leasing and control the availability of used goods (Hendel and Lizzeri, 1999; Huang *et al.*, 2001). Our results suggest that the fit risk may result in a SHM dealing with new products. If a SHM hurts retailers, providing an MBG to kill off a SHM may be one of fewer choices for retailers.

### (b): Facilitate transactions in a SHM

If a SHM is indeed beneficial to retailers in the primary market, retailers have an incentive to reduce the transaction cost. One option is to create an electronic SHM to serve as a virtual mall that allows geographically dispersed buyers and seller to trade used products. Electronic SHMs are widely used such as Ebay, Amazon, and half.com, etc. For example, the classifieds at Yellow Pages Online allow used-car shoppers to quickly obtain nearby offerings at desired ranges of price, year, model, and mileage (www.ypo.com).

Vertically integrated manufacturers have the following alternative strategies to facilitate transactions in the SHM: (a) retailers allow transferability of warranty coverage across successive owners; (b) car manufacturers encourage dealers to take trade-ins, or other mechanism. General Motors, Ford and Chrysler initiated programs in 1990 that will allow them to buy back all of their sales to rental companies (Wall Street Journal 1990), and subsequently sell these used cars to their dealers; (c) some retailers are engaged in both primary and SHM such as Dell; and (d) IBM provides a three-month quality satisfaction guarantee on refurbished products, a seven-day money-back guarantee on refurbished personal computer products, and service support and installation for refurbished servers and refurbished networking products.[7]

Our results show that both MBG and SHM can effectively reduce the fit risk. An MBG may lessen the competition from the SHM due to the fact that buyers obtain a higher benefit by redeeming the return option. We shall be cautious about interpretations of this finding. For example, if buyers need a longer time than the prespecified return period to find out whether a product fits their need, an MBG is not a good substitute for a SHM. The longer the grace period, the more likely an MBG option will eliminate the SHM.

## 5 Conclusions and Research Extensions

We present an economic framework at the micro-level for analyzing how a SHM and an MBG option reduce the fit risk. We find the following key parameters affecting the desirability of these two mechanisms from the perspective of consumers and retailers: (a) the perceived value difference between new and used products; (b) the transaction cost in the SHM; (c) return costs of an MBG option; and (d) the marginal production cost relative to the maximum product benefit. The lower the value difference, the higher the transaction cost, and/or the lower the relative marginal production cost, the lower the value of a SHM to retailers and consumers.

A SHM plays an allocative role, and consumers segment themselves into two groups: those with high product valuations will buy the new product; those with intermediate product valuations will buy the used

[7] http://www-132.ibm.com/content/search/used-computers.html.

product; and those with low product valuations will not buy at all. A SHM may increase the new product demand because it provides an insurance against the fit risk. However, it also provides another supply source of the product because consumers sell their unwanted products at a lower price. We conclude the following findings: (a) a SHM always increases the new product price; and (b) a SHM increases retail profits and consumer surplus when it has a lower transaction cost and/or retailers have a high marginal production cost relative to the maximum product benefit. However, if consumers perceive a low value difference between the new and used products, the transaction cost is sufficiently high, and/or retailers have a relative high marginal production cost, a SHM will not exist due to the shortage of the demand and/or supply of the used product.

Both MBG and SHM can effectively reduce the fit risk. When consumers and retailers incur a low return cost, retailers obtains a higher profit to provide an MBG than welcoming a SHM if the transaction cost is sufficiently high and/or consumers perceive a sufficiently high value difference between the new and used products. Additionally, if the total return cost per unit equals the transaction cost, retailers obtain a higher profit to provide an MBG.

Many extensions of our model can be envisioned: (a) On a more relatively realistic setting, we have a case such that both SHM and MBG are available. Buyers can either return the product to retailers if they find a misfit within the option period, or sell in a SHM if the return option is expired. Therefore, it is important for retailers to endogenously design an appropriate grace period of an MBG option; and (b) It is common for retailers to be engaged in multiple channels: selling new products in the primary market and sell returned products in the SHM such as Dell. Or retailers can even be engaged in rental and leasing. Thus, retailers have several revenue streams, which will change the model specification and results consequentially.

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# A Proof of Proposition 1

Differentiating $\pi_1(p_1^*)$ in equation (10) with respect to $R$ and $RC$ and evaluatiing at the optimal price yields the following inequalities:

$$\frac{d\pi_1(p_1^*)}{dR} = \frac{\partial \pi_1}{\partial p_1}\frac{\partial p_1}{\partial R} + \frac{\partial \pi_1}{\partial R} = \frac{\partial \pi_1}{\partial R} = -(1-q)RD_1(p_1^*) < 0, \tag{A.1a}$$

$$\frac{d\pi_1(p_1^*)}{dRC} = \frac{\partial \pi_1}{\partial p_1}\frac{\partial p_1}{\partial RC} + \frac{\partial \pi_1}{\partial RC} = \frac{\partial \pi_1}{\partial RC} = -(1-q)\left(p_1^* - c - \frac{1-q}{q}R\right)f(x') < 0, \tag{A.1b}$$

where $\frac{\partial \pi_1}{\partial p_1} = 0$ is the first order condition of Equation (10); $\left(p_1^* - c - \frac{1-q}{q}R\right) > 0$ is the profit per unit of the final sales; and $f(x') = f\left(p_1^* + \frac{1-q}{q}RC\right) > 0$ is the proportion of consumers who are indifferent to buying and not buying the product. Therefore, we obtain two inequalities above.

Differentiating the retail profit $\pi_2(p_n^{n*}, p_2^{s*})$ in equation (23) with respect to $p_2^s$, $T_s$, $T_b$, and $\beta$ yields the following equations,

$$\frac{\partial \pi_2^n(p_2^{n*}, p_2^{s*})}{\partial p_2^s} = \frac{1}{(1-\beta)q}f(x_2^{ns*})(p_2^{n*} - c), \tag{A.2a}$$

$$\frac{\partial \pi_2^n(p_2^{n*}, p_2^{s*})}{\partial T_s} = 0, \tag{A.2b}$$

$$\frac{\partial \pi_2^n(p_2^{n*}, p_2^{s*})}{\partial T_b} = \frac{f(x_2^{ns*})}{(1-\beta)q}(p_2^{n*} - c), \tag{A.2c}$$

$$\frac{\partial \pi_2^n(p_2^{n*}, p_2^{s*})}{\partial \beta} = -\frac{p_2^{n*} - p_2^{s*} - T_b}{(1-\beta)^2 q}f(x_2^{ns*})(p_2^{n*} - c) = -\frac{x_2^{ns*}}{1-\beta}f(x_2^{ns*})(p_2^{n*} - c). \tag{A.2d}$$

Differentiating equation (21) with respect to $p_2^s$ and $T_s$, $p_2^s$ and $T_b$, $p_2^s$ and $\beta$, and $p_2^s$, yields the follows:

$$\frac{dp_s}{dT_s} = -\frac{(1-\beta)(1-q)qf(x_2^{s*})}{(1-\beta)q^2 f(x_2^{s*}) + \beta f(x_2^{ns*})} \tag{A.3a}$$

$$\frac{dp_s}{dT_b} = -\frac{(1-\beta)qf(x_2^{s*}) + \beta f(x_2^{ns*})}{(1-\beta)q^2 f(x_2^{s*}) + \beta f(x_2^{ns*})} \tag{A.3b}$$

$$\frac{dp_s}{d\beta} = \frac{(1-\beta)q^2 x_2^{s*} f(x_2^{s*}) + \beta q x_2^{ns*} f(x_2^{ns*})}{(1-\beta)q^2 f(x_2^{s*}) + \beta f(x_2^{ns*})} \tag{A.3c}$$

Totally differentiating the retail profit $\pi_2(p_n^{n*}, p_2^{s*})$ with respect to $T_s$, $T_b$, and $\beta$, and evaluating at the optimal prices yields the following equations:

$$\frac{d\pi_2^n(p_2^{n*}, p_2^{s*})}{dT_s} = \left[\frac{\partial \pi_2^n}{\partial p_2^n} + \frac{\partial \pi_2^n}{\partial p_2^s}\frac{dp_2^s}{dp_2^n}\right]\frac{dp_2^n}{dT_s} + \frac{\partial \pi_2^n}{\partial p_2^s}\frac{\partial p_2^s}{\partial T_s} + \frac{\partial \pi_2^n}{\partial T_s} = \frac{\partial \pi_2^n}{\partial p_2^s}\frac{\partial p_2^s}{\partial T_s}, \tag{A.4a}$$

$$\frac{d\pi_2^n(p_2^{n*}, p_2^{s*})}{dT_b} = \left[\frac{\partial \pi_2^n}{\partial p_2^n} + \frac{\partial \pi_2^n}{\partial p_2^s}\frac{dp_2^s}{dp_2^n}\right]\frac{dp_2^n}{dT_b} + \frac{\partial \pi_2^n}{\partial p_2^s}\frac{\partial p_2^s}{\partial T_b} + \frac{\partial \pi_2^n}{\partial T_b} = \frac{\partial \pi_2^n}{\partial p_2^s}\frac{\partial p_2^s}{\partial T_b} + \frac{\partial \pi_2^n}{\partial T_b}, \tag{A.4b}$$

$$\frac{d\pi_2^n(p_2^{n*}, p_2^{s*})}{d\beta} = \left[\frac{\partial \pi_2^n}{\partial p_2^n} + \frac{\partial \pi_2^n}{\partial p_2^s}\frac{dp_2^s}{dp_2^n}\right]\frac{dp_2^n}{d\beta} + \frac{\partial \pi_2^n}{\partial p_2^s}\frac{\partial p_2^s}{\partial \beta} + \frac{\partial \pi_2^n}{\partial \beta} = \frac{\partial \pi_2^n}{\partial p_2^s}\frac{\partial p_2^s}{\partial \beta} + \frac{\partial \pi_2^n}{\partial \beta}. \tag{A.4c}$$

where $\frac{\partial \pi_2^n}{\partial p_2^n} + \frac{\partial \pi_2^n}{\partial p_2^s}\frac{dp_2^s}{dp_2^n}$ is the first-order condition of equation (23), and it equals to zero at the optimal price.

Substituting equations (A.2b) and (A.3a) into equation (A.4a), equations (A.2a), (A.2c), and (A.3b) into equation (A.4b), equations (A.2a), (A.2d), and (A.3c) into equation (A.4c) yields the following inequalities:

$$\frac{d\pi_2^n(p_2^{n*}, p_2^{s*})}{dT_s} = \frac{\partial \pi_2^n}{\partial p_2^s}\frac{\partial p_2^s}{\partial T_s} = -\frac{(1-q)qf(x_2^{s*})f(x_2^{ns*})(p_2^{n*}-c)}{\beta f(x_2^{ns*}) + (1-\beta)q^2 f(x_2^{s*})} < 0, \tag{A.5a}$$

$$\frac{d\pi_2^n(p_2^{n*}, p_2^{s*})}{dT_b} = = \frac{\partial \pi_2^n}{\partial p_2^s}\frac{\partial p_2^s}{\partial T_b} + \frac{\partial \pi_2^n}{\partial T_b} = -\frac{(1-q)f(x_2^{s*})f(x_{ns*})(p_2^{n*}-c)}{\beta f(x_2^{ns*}) + (1-\beta)q^2 f(x_2^{s*})} < 0 \tag{A.5b}$$

$$\frac{d\pi_2^n(p_2^{n*}, p_2^{s*})}{d\beta} = \frac{\partial \pi_2^n}{\partial p_2^s}\frac{\partial p_2^s}{\partial \beta} + \frac{\partial \pi_2^n}{\partial \beta} = \frac{qf(x_2^{s*})f(x_2^{ns*})(p_2^{n*}-c)}{\beta f(x_2^{ns*}) + (1-\beta)q^2 f(x_2^{s*})}\left(x_2^{s*} - qx_2^{ns*}\right)$$
$$\begin{cases} > 0 & \text{if } \beta < \frac{qp_2^s + (1-q)T_s + T_b}{p_2^n + (1-q)T_s} \\ < 0 & \text{otherwise} \end{cases} \tag{A.5c}$$

Based on equations (A.1a), (A.1b), (A.5a), (A.5b), and (A.5c), we obtain the following results:

$$\frac{d(\pi_1(p_1^*) - \pi_2^n(p_2^{n*}, p_2^{s*}))}{dR} = -(1-q)RD_1(p_1^*) < 0, \tag{A.6a}$$

$$\frac{d(\pi_1(p_1^*) - \pi_2^n(p_2^{n^*}, p_2^{s*}))}{dRC} = -(1-q)\left(p_1^* - c - \frac{1-q}{q}R\right) f\left(p_1^* + \frac{1-q}{q}RC\right) < 0. \tag{A.6b}$$

$$\frac{d(\pi_1(p_1^*) - \pi_2^n(p_2^{n*}, p_2^{s*}))}{dT_s} = (1-q)q(p_2^{n*} - c)f(x_2^{s*})\frac{dp_2^s}{dp_2^n} > 0, \tag{A.6c}$$

$$\frac{d(\pi_1(p_1^*) - \pi_2^n(p_2^{n*}, p_2^{s*}))}{dT_b} = (1-q)(p_2^{n*} - c)f(x_2^{s*})\frac{dp_2^{s*}}{dp_2^{n*}} > 0, \tag{A.6d}$$

$$\frac{d(\pi_1(p_1^*) - \pi_2^{n*}(p_2^{n*}, p_2^{s*}))}{d\beta} = -q(p_2^{n*} - c)f(x_2^{s*})\left(x_2^{s*} - qx_2^{ns*}\right)\frac{dp_2^{s*}}{dp_2^{n*}}\begin{cases} < 0 & \text{if } \beta < \frac{qp_2^{s*} + (1-q)T_s + T_b}{p_2^{n*} + (1-q)T_s} \\ > 0 & \text{otherwise.} \end{cases} \tag{A.6e}$$

■

## B Proof of Propsition 3

Consumers will not buy used products if $\beta < \beta_{min}$; and buyers will sell their unwanted products only if $p_2^s > T_s$. Substituting the optimal prices, $p_2^{s*}$ and $p_2^{n*}$, into these two conditions yields the followings:

$$TT < TT_{0'} = \beta q\overline{x} + \frac{q}{1-q}(\overline{x}q - c) \text{ and } TT < TT_0 = \beta q\overline{x} - \frac{\beta q(q\overline{x} - c)}{2\lambda - \beta + \beta q}.$$

$TT_{0'} - TT_0 = \frac{2q\lambda(q\overline{x} - c)}{(2\lambda - \beta + \beta q)(1-q)} > 0$ suggests that $TT_0 < TT_{01'}$. Solving $TT_0 > 0$ yield that $\frac{c}{\overline{x}} > \beta + q - \beta q - 2\lambda$. Thus, a SHM exist only if $\frac{c}{\overline{x}} > \beta + q - \beta q - 2\lambda$ and $TT < TT_0$. ■

## C Proof of Propsition 4

The comparison of the new product price with and without a SHM shows that a SHM increases the new product price if $TT < TT_p$ where $TT_p = \beta q\overline{x}$. We know $TT_p > TT_0$, and the proof is given below:

$$TT_p - TT_0 = \beta q\overline{x} - \left[\frac{\beta q((2\lambda - \beta + \beta q - q)\overline{x} + c)}{2\lambda - \beta + \beta q}\right] = \frac{\beta q(q\overline{x} - c)}{2\lambda - \beta + \beta q} > 0.$$

When a secondary market exists ($TT < TT_0$), retailers charge a higher price because $TT < TT_0 < TT_p$. Differentiating $p_2^{n*} - p_2^{s*}$ with respect to $\beta$ and $TT$ yield the following inequalities:

$$\frac{d\left(p_2^{n*} - p_0^{*}\right)}{d\beta} = \frac{1}{2}(1-q)\overline{x} > 0, \tag{C.7a}$$

$$\frac{d\left(p_2^{n*} - p_0^{*}\right)}{dTT} = \frac{1-q}{2q} < 0. \tag{C.7b}$$

Equations (C.7a) and (C.7b) show that the price difference is much higher if consumers perceive a low value loss of used products, and/or s SHM has a low transaction cost. ■

## D Proof of Propsition 5

The comparison of the intial new product demand with and without a SHM shows that a SHM decreases the initial equilibrium quantity of the new product if $TT > \max\{0, TT_q\}$. First, we claim that $TT_q < TT_0$, and the the proof is given below.

$$TT_q - TT_0 = -\beta(q\overline{x} - c)\frac{\beta + 2(1-q^2)(1-q) + (1-\beta)q^2}{(2\lambda - \beta + \beta q)q} < 0$$

Secondly, we obtain the following inequalities:

$$TT_q > 0 \Rightarrow \frac{c}{\overline{x}} > \frac{q}{1+q}.$$

If both $\frac{c}{\overline{x}} > \frac{q}{1+q}$ and $0 < TT < TT_q$ are satisfied, a SHM increases the equilibrium quantity of the new product. ■

## E Proof of Propsition 6

The comparison of retail profits and consumer surplus with and without a SHM shows that a SHM decreases the welfare of both retailers and consumers if $TT > \max\{0, TT_\pi\}$. First, we can proof that $TT_\pi < TT_0$. Secondly, we obtain the following inequalities:

$$TT_\pi > 0 \Rightarrow \frac{c}{\overline{x}} > q\left(1 - \frac{\beta(1-q)}{\sqrt{\lambda} - q}\right).$$

If both $\frac{c}{\overline{x}} > q\left(1 - \frac{\beta(1-q)}{\sqrt{\lambda}-q}\right)$ and $0 < TT < TT_\pi$ are satisfied, a SHM increases retail profits and consumer surplus. ■

## F Proof of Propsition 7

Comparing retail profits and consumer surplus with and without an MBG yield the following result: An MBG is more profitable if $c > R + RC$. Similarily, the comparison of retail profits with SHM and MBG shows that an MBG increases retail profits and consumer surplus if $TT > \max\{0, TT_\pi\}$. Therefore, an MBG is more profitable if $c > R + RC$ and $TT > \max\{0, TT_\pi\}$.

Assuming $TT = R + RC = A$, we obtain the profit difference $\pi_2^n - \pi_1$.

$$\pi_2^n - \pi_1 = \frac{q}{4\Delta x}\left[\frac{1}{\sqrt{\beta+(1-\beta)q^2}}\left((\beta+q-\beta q)\overline{x} - \frac{1-q}{q}A - c\right)\right]^2 - \frac{q}{4\Delta x}\left[\overline{x} - c - \frac{1-q}{q}A\right]^2$$

$$= \frac{q}{4\Delta x}\left[\underbrace{\left(\frac{\beta+q-\beta q}{\sqrt{\beta+(1-\beta)q^2}} - 1\right)}_{-}\overline{x} - \left(\underbrace{\frac{1}{\sqrt{\beta+(1-\beta)q^2}} - 1}_{+}\right)(A+c)\right]$$

$$\left[\underbrace{\left(\frac{\beta+q-\beta q}{\sqrt{\beta+(1-\beta)q^2}} + 1\right)\overline{x} - \left(\frac{1}{\sqrt{\beta+(1-\beta)q^2}} + 1\right)(A+c)}_{+}\right]$$

where $\frac{\beta+q-\beta q}{\sqrt{\beta+(1-\beta)q^2}} - 1 = \frac{-\beta(1-\beta)(1-q)^2}{\sqrt{\beta+1-\beta)q^2}} < 0$ and $\frac{1}{\sqrt{\beta+(1-\beta)q^2}} - 1 > 0$. Therefore, $\pi_2^n < \pi_1$, which implies that an MBG is more profitable if the total return cost per unit equals the transaction cost.