Collaborative Consumption: Strategic and Economic Implications of Product Sharing

Baojun Jiang, Lin Tian

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Abstract

Recent technological advances in online and mobile communications have enabled collaborative consumption or product sharing among consumers on a massive scale. Collaborative consumption has emerged as a major trend as consumers are financially squeezed during the global economic recession and as global concerns on consumption sustainability brings society to explore more efficient use of resources and products. We develop an analytical framework to examine the strategic and economic impact of consumers' collaborative consumption. A consumer who purchased a firm's product can derive different use values across different usage periods. In a period with low self-use value, the consumer may rent out her purchased product through a third-party sharing platform. Thus, the consumer can potentially generate some income though she will have to pay a percentage fee to the platform and also bear some moral hazard cost because of the renter's more aggressive/abusive use of the product. Our analysis shows that the moral hazard cost and the platform's percentage fee may have a non-monotonic effect on the firm's profits, consumer surplus, and social welfare. We find that when the firm strategically chooses its retail price, product sharing among consumers can be a win-win or lose-lose situation for both the firm and the consumers. Further if the firm also strategically chooses its product quality, the potential positive effect of collaborative consumption on consumer surplus disappears while the firm will benefit from the consumers' product sharing behavior.

Key words: sustainability; collaborative consumption; consumer product sharing; moral hazard; pricing; quality; analytic models

1. Introduction

Consumers often buy or own products but do not fully utilize them. Product sharing among consumers—collaborative consumption—has emerged as a major trend in recent years as consumers are financially squeezed during the global economic recession and as global concerns about consumption sustainability lead society to explore more efficient use of resources and products. Technological advances in online and mobile communications have enabled collaborative consumption on a massive scale in recent years. Many websites, online communities, and social media platforms have helped to facilitate sharing among consumers in their local areas and sometimes even across states or countries for a wide range of products and services such as bicycles (Spinlister), boats (Boatbound, GetMyBoat), rides or cars (RelayRides, Lyft, Uber, Getaround, Zimride), working or parking spaces (Citizen Space, JustPark), short-term rental (Airbnb, Roomorama), gardens (Shared Earth, Landshare), clothing, portable tools/appliances and household items (FriendsWithThings).[1] In many farmer communities in developing countries, the sharing of agricultural equipment is especially common. Many product-sharing transactions involve the renters paying a fee to the product owners through the sharing platform. From the consumer's perspective, sharing under-utilized products seems profitable and also environmentally responsible. How is the manufacturer or firm affected by the customers' collaborative consumption? Though managers are wary of such sharing, anecdotal evidence shows that some firms are proactively responding to the emerging trend of collaborative consumption. For example, General Motors (GM) has worked with RelayRides to make it easier for drivers to rent out their under-used OnStar-enabled GM vehicles by introducing features such as the remote unlocking of doors by authorized renters using their smartphones.[2]

[1] The rise of collaborative consumption is well documented in the recent book "What's Mine is Yours" by Botsman and Rogers.

[2] http://in.reuters.com/article/2012/07/17/gm-onstar-idINL2E8IH1QJ20120717, last accessed in September 2014.

This paper focuses on the consumer-to-consumer sharing of products that they buy, not the peer-to-peer offering of services.[3] Our model captures the idea that a consumer's own use value for the product that she purchased may vary over time in multiple usage periods.[4] In each usage period, a consumer who purchased the product can decide whether to use the product herself or to rent it out to others through a third-party product-sharing platform, and a consumer who did not purchase the product can decide whether to rent the product from the sharing platform. For each sharing transaction, the renting consumer has to pay a rental fee while the consumer owning the product needs to pay the platform a fee or commission (a percentage of the rental fee). Note that there is a moral hazard issue in the sharing market. The renter will likely use the product in less careful ways, e.g., driving the rented car more aggressively with fast acceleration and braking and paying less attention to speed bumps than the owner would. Such actions by the renting customer may lead to the product owner having to do more frequent maintenance for the product than if only she herself had used the product. Thus, when renting out her purchased product, the product owner will expect to incur some moral-hazard cost in addition to the platform's percentage fee. We develop an analytical framework with these key features of the marketplace. We study the consumer's purchasing and sharing decisions, and investigate how a firm—the brand owner or manufacturer of the product—should strategically choose its retail price and/or product quality to respond to the anticipated collaborative consumption of the consumers. We investigate the impacts of the consumer's collaborative consumption on the firm's profits, the consumer surplus, and the social welfare.

We highlight a few major findings from our analysis. First, the moral hazard cost has a non-monotonic effect on the firm's profits, consumer surplus, and social welfare. One may intuit that when the moral hazard problem in the sharing market is more severe, the firm should be able to increase its retail price leading to higher profitability, lower consumer surplus and social welfare since the firm's customers will be less likely

[3] Though we use consumer-to-consumer sharing as the context, our model applies equally to business-to-business sharing of products, e.g., the sharing of equipment among businesses or hospitals. The essence is that a firm/manufacturer's customer may rent out the purchased product to the firm's other potential customers during periods of low self-use value.

[4] For expositional convenience, we refer to the firm as "it" and a consumer as "she."

to offer the competing rental option to other consumers, who will then more likely buy the firm's product. Our analysis shows that the firm may actually be worse off because some of the product buyers with a high use value in one period but a low use value in the other period will not be able to earn as much rental income from the sharing market and hence will no longer be willing to buy the product at the same price. To compensate and attract some buyers back, the firm will find it optimal to reduce its price leading to lower profitability, higher consumer surplus and social welfare. For similar intuition, the platform's percentage fee may also have a non-monotonic effect on the firm's profits, consumer surplus, and social welfare.

Second, if the firm strategically chooses its retail price while taking product quality as given (i.e., its product has already been developed), then product sharing among consumers can be a lose-lose or win-win situation for the firm and the consumers. It is lose-lose when the firm's unit cost and the moral hazard cost are low. When the firm's unit cost is high, a win-win will happen for the firm and the consumers. This is because the firm with a high unit cost will save much marginal costs by selling fewer units at much higher prices, which many consumers are still willing to pay because of the potential earnings from renting out the product in the sharing market. In contrast, without the sharing market, many consumers who have high use values only in one period will not be willing to buy the firm's high-cost product because of the forgone income from sharing.

Third, if the firm strategically changes both its retail price and product quality, the consumer's collaborative consumption will increase the firm's profit but reduce the consumer surplus even though the firm will increase its quality in equilibrium. The underlying reason is that those consumers with more variable use values across different usage periods (i.e., a high use value in one period and a low use value in the other period) will be willing to pay more to buy the product since they can earn some income by renting out the product in the sharing market when their own use value is low. This essentially increases those consumers' willingness to pay for product quality and hence gives the firm an incentive to raise its product quality in equilibrium. Meanwhile, the firm's endogenous quality decision allows it to select a strategic price-quality pair to ensure higher profitability by extracting more surplus from consumers anticipating their product sharing behaviors.

1.1. Related Literature

Consumers' social sharing (or piracy) of information goods has received considerable attention in the literature. It has been shown that strong protection against piracy may reduce the social welfare (e.g., Novos and Waldman 1984; Johnson 1985; Liebowitz 1985; Besen and Kirby 1989) and that the consumer's sharing of information goods can actually benefit the firm because of the firm's strategic pricing to target sharing groups rather than individuals (e.g., Bakos et al. 1999; Galbreth et al. 2012), positive network externalities (e.g., Conner and Rumelt 1991; Takeyama 1994; Shy and Thisse 1999; Varian 2005), and reduced price competition as price-sensitive consumers will copy (Jain 2008). There is also a stream of literature that examines the impact of the consumer's illegal sharing of information goods on the firm's incentives to invest in quality (e.g., Novos and Waldman 1984; Lahiri and Dey 2013). Our research differs from the aforementioned literature in several ways. First, we focus on physical products, which cannot be costlessly duplicated by consumers and hence present no piracy issue that plagues digital products. In our model, the consumers must forgo their own use of the product for any period in which they rent it out to others. Second, we explicitly model the consumer's economic incentives to legally share a purchased product—unlike the case of information goods, the owners of a physical product typically have transferable usage rights and can share the product at their own discretion. We endogenously determine which segments of consumers will buy the product and which will share or rent on a product-sharing intermediary that facilitates sharing among consumers. Third, in investigating the economic impacts of the consumers' product sharing on the firm's pricing and quality decisions, we closely examine the critical roles played by the firm's unit cost and the moral hazard issue in the sharing market, which are neglected in that literature.

Our research also complements the stream of literature on secondary markets for durable goods. Used goods from the secondary market may directly compete as lower quality (or depreciated) product with the firm's new or upgraded products potentially reducing the firm's demand for these products (e.g., Coase 1972; Bulow 1982, 1986; Waldman 1997; Fudenberg and Tirole 1998; Chen et al. 2013). But a product's resale value in the secondary market also increases the forward-looking consumer's valuation for the firm's product in its primary retail market (e.g., Miller 1974; Rust 1986; Hendel and Lizzeri 1999; Chevalier and

Goolsbee 2009). The empirical literature has tried to quantify the effects of secondary markets on the firm's sales or profits in various industries and market settings (e.g., Chevalier and Goolsbee 2009; Chen et al. 2013). The theoretical literature on secondary markets has examined firms' optimal decisions on product durability as a quality measure (e.g., Anderson and Ginsburgh 1994; Waldman 1996a; Hendel and Lizzeri 1999; Johnson 2011),[5] and firms' strategic pricing and new product introduction decision when facing competition from used goods (e.g., Waldman 1993, 1996b; Fishman and Rob 2000). Waldman (2003) provides a detail review of the research on secondary markets and durable goods.

There are important conceptual differences between the secondary used-good market that the existing literature has studied and the product-sharing market that we examine. First, a resale transaction in the used-good market involves the *permanent* transfer of product ownership from the seller to the buyer, whereas a sharing transaction in the product-sharing market involves a *temporary* transfer of use right from the product owner to the renter only for the particular sharing period (e.g., one afternoon, one day, or one week) and the owner still owns the product's future continuation value for future periods. Thus, the used-good market has a salient "lemons problem," where the owner/seller may hide the negative private information about the product. For example, when selling a used car, the car owner may not reveal to the buyer the defects of the car, which the buyer will learn only after driving the car for some time (after the sales transaction). In contrast, the product-sharing market has a salient moral hazard problem, where the renter/customer may use the product in unobserved negative ways that hurt the owner's welfare. For example, when renting out their cars on RelayRides.com, the car owners do not directly observe how the renters will use the cars and cannot prevent the renters' aggressive use (e.g., fast acceleration, hard braking, or not slowing down on uneven or speed-bumped roads). The renters will certainly not take care of the cars as well as the car owners themselves will. The renters' actions impose some costs on the owners, who for instance may need car maintenance services sooner than if they had not rented out the cars. In this paper,

[5] Conceptually, a firm can make endogenous product-quality decisions in two dimensions—the initial baseline quality (e.g., the speed of micro-processors or the resolution of touchscreen for a firm's smartphone product) and the rate of depreciation over time of that quality (i.e., the durability of the product). Our paper focuses on the former product-quality decision rather than the latter durability decision that this literature studies.

we will explicitly model the moral hazard cost to the product owner who rents out the product through a sharing intermediary.

Second, unlike the existing theoretical literature on used goods (with the exception of Johnson 2011), in our product-sharing setting, some consumers' per-period use value for the product may increase from one period to the next while other consumers' use values may decrease.[6] For example, one consumer may have a high use value during weekdays and a low use value during weekends whereas another consumer may have a low use value during weekdays and a high use value during weekends. Hence a product-sharing transaction may arise when a consumer with a purchased product has a lower use value in a particular period than does another consumer who did not purchase the product.[7] Further, typically, a consumer who needs to use a product will not buy and sell the same used product frequently on a period-by-period basis. In contrast, a consumer with a purchased product may have multiple sharing transactions in periods of her own low use value.

Our paper also contributes to the bundling literature (e.g., Adams and Yellen 1976; Dansby and Conrad 1984) by studying the consumer's strategic unbundling and reselling behavior. Our framework can be conceptually reinterpreted as the firm selling a bundled product while the forward-looking consumer may strategically unbundle the product and resell to other consumers some parts of it that she has low use values for; the product sold by the firm is essentially a bundle of all uses of the product over all periods. This also relates to the rent-or-buy literature (e.g., Desai and Purohit 1998; Hendel and Lizzeri 2002; Johnson and Waldman 2003). Different from these streams of literature which examine a firm's bundling-unbundling or selling-renting strategies, our research studies the consumer's rent-or-buy decision where the firm's customers themselves may rent out a purchased product during time periods in which they have low self-use values for the product. Thus, in our collaborative consumption setting, consumers make purchase

[6] In a generalized multiple-period ($n > 2$) model, each consumer's use value can change non-monotonically over time.

[7] In contrast, in the used-goods literature, the high-valuation consumers who bought a new product before may later buy another new or upgraded product and sell their used (depreciated) product to low-valuation consumers in the secondary market, because it is implicitly assumed that conditional on buying another new product, high-valuation consumers have a zero use value for their used product.

decisions based on both their own use values for the product and the possibility that they can earn some income by renting the product out in the sharing market when they have low use values.

2. Model

A monopolist firm produces a product of quality q at a constant marginal cost of c. The monopolist sells the product at price p to consumers, each of whom buys at most one unit and can derive use value from the product in $n > 1$ time periods. Note that the consumer's product sharing is a short-run phenomenon in the sense that the firm's strategically chosen price is fixed over the sharing periods. For example, car owners typically rent out their cars on RelayRides on a daily basis, but car manufacturers do not dynamically change their prices on a daily basis even though they make strategic pricing decision or even change their product quality (e.g., General Motors added new features to their cars to facilitate consumers' easier and more reliable car-sharing on RelayRides). Thus, to reduce analytical complexity, we focus on the fairly reasonable case where the firm will strategically choose its price but will not dynamically adjust that price from one sharing period to another.

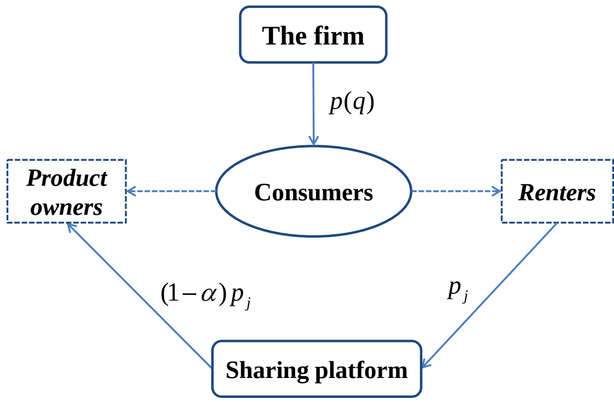
At the end of the n usage periods, the product has a salvage value of ε.[8] Each consumer's per-period use value from the product may vary over time. Consumer i knows her use values v_{ij} for $j = 1, 2, \dots, n$, which depend on the product's quality (q) and her willingness to pay for quality (θ_{ij}); we assume $v_{ij} = q\theta_{ij}$, where θ_{ij} is uniformly distributed in the consumer population: $\theta_{ij} \sim U\,[0, 1]$.[9] Without loss of generality, we normalize the total number of consumers to one. This type of model for quality and consumer heterogeneity has been widely adopted in the economics and marketing literature since Mussa and Rosen

[8] This salvage value can be considered as the product's resale value in the secondary used-goods market after the n usage periods.

[9] This formulation does not explicitly model any depreciation of the product over time. If we allow for depreciation (e.g., the product quality is q for the first period but $q(1 - \Delta)$ for the second period, where Δ represents the rate of depreciation over time), we find that the firm's price and the second-period sharing price will both be lower as Δ increases. The analytical solutions for such a model become much more cumbersome, but our main qualitative insights and intuitions remain the same. Hence, we present the current simplified model in the main paper.

(1978). Without loss of generality, we assume $n = 2$, that is, the consumer can derive use value from the product in two usage periods $j = 1, 2$.

Figure 1 Model Structure



During a period of low use value, the consumer may share her purchased product through a third-party, product-sharing platform. If the consumer rents out her product, she will earn the rental fee for that period but needs to pay the sharing platform a percentage fee, denoted by $\alpha \in [0,1)$ fraction of the rental fee. Typically in practice, the sharing platform collects the rental fee from the renter, keeps a fixed α fraction of that fee as service charge, and will give the remaining fraction $(1-\alpha)$ to the product owner. This market structure is illustrated in Figure 1. In reality, the sharing platforms charge a fixed percentage fee across different products, and that percentage is typically around 10% (e.g., on Spinlister) to 25% (e.g., on RelayRides).

In a sharing transaction, there may exist a moral hazard problem. While the consumer renting other's product typically does not take good care of the product as the product's owner would. For example, the renter may drive a rented car much more aggressively with fast acceleration or hard braking or not slowing down on uneven or speed-bumped roads; this can require the owner to do more frequent maintenance or repair than if she had used the product herself. Hence, to capture this important issue, in our model the product owner will incur some moral hazard cost, denoted by $m \geq 0$, for each period she rents out her product. This moral hazard cost represents the extra cost needed for the product owner to "restore" the product to its original (pre-sharing) condition.[10] The key notations in this paper are summarized in Table 1.

Table 1 Summary of Notations

Symbol	Description
$j = 1, 2$	Product usage periods
p	Retail price of the product
q	Quality of the product
c	Marginal cost or unit cost
$v_{ij} = q\theta_{ij}$	Consumer i's use value for the product in period j, where $\theta_{ij} \sim U(0,1)$
p_j	The market clearance price for the secondary sharing market in period j
m	The moral hazard cost (per period of sharing)
α	The sharing platform's percentage fee
$d(p,q)$	Firm's market demand given its retail price p and product quality q
U_i	Consumer i's utility
π	The firm's profit
sw	The social welfare
cs	The consumer surplus
^{N}	This superscript indicates the case without sharing or collaborative consumption
^{S}	This superscript indicates the case with sharing or collaborative consumption
$_q$	This subscript indicates in the case where the firm strategically chooses its quality

It is also important to point out that, in contrast to the typical case of information goods, in our model the consumer who rents out her product in a period cannot derive any use value from the product in that period. Also in clear contrast to the case of a used-good resale transaction, the original owner of the product in a product-sharing transaction still owns the product's future continuation value, i.e., the sharing transaction is only for the product's usage right for one usage period, after which the product will be returned to the original owner.

Consumer's Strategic Options. Consumers are forward-looking and anticipate, at the time of their product-purchase decision, the possibility of sharing or renting the product in the product-sharing market

[10] Alternatively, we could model the moral hazard cost as a reduction in v_{ij} or a reduction in product quality. Our main results remain qualitative the same.

at price p_j in period j. Each consumer i can choose one of the eight (not clearly dominated) options listed below with the corresponding surplus, denoted by U_i.[11]

(i) Buy the product and use it in both periods: $U_i = v_{i1} + v_{i2} - p + \varepsilon$.

(ii) Buy the product, use it in period one and rent it out in the sharing market in period two: $U_i = v_{i1} + (1-\alpha)p_2 - m - p + \varepsilon$.

(iii) Buy the product, rent it out in the sharing market in period one and use it in period two: $U_i = v_{i2} + (1-\alpha)p_1 - m - p + \varepsilon$.

(iv) Do not buy the product but rent it from the sharing market in both periods: $U_i = v_{i1} - p_1 + v_{i2} - p_2$.

(v) Do not buy the product but rent it from the sharing market only in period one: $U_i = v_{i1} - p_1$.

(vi) Do not buy the product but rent it from the sharing market only in period two: $U_i = v_{i2} - p_2$.

(vii) Buy the product (as a speculator) and rent it out in both periods: $U_i = (1-\alpha)p_1 - m + (1-\alpha)p_2 - m - p + \varepsilon$.

(viii) Neither buy nor rent the product (i.e., the outside option): $U_i = 0$.

Market Clearing Mechanism. With collaborative consumption, consumers may choose any of the above eight options. In each product-usage period, some consumers may rent out their purchased product while others may rent a product from the product-sharing market. In equilibrium, the supply and the demand for product sharing will be equal.[12] In each period j, there will be a market-clearing price (p_j) that works

[11] Since the firm's retail price does not change across the two usage periods, it is suboptimal for consumers to buy the product in the second period. Note also that our model does not actually need to require the consumer to know *ex ante* (at the time of purchase) her exact valuation for each period, e.g., if consumer *i* has use her values v_{i1} and v_{i2} switched between two periods, it makes no difference in our analysis as long as the consumer learns her use value for each period at the beginning of that period.

[12] We assume that the firm will not play any direct role in the product-sharing market. In reality, in many markets, the firms (manufacturers) themselves do not offer hour-to-hour or day-to-day rentals of their products. This may be because the firm's transaction cost for managing renting of its products is much higher than that for consumers. For example, a consumer with an Xbox console can rent it to others in her local area on a daily or weekly basis much more efficiently than Microsoft Inc., the producer of the Xbox, since the company would have many logistical issues (e.g., due to the lack of physical presence in the consumer's local area or city). So, on these product-sharing platforms (or the firms' stores), we typically do not see the firms themselves offering to rent their products on a day-to-day basis;

to match the supply and demand; a consumer needs to pay p_j to rent the product from the market and a consumer who rents out her product will receive a fee of $(1-\alpha)p_j$ while the platform keeps αp_j as its service fee.[13]

Timing of Events. The timing of events in the core model is as follows. First, the firm chooses its retail price p.[14] Second, consumers decide whether to buy the product. Third, in each product-usage period, consumers who bought the product before decide whether to use it themselves or to rent it out in the product-sharing market while consumers who did not buy the product decide whether to rent it from the sharing market; the sharing market clears at some price p_j at which there is no excess demand or supply for sharing. Note that after the sharing transaction in a usage period, the product is returned from the renter to the original owner, who will obtain the product's salvage value (ε) at the end of the last usage period.

3. Analysis

In this section, we assume that the firm has developed the product, which has a quality level of q with a marginal cost of production c. The question is how the firm should optimally set its retail price for this product in response to the anticipated collaborative consumption behavior of the consumer.

The firm's profit is given by $\pi(p,q)=(p-c)d(p,q)$, where $d(p,q)$ denotes the firm's market demand given its retail price p and product quality q. Note that the firm will not enter the market to sell any product if $c \geq 2q$, so we will focus on the nontrivial parameter range of $c \in [0,2q)$. Also, without

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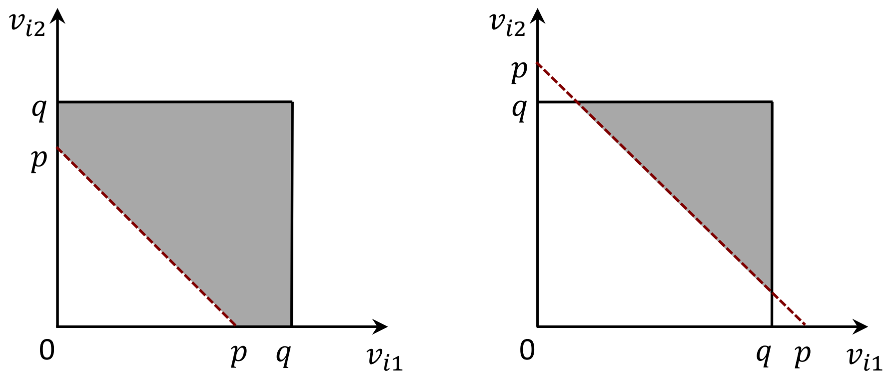
for example, we do not see General Motors offering hourly rental of their cars on car-sharing websites or at its own dealerships.

[13] Note that in our core model the platform's percentage fee (α) is taken as given; this is a reasonable setting since in practice the sharing platform's percentage fee is the same across different products, which implies that the platform does not optimize its fee on an *individual* product level of granularity. Further, our numerical study shows that our main results remain qualitatively the same even if the platform endogenously chooses its percentage fee.

[14] In Section 3, we analyze the core model in which the firm has developed a product of some exogenous quality q. Section 4 examines the case in which the firm will strategically choose both its quality and price in anticipation to consumers' collaborative consumption.

loss of generality, we normalize the product's salvage value to zero (i.e., $\varepsilon = 0$).[15] Since $d(p, q) = 0$ if $p \geq 2q$, we need to examine only the case of $p \in [0, 2q)$.

Figure 2 Consumer Purchase Decision in the Absence of Sharing Market



(a) $p \leq q$ case (b) $q < p < 2q$ case

3.1. No Product-Sharing Market (*N*)

Let us first consider the benchmark case in which there is no product-sharing market for consumers to share products. This case can happen, for example, when the transaction cost for sharing is very high or when the moral hazard cost is forbiddingly high (i.e., $m \geq q$).

As illustrated in Figure 2, consumers are uniformly distributed on the $q \times q$ square; given the firm's retail price p, only the consumers with a total use value $v_{i1} + v_{i2} \geq p$ will buy the product. The firm's demand conditional on p and q is easily computed below depending on whether $p \leq q$ or $p > q$.

$$d(p, q) = \begin{cases} 1 - \frac{p^2}{2q^2} & \text{if } 0 \leq p \leq q, \\ \frac{1}{2}\left(2 - \frac{p}{q}\right)^2 & \text{if } q < p < 2q. \end{cases}$$

[15] Much of the used-good, secondary market literature essentially focuses on studying the effect of this salvage or resale value on the firm. In our setting, the salvage value plays no significant role. If the product's salvage value is bigger than zero (i.e., $\varepsilon > 0$), the firm's optimal price will simply increase by ε in equilibrium and all our main results are qualitatively the same.

To reduce notational clutter, we define $\tilde{c} \equiv \frac{c}{q}$ and use a superscript N to represent the equilibrium outcome in the current case of no product-sharing market. It can be shown that the firm's optimal retail price is

$$p^N = \begin{cases} \frac{\tilde{c}+\sqrt{\tilde{c}^2+6}}{3} q & \text{if } 0 \leq \tilde{c} < \frac{1}{2}, \\ \frac{2+2\tilde{c}}{3} q & \text{if } \frac{1}{2} \leq \tilde{c} < 2. \end{cases}$$

The firm's demand when optimally pricing its product is given by

$$d^N = \begin{cases} \frac{6-\tilde{c}^2-\tilde{c}\sqrt{\tilde{c}^2+6}}{9} & \text{if } 0 \leq \tilde{c} < \frac{1}{2}, \\ \frac{2(2-\tilde{c})^2}{9} & \text{if } \frac{1}{2} \leq \tilde{c} < 2. \end{cases}$$

The firm's optimal profit is given by

$$\pi^N = \begin{cases} \frac{\tilde{c}^3+(\tilde{c}^2+6)\sqrt{\tilde{c}^2+6}-18\tilde{c}}{27} q & \text{if } 0 \leq \tilde{c} < \frac{1}{2}, \\ \frac{2(2-\tilde{c})^3}{27} q & \text{if } \frac{1}{2} \leq \tilde{c} < 2. \end{cases}$$

The total consumer surplus and the social welfare are given by

$$cs^N = \begin{cases} \left[1 + \frac{2\tilde{c}^3+(2\tilde{c}^2-24)\sqrt{\tilde{c}^2+6}-18\tilde{c}}{81}\right] q & \text{if } 0 \leq \tilde{c} < \frac{1}{2}, \\ \left[\frac{4}{3} + \frac{8(1+\tilde{c})^3}{81} - \frac{4(1+\tilde{c})^2}{9} - \frac{2\tilde{c}(2-\tilde{c})^2}{9} - \frac{2(2-\tilde{c})^3}{27}\right] q & \text{if } \frac{1}{2} \leq \tilde{c} < 2 \end{cases}$$

and $sw^N = \begin{cases} \left[1 + \frac{5\tilde{c}^3+(5\tilde{c}^2-6)\sqrt{\tilde{c}^2+6}-72\tilde{c}}{81}\right] q & \text{if } 0 \leq \tilde{c} < \frac{1}{2}, \\ \left[\frac{4}{3} + \frac{8(1+\tilde{c})^3}{81} - \frac{4(1+\tilde{c})^2}{9} - \frac{2\tilde{c}(2-\tilde{c})^2}{9}\right] q & \text{if } \frac{1}{2} \leq \tilde{c} < 2 \end{cases}$ respectively.

It is easy to verify that p^N increases in c while d^N, π^N, cs^N, and sw^N all decrease in c.

3.2. Product-Sharing Market (*S*)

We now examine the case in which there exists a product-sharing market. For nontrivial analysis, we consider only the case of $m \in [0, (1-\alpha)q)$ since if $m \geq (1-\alpha)q$ there will be no sharing transactions in equilibrium and the analysis will be the same as that in Section 3.1.

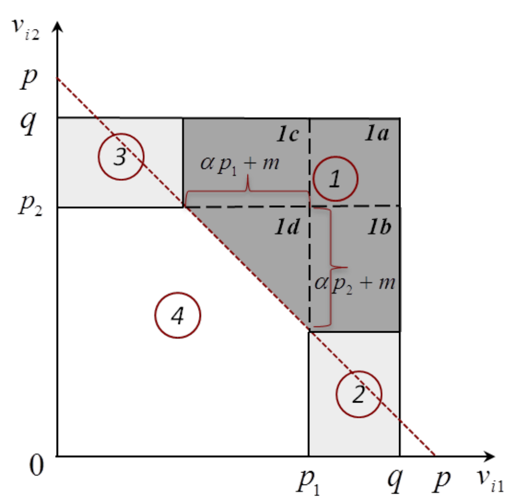
First, let us examine the equilibrium of the subgame for the product-sharing market given the firm's retail price p. Note that if $0 \leq p \leq \frac{m}{1-\alpha}$, no consumers will rent the product from the sharing market and that if $(2-\alpha)q-m<p<2q$, no consumers will buy and rent out the product. There will be sharing transactions in the product-sharing market only if $\frac{m}{1-\alpha}<p\le(2-\alpha)q-m$. The firm's demand function and the market-clearing prices in the product-sharing market (when transactions exist) are shown in Lemma 1.[16]

LEMMA 1. *In the subgame following the firm's price decision, the firm's demand is given by:*[17]

$$d(p,q)=\begin{cases}1-\frac{p^2}{2q^2} & \text{if } 0\le p\le\frac{m}{1-\alpha},\\ 1-\frac{\alpha}{2(2-\alpha)}\frac{p^2}{q^2}-\left(\frac{1-\alpha}{2-\alpha}+\frac{1}{2-\alpha}\frac{m}{q}\right)\frac{p}{q}+\frac{1}{2-\alpha}\frac{m}{q} & \text{if } \frac{m}{1-\alpha}<p\le(2-\alpha)q-m,\\ \frac{1}{2}\left(2-\frac{p}{q}\right)^2 & \text{if } (2-\alpha)q-m<p<2q.\end{cases}$$

There are sharing transactions in the product-sharing market only if $\frac{m}{1-\alpha}<p\le(2-\alpha)q-m$ *and the market-clearing prices are* $p_1=p_2=\frac{p+m}{2-\alpha}$.

Figure 3 Consumer Decisions in the Presence of Product Sharing Market



Given the firm's price (p) and the product-sharing prices (p_j) are in the relevant ranges for the existence of sharing transactions, we can divide all consumers into four segments based on the consumer's use value

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[16] All proofs in this paper are provided in the Appendix.

[17] Here we have assumed $m\in[0,(1-\alpha)q)$. If $m\ge(1-\alpha)q$, the firm's demand is the same as in the case of no sharing market.

in the two usage periods, as illustrated in Figure 3. If in equilibrium there are transactions in the product-sharing market, consumers in segment *1* (i.e., *1a*, *1b*, *1c*, *1d*) will buy the product from the firm and use it themselves in both periods. Consumers in segment *2* will use the product in the first period but not in the second period, and they are indifferent between (a) buying the product and renting it out in the sharing market in the second period and (b) not buying the product but renting it from the sharing market in the first period. Similarly, consumers in segment *3* will use the product in the second period but not in the first period, and they are indifferent between (a) buying the product and renting it out in the sharing market in the first period and (b) not buying the product but renting it from the sharing market in the second period. Consumers in segment *4* will not use the product in either period, and they will also find it unprofitable to buy and rent out the product. Note that, for the market-clearing equilibrium, we do not need to consider exactly which consumers in segments *2* and *3* will buy the product, use it in one period and rent it out in the other period, or who among them will only rent the product from the sharing market. We need only match the aggregate product-sharing demand and supply from the two segments to determine the equilibrium prices in the sharing market.

Comparing Figure 3 with Figure 2, we see clearly that the consumer's collaborative consumption makes a difference in reshaping the firm's demand in the primary (retail) market. First, when a product-sharing market exists, a consumer with a total use value lower than p may choose to buy the product from the firm. This is because she anticipates the possibility of generating some profit from the product by renting it out to another consumer when her own use value is low. Of course, the consumer needs to take into account the use value she foregoes and her cost of sharing, which includes the moral hazard cost and the percentage fee paid to the sharing platform. Her net profit from a sharing transaction in period j is thus $(1-\alpha)p_j - v_{ij} - m$. Because of this anticipated profit from the product-sharing market, consumers in segments 2 and 3 will ascribe more value to the product than their own total use value. In particular, the consumers in segments 2 and 3 below the line $v_{i1} + v_{i2} = p$, as illustrated in Figure 3, may now decide to buy the product at price p whereas they will not buy it when no product-sharing market exists.

Second, when the product-sharing market exists, a consumer with a total use value higher than p may no longer buy the product from the firm. This is because she can also rent the product from the sharing market. In particular, all consumers in segments 2 and 3 that are above the line $v_{i1} + v_{i2} = p$ will buy the product at price p if the product-sharing market does not exist, but they may now decide to rent the product from the sharing market instead. That is, the consumer's product sharing can also reduce the firm's product demand.

Having examined the equilibrium of the product-sharing market given the firm's retail price p, we now consider the firm's strategic pricing decision and the overall equilibrium outcome. We will focus on the equilibrium outcome in which there are sharing transactions in equilibrium.[18] To reduce notational clutter, we define a constant $\widetilde{m} \equiv \frac{m}{q}$ and use a superscript S to denote the equilibrium outcome for the current case with the existence of the product-sharing market. One can show that the firm's optimal retail price is given by

$$p^S = \frac{\sqrt{[2(1-\alpha+\widetilde{m})-\alpha\tilde{c}\,]^2+6\alpha[(2-\alpha+\widetilde{m})+(1-\alpha+\widetilde{m})\tilde{c}]}-[2(1-\alpha+\widetilde{m})-\alpha\tilde{c}\,]}{3\alpha}q\,.$$

The firm's demand at optimal pricing is given by

$$d^S = -\frac{\alpha}{2(2-\alpha)}\frac{(p^S)^2}{q^2} - \left(\frac{1-\alpha}{2-\alpha} + \frac{1}{2-\alpha}\widetilde{m}\right)\frac{p^S}{q} + \frac{1}{2-\alpha}\widetilde{m} + 1.$$

The firm's profit is

$$\pi^S = (p^S - c)d^S\,.$$

The social welfare is

$$sw^S = \frac{1}{3(2-\alpha)^3 q^2}\{-\alpha(6+(-6+\alpha)\alpha)(p^S)^3 + 3(-1+\alpha)(2+(-3+\alpha)\alpha+4\widetilde{m})(p^S)^2 q$$

$$+6\widetilde{m}[2+\alpha(-3+\alpha+\widetilde{m})]p^S q^2 + \left[4\widetilde{m}^3 + (3\alpha-6)\widetilde{m}^2 - 3\alpha^3 + 18\alpha^2 - 36\alpha + 24\right]q^3\} - \tilde{c}d^S q.$$

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[18] Essentially, this means we will focus on the parameter range that $m < m^* = \begin{cases} \widetilde{m}_A q & \text{if } 0 \le c < \frac{q}{2}, \\ \widetilde{m}_C q & \text{if } \frac{q}{2} \le c < 2q, \end{cases}$ where $\widetilde{m}_A = \frac{(1-\alpha)[\tilde{c}-(1-\alpha)+\sqrt{\tilde{c}^2+(1-\alpha)(6-2\alpha)\tilde{c}+3\alpha^2-14\alpha+17}]}{4-\alpha}$ and $\widetilde{m}_C$ is the solution of equation $sw^S = sw^N$. When m is larger than that threshold, there will be no transaction in the product-sharing market in equilibrium, which is not interesting.

The total consumer surplus is

$$cs^S = sw^S - \pi^S - \alpha \frac{p^S/q+\widetilde{m}}{2-\alpha}\left(1 - \frac{p^S/q+\widetilde{m}}{2-\alpha}\right)\left[(1-\alpha)\frac{p^S/q+\widetilde{m}}{2-\alpha} - \widetilde{m}\right] q.$$

As in the case without any sharing market, we find that p^S increases in c while d^S, π^S, cs^S, and sw^S all decrease in c.

3.3. Impact of Collaborative Consumption

We have analyzed the equilibrium outcomes for two cases based on whether the product-sharing market exists and assuming that the firm will strategically set its retail price. We now examine the impact of the consumer's collaborative consumption (i.e., the presence of a product-sharing market) on the firm's price, unit sales, profit, the consumer surplus and social welfare. We will study how two key factors—the moral hazard cost (m) and the firm's unit cost (c)—affect the impact of collaborative consumption.

PROPOSITION 1. *As the moral hazard cost (m) increases, the firm will reduce its retail price p^S, but the impacts of m on π^S, sw^S, and cs^S are non-monotonic.*

One may intuit that when the moral hazard problem in the sharing market is more severe, the firm should increase its retail price since the firm's customers will be less likely to offer the competing rental option to other consumers, who may now be more likely to buy the product from the firm. However, as Proposition 1 shows, a higher moral hazard cost in the sharing market will actually lead to a price drop by the firm. This is because some of the product buyers, who have a high self-use value of the product in one period but a low use value for the other period, will not be able to earn as much rental income from the sharing market and hence will no longer be willing to buy the product at the same price. To compensate and attract some buyers back, the firm will find it optimal to reduce its price. In practice, the sharing platform often tries to reduce the moral hazard cost to the product owners by offering insurance coverage or by enabling the product owners to rate the renters after transactions, which will to some extent alleviate the moral hazard problem. Our result implies that the consumer's increased incentive for sharing a purchased product can induce the manufacturer to raise rather than lower its price.

According to Proposition 1, because of the firm's strategic pricing, a change in the moral hazard cost may lead to a non-monotonic effect on the firm's profit, the social welfare and the total consumer surplus. We find that as the moral hazard cost decreases, the firm's profit, the social welfare and the consumer welfare may decrease or increase. So the sharing platform's efforts to reduce moral hazard costs may not always benefit the consumers or the manufacturer. In particular, as the moral hazard cost decreases, product owners are more likely to share their products to earn higher fees (net of costs including the moral hazard cost and the platform fee), but the firm will strategically increase its price, which not only reduces the sharing benefit but also leads to some customers who only use the product themselves (e.g., in segment *1d* in Figure 3) to drop out of the market. Hence, the total consumer surplus in the market may drop. Further, by similar analysis and intuition, we easily obtain the corollary that the decrease of the sharing platform's percentage fee (i.e., α) may not always benefit the consumers or the manufacturer.

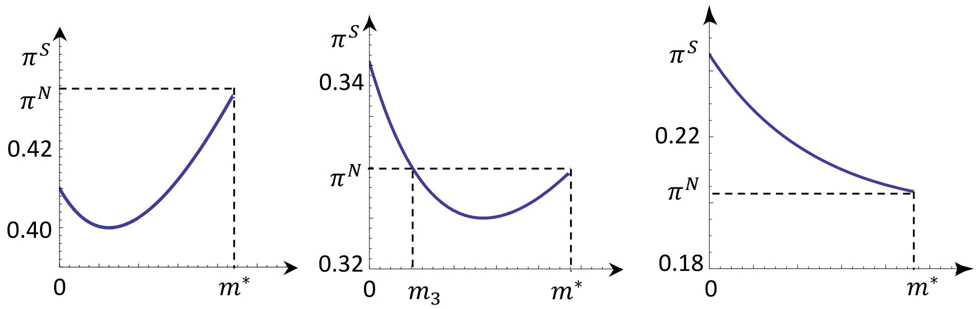
COROLLARY. *The impacts of* α *on* π^S *and* cs^S *are non-monotonic.*

Note that if the sharing platform's percentage fee is excessively high (i.e., $\alpha > 1 - \frac{m}{q}$), there will not be any sharing transaction in equilibrium (and the platform will earn no profits). If the platform's percentage fee is not too high (i.e., $\alpha < \alpha^*$, where $0 < \alpha^* < 1 - \frac{m}{q}$), we can obtain the following results by comparing the equilibrium outcome under the case without a sharing market with that under the case with a sharing market.

PROPOSITION 2. *Compared with the case when there is no product-sharing market, when a sharing market exists the firm will charge a higher retail price if the moral hazard cost of product sharing is low, and it will charge a lower price if the moral hazard cost is high. Or mathematically,* $\exists\, m_1 \in (0, m^*]$ *such that* $p^S > p^N$ *if* $m \in [0, m_1)$ *and* $p^S < p^N$ *if* $m \in (m_1, m^*)$.

PROPOSITION 3. *The product-sharing market will benefit the firm if its unit cost is relatively high but will hurt the firm if its unit cost is very low. When the firm's unit cost is intermediate, the product-sharing market will benefit the firm if the moral hazard cost is low enough but hurt the firm if the moral hazard cost* *is high. Or mathematically,* $\exists\, c_1 \in (0, \frac{q}{2})$ *such that* $\pi^S < \pi^N$ *when* $c < c_1$*, and when* $c_1 < c < \frac{q}{2}$*,* $\exists\, m_3 \in (0, m^*)$ *such that* $\pi^S > \pi^N$ *if* $m \in [0, m_3)$ *and* $\pi^S < \pi^N$ *if* $m \in (m_3, m^*)$*; when* $\frac{q}{2} \leq c < 2q$*,* $\pi^S > \pi^N$*.*

Figure 4 Firm's Optimal Profit (π^S) as a Function of m



(a) $c < c_1$ case (b) $c_1 < c < \frac{q}{2}$ case (c) $\frac{q}{2} < c < 2q$ case

The conventional wisdom is that since the product-sharing market competes with the firm by providing consumers a sharing alternative, the firm will be pressured to reduce its retail price leading to lower profitability, higher consumer surplus and social welfare. Propositions 2 and 3 show that, interestingly, the product-sharing market can in equilibrium either increase or decrease the firm's price and profit (see Figure 4 for an illustration of the firm's profit). Further, the effects of the product-sharing market on consumer surplus and social welfare can also be either negative or positive (Proposition 4). We find that the firm's marginal cost of production and the moral hazard cost product sharing play an important role in determining the effects of the consumers' sharing behavior.

PROPOSITION 4. *If the firm's unit cost is below some threshold, then the existence of the product-sharing market will reduce (increase) the consumer surplus and the social welfare if the moral hazard cost is low (high). Or mathematically, when* $c < \frac{q}{2}$*,* $\exists\, m_4 \in (0, m^*]$ *such that* $cs^S < cs^N$ *if* $m \in [0, m_4)$ *and* $cs^S > cs^N$ *if* $m \in (m_4, m^*)$*; when* $c < c_2$ *where* c_2 *is some constant on* $(0, \frac{q}{2})$*,* $\exists\, m_5 \in (0, m^*]$ *such that* $sw^S < sw^N$ *if* $m \in [0, m_5)$ *and* $sw^S > sw^N$ *if* $m \in (m_5, m^*)$*.*

If the moral hazard cost in the product-sharing market is relatively low, the firm will actually charge a higher retail price and make higher profits than when the sharing market does not exist, and the total consumer surplus and the social welfare will both be lower since the demand becomes lower due to the higher price. In contrast, when the moral hazard cost is relatively high (but not so prohibitively high as to preclude any sharing transaction), the firm will in equilibrium be more likely to charge a lower retail price and make lower profits than when there is no sharing market, leading to an increase in consumer surplus and social welfare. Contrary to the conventional wisdom, our findings suggest that the firm may have incentives to improve the consumer's sharing market and facilitates consumers' product sharing even if the firm does not directly make any profit from the sharing market whereas such improvements can make consumers worse off because of the firm's strategic increase of prices.

Some questions naturally come up. Which type of firm will benefit from consumers' product sharing? Under what situation will the consumer's product-sharing behavior increase consumer surplus and social welfare? Proposition 3 shows that a firm with a high marginal cost will benefit from the product-sharing market. Interestingly, our analysis suggests that when the firm's unit cost of production is high, product sharing among consumers is a win-win situation for both the firm and the consumers. This is because the firm with a high unit cost will save a lot of costs by selling fewer units at much higher prices, which many consumers are willing to pay because of the potential earnings from renting out the product in the sharing market. Without the sharing market, many consumers who have high use values only in one period will not be willing to buy the firm's high-cost product because of the forgone income from sharing. Thus, our analyses suggest that the consumer's sharing of high-cost products (such as high-tech products, cars, or agricultural equipment in developing countries) is overall beneficial for both consumers and the manufacturer. In contrast, according to Propositions 3 and 4, the collaborative consumption of products with very low marginal costs (such as digital products or information goods) may be bad for both consumers and the firm. Our findings are consistent with the anecdotal observations that firms in industries with high unit costs tend to encourage or facilitate sharing (e.g., GM) and firms selling information goods tend to discourage or curb consumers' sharing.

4. Strategic Pricing and Quality Decision

In response to the existence of a product-sharing market, the firm may strategically change not only its price but also its product quality. How will that influence the market outcome and the impact of the product-sharing market? In this section, we address this research question by extending the core model to allow for strategic, endogenous quality decisions.

The firm's unit cost of production typically depends on the quality of the product. For analytical tractability, we use the commonly-adopted quadratic cost function: $c = kq^2$, where k is a constant. Also, the consumer's moral hazard cost (m) for sharing is related to the product's value, which depends on the quality of the product. For example, other things being equal, a consumer will assess a higher moral hazard cost when sharing an expensive high-quality car than when sharing a low-quality economy car. This can be due to, for instance, the anticipated higher costs of maintenance services for the high-quality car or other risks from sharing. For simplicity, we assume that $m = \tau q$, where τ represents the level of moral hazard in the product-sharing market. Note that the extended game builds upon the core model in Section 2; the only difference is that the firm will now strategically choose both p and q to maximize its profit. We will use a subscript q to indicate the current, endogenous-quality case.

4.1. No Product-Sharing Market (*N*)

We first examine the benchmark case with no product-sharing market. With similar analysis to Section 3.1, we can obtain the firm's optimal retail price and quality of $p_q^N = \frac{1}{2k}$ and $q_q^N = \frac{1}{2k}$, respectively, with a corresponding demand of $d_q^N = \frac{1}{2}$ and profit of $\pi_q^N = \frac{1}{8k}$. The total consumer surplus is $cs_q^N = \frac{1}{12k}$, and the social welfare is $sw_q^N = \frac{5}{24k}$.

4.2. With Product-Sharing Market (*S*)

We now examine the case with a product-sharing market. Note that if moral hazard is a very severe problem in the sharing market (i.e., when $\tau \geq 1$), there will not be any sharing among consumers and hence the market outcome will be the same as the case with no product-sharing market (Section 4.1). So, we will only focus on the case with $\tau < 1$. With similar analysis to Section 3.2, it can be shown that the firm's optimal quality level is given by

$$q_q^S = \frac{-3+3\alpha-3\tau+\sqrt{9\tau^2+(18-2\alpha)\tau-7\alpha^2+14\alpha+9}}{8k\alpha}.$$

The firm's optimal retail price is given by

$$p_q^S = \frac{-3+3\alpha-3\tau+\sqrt{9\tau^2+(18-2\alpha)\tau-7\alpha^2+14\alpha+9}}{4\alpha} q_q^S.$$

The firm's demand at optimal pricing is

$$d_q^S = 1 - \frac{\alpha(p_q^S)^2}{2(2-\alpha)(q_q^S)^2} - \frac{(1-\alpha+\tau)p_q^S}{(2-\alpha)q_q^S} + \frac{\tau}{2-\alpha}.$$

The firm's profit is $\pi_q^S = [p_q^S - k(q_q^S)^2]d_q^S$, and the social welfare is given by

$$sw_q^S = \frac{1}{3(2-\alpha)^3(q_q^S)^2} \{\alpha[(6-\alpha)\alpha-6](p_q^S)^3 - 3(1-\alpha)[2+(\alpha-3)\alpha+4\tau](p_q^S)^2 q_q^S$$

$$+6\tau[2+\alpha(-3+\alpha+\tau)]p_q^S(q_q^S)^2 + [4\tau^3+(3\alpha-6)\tau^2-3\alpha^3+18\alpha^2-36\alpha+24](q_q^S)^3\}$$

$$-k(q_q^S)^2 d_q^S.$$

The total consumer surplus is

$$cw_q^S = sw_q^S - \pi_q^S - \alpha\frac{p_q^S/q_q^S+\tau}{2-\alpha}[1-\frac{p_q^S/q_q^S+\tau}{2-\alpha}][(1-\alpha)\frac{p_q^S/q_q^S+\tau}{2-\alpha}-\tau]\, q_q^S.$$

4.3. Impact of Collaborative Consumption

Next we examine the economic impact of the product-sharing market by comparing the market outcomes in the cases with versus without the sharing market (analyzed in Sections 4.1 and 4.2). Since no consumers will share the product if $\tau \geq 1$ (i.e., whether the sharing market exists or not makes no difference), we will focus on the nontrivial parameter region of $\tau \in [0,1)$.

PROPOSITION 5. *There exists some $\alpha^{**} > 0$ such that if $\alpha < \alpha^{**}$, then*

(i) $p_q^S > p_q^N$, $q_q^S > q_q^N$, $d_q^S < d_q^N$, $\pi_q^S > \pi_q^N$, $cs_q^S < cs_q^N$, *and*

(ii) there exists $\tau_1 \in (0,1)$ *such that* $sw_q^S > sw_q^N$ *if* $\tau \in [0, \tau_1)$ *and* $sw_q^S < sw_q^N$ *if* $\tau \in (\tau_1, 1)$.[19]

Proposition 5 shows that the consumer's collaborative consumption can give the firm a strategic incentive to increase product quality. The underlying reason is that those consumers with more variable use values across different usage periods (i.e., a high use value in one period and a low use value in the other period) will be willing to pay more to buy the product since they can earn some income by renting out the product in the sharing market when their own use value is low. This essentially increases those consumers' willingness to pay for product quality and hence gives the firm an incentive to raise its product quality in equilibrium. However, the increase in product quality does not mean high consumer surplus. In fact, because the firm will strategically raise its retail price to extract more surplus by selling to a smaller number of customers, the total consumer surplus in the market will be lower. We find that, with its strategic quality and pricing decisions, the firm will make more profits when the product-sharing market exists. Note that this result is slightly different from the case where the firm strategically chooses only its price. The potential positive effect of collaborative consumption on the consumer surplus (shown in Proposition 3 and 4) goes away and the firm is always better off when the firm strategically chooses both its product quality and price. This difference mainly comes from the fact that the firm's endogenous quality decision allows it to select a strategic price-quality pair to ensure higher profitability by extracting more surplus from consumers anticipating their product sharing behaviors.

Proposition 5 also shows that the existence of the product-sharing market increases the social welfare when moral hazard is not a severe problem (i.e., when τ is low). This result is qualitatively different from that in Proposition 4 for the case in which the firm strategically responds to consumers' product sharing by changing only its price (not its product quality), where collaborative consumption is likely to increase the social welfare when the moral hazard cost is *high*. This difference comes from the fact that when the moral hazard problem is more severe, the firm that takes its quality as given will lower its retail price to expand

[19] Note that $\alpha \leq 1 - \tau$ is a *sufficient* condition for $p_q^S > p_q^N$, $q_q^S > q_q^N$, and $d_q^S < d_q^N$. Also, our numerical study shows that even if the platform owner endogenously chooses the percentage fee (α), it will select a much lower fee than $1 - \tau$; thus the results in Proposition 5 will hold in equilibrium of such an extended game.

market coverage, whereas the firm that strategically chooses both quality and price will have reduced incentive to offer high product quality.

5. Discussions and Conclusions

Product sharing or collaborative consumption has emerged as a major trend in recent years as consumers are financially squeezed during the global economic recession and as global concern about consumption sustainability brings society's attention to effective use of resources and products. Advances in mobile communication technologies and online product-sharing platforms have helped to facilitate product sharing among consumers on an unprecedented scale. Consumers share a wide range of products from bicycles, cars, videogame consoles, to clothing, portable tools and household appliances and even agricultural equipment. We have provided an analytical model that captures the idea that a consumer's own use value for her purchased product may vary over multiple usage periods. In a period of low use value, the consumer who purchased the product can forgo the product use and rent it out to others through a third-party product-sharing platform. For each sharing transaction, the renting consumer pays a rental fee while the consumer owning the product needs to pay the platform a percentage fee or commission. In addition, we explicitly model the moral hazard issue in the sharing market, where the renter will likely use the product in less careful ways, e.g., driving the rented car more aggressively with fast acceleration and braking and paying less attention to speed bumps than the owner would. Such actions by the renting customer will impose some additional costs on the product owner, who may have to, for example, do more frequent maintenance for the product than if only she herself had used the product. That is, when renting out her purchased product, the product owner will expect to incur some moral-hazard cost in addition to the platform's percentage fee. We have examined the consumer's purchasing and sharing decisions, and investigated how a brand owner or manufacturer of the product should strategically choose its retail price and/or product quality to respond to the anticipated collaborative consumption of the consumers. Our analysis shows that the firm's unit cost of production and the moral hazard cost in the product-sharing market play a critical role in determining the market outcome.

We have shown several main findings. First, the moral hazard cost in the sharing market has a non-monotonic impact on the firm's profits, consumer surplus, and social welfare. One may intuit that a more severe moral hazard problem will lead to higher profits for the firm, lower consumer surplus and social welfare since the firm's customers will be less likely to offer the competing rental option to other consumers, who will then more likely buy the firm's product. Interestingly, our analysis shows that the firm may actually be worse off because some buyers with a high use value in one period but a low use value in the other period will not be able to earn as much rental income from the sharing market and hence will no longer be willing to buy the product at the same price when the sharing market has more friction (with more severe moral hazard). To compensate and attract some buyers back, the firm will find it optimal to reduce its price leading to lower profitability, higher consumer surplus and social welfare. Similarly, the platform's percentage fee may also have non-monotonic impacts on the firm's profits, consumer surplus, and social welfare.

Second, if the firm strategically chooses its retail price while taking product quality as given, then product sharing among consumers can be a lose-lose or win-win situation for the firm and the consumers. It is lose-lose when the firm's unit cost and the moral hazard cost are low. When the firm's unit cost is high, a win-win will happen for the firm and the consumers. This is because the product costs a lot to product, the firm will save much marginal costs by selling fewer units at much higher prices, which many consumers are still willing to pay because of the potential earnings from renting out the product in the sharing market. In contrast, without the sharing market, many consumers who have high use values only in one period will not be willing to buy the firm's high-cost product because of the forgone income from sharing.

Third, if the firm strategically changes both its price and product quality, the consumer's product-sharing behavior will increase the firm's profit but reduce the consumer surplus even though in equilibrium the firm will increase its quality. The underlying reason is that those consumers with more variable use values across different periods (i.e., a high use value in one period and a low use value in the other period) will be willing to pay more to buy the product since they anticipate being able to generate some income by renting out the product in the sharing market when their own use value is low. This essentially increases those consumers' willingness to pay for product quality giving the firm an incentive to raise its product quality in equilibrium. The firm's strategic quality decision allows it to select a strategic price-quality pair to ensure higher profitability by extracting more surplus from the forward-looking consumers with the collaborative-consumption behaviors.

Lastly, we point out the caveat that we have made a few simplifying assumptions in our model. First, we have assumed that all consumers are forward-looking and fully anticipate the possibility of product sharing with other consumers. The other opposite, extreme assumption is that consumers are all myopic, i.e., their decisions will be based on only their current-period utility and hence when deciding whether to buy the product they will not consider the possibility of sharing the product. In that extreme case, obviously, the firm's pricing and quality decisions will be the same as if the product-sharing market does not exist. However, since consumers can *ex post* decide to rent out the product during the usage periods with low self-use values, the consumer surplus will be higher than in the case of forward-looking consumers—interestingly, consumers are better off being fully myopic than fully strategic and forward-looking. In a model in which a fraction of the consumers are myopic, our results are likely moderated by that fraction though we expect our main results and intuition to stay qualitatively the same as long as there are a large enough number of strategic consumers. Second, we have assumed that the firm is a monopolist; if there are competing firms in the market, we expect the firms' ability to exact consumer surplus will be moderated by the level of competition and product differentiation in the market. Third, we have not explicitly modeled the uncertainty in the product-sharing market. In essence, we have assumed that the consumer is risk neutral and makes her decision based on the average of the anticipated revenue from product-sharing transactions. We have also focused on search goods rather than experience goods, whose quality may not be fully observed by the consumers prior to purchase. We will leave it to future research to study the effects of uncertainty in the sharing market and uncertainty in the firm's product quality. Lastly, we have assumed an exogenous proportional fee by the sharing platform in line with the observed reality, where the platform's percentage fee does not vary across different products. However, it might still be of interest to examine what happens if the platform charges different percentages based on some product characteristics (e.g., a lower percentage for high-end products to encourage sharing of such products). We will also leave it to future research to tackle price discrimination issues by the platform, which deserves its own theoretical study. Collaborative consumption in the sharing economy is a fast growing trend; both theoretical and empirical research in this area may be of great managerial and academic interest.

Online Appendix

PROOF OF LEMMA 1. First, we will show Lemma A.

LEMMA A. *Given the firm's retail price p, if there are transactions in the product-sharing market in equilibrium, then $p_1 = p_2$ and $(1-\alpha)p_1 + p_2 - m = p$ (and $p_1 + (1-\alpha)p_2 - m = p$) in equilibrium.*

PROOF: Note that because of symmetry, the demand and the supply in the sharing market are the same across the two periods; hence the market-clearing prices for the two periods should be also the same, that is, at equilibrium $p_1 = p_2$.

Note that each consumer has eight options. Let us first suppose $(1-\alpha)p_1 + p_2 - m > p$ (i.e., $p_1 + (1-\alpha)p_2 - m > p$). Then, option (v) is dominated by option (ii) (i.e., $v_{i1} + (1-\alpha)p_2 - m - p > v_{i1} - p_1$); option (vi) is dominated by option (iii) (i.e., $v_{i2} + (1-\alpha)p_1 - m - p > v_{i2} - p_2$); option (iv) is dominated by option (i) (i.e., $v_{i1} + v_{i2} - p > v_{i1} - p_1 + v_{i2} - p_2$). In summary, all consumers will prefer buying the product from the firm rather than renting it from the sharing market. That is, there will be no product-sharing transactions if $(1-\alpha)p_1 + p_2 - m > p$ or $p_1 + (1-\alpha)p_2 - m > p$. Now suppose $(1-\alpha)p_1 + p_2 - m < p$ (i.e., $p_1 + (1-\alpha)p_2 - m < p$). Then, option (v) dominates option (ii) (i.e., $v_{i1} + (1-\alpha)p_2 - m - p < v_{i1} - p_1$); option (vi) dominates option (iii) (i.e., $v_{i2} + (1-\alpha)p_1 - m - p < v_{i2} - p_2$); no one will choose option (vii) (i.e., $(1-\alpha)p_1 - m + (1-\alpha)p_2 - m - p < 0$). In summary, no one will buy the product to rent it out in the sharing market. That is, if $(1-\alpha)p_1 + p_2 - m < p$ (i.e., $p_1 + (1-\alpha)p_2 - m < p$), there will be no transactions in the product-sharing market, either. Thus if there are transactions in the sharing market, we must have $(1-\alpha)p_1 + p_2 - m = p$ (i.e., $p_1 + (1-\alpha)p_2 - m = p$) in equilibrium. This ends the proof of Lemma A.

We now prove Lemma 1. Clearly, if $0 \leq p \leq \frac{m}{1-\alpha}$, no consumer will rent the product from the sharing market and the firm's demand is easily computed: $d(p,q) = 1 - \frac{p^2}{2q^2}$.

If $(2-\alpha)q - m < p < 2q$, no one will buy the product and then rent it out in the product-sharing market (i.e., there will be no sharing transactions), and the firm's demand is given by $d(p,q) = \frac{1}{2}\left(2 - \frac{p}{q}\right)^2$.

Now we consider the case that $\frac{m}{1-\alpha} < p \leq (2-\alpha)q - m$. From Lemma A, if there are sharing transactions in equilibrium, we must have $p_1 = p_2$ and $(1-\alpha)p_1 + p_2 - m = p$ (i.e., $p_1 + (1-\alpha)p_2 - m = p$). If a consumer chooses option (vii), her surplus will be $(1-\alpha)p_1 - m + (1-\alpha)p_2 - m - p < -m < 0$, so no consumers will work as pure speculators. Next, we consider consumers' preferences over the other seven options. For ease of analysis, as illustrated in Figure 3, we divide all consumers into four segments based on the consumer's valuation in the two usage periods. Segment *1:* consisting of two sub-segments, i.e., *1a*: $v_{i1} \geq p_1, v_{i2} \geq p_2$; *1b*: $v_{i1} \geq p_1$ and $(1-\alpha)p_2 - m \leq v_{i2} < p_2$; *1c*: $(1-\alpha)p_1 - m \leq v_{i1} < p_1$ and $v_{i2} \geq p_2$; *1d*: $v_{i1} < p_1$, $v_{i2} < p_2$, and $v_{i1} + v_{i2} \geq p$. Segment *2:* $v_{i1} \geq p_1$ and $v_{i2} < (1-\alpha)p_2 - m$. Segment *3:* $v_{i1} < (1-\alpha)p_1 - m$ and $v_{i2} \geq p_2$. Segment *4:* $v_{i1} < p_1$, $v_{i2} < p_2$ and $v_{i1} + v_{i2} < p$.

First, clearly, consumers in segment *1a* will use the product in both periods. For option (i), consumer i's surplus is $v_{i1} + v_{i2} - p = (v_{i1} - (1-\alpha)p_1) + (v_{i2} - p_2) + m > 0$; for option (iv), the surplus is $(v_{i1} - p_1) + (v_{i2} - p_2)$. So consumers in segment *1a* will choose option (i). Second, consumers in segment *1b* and segment *2* will use the product in the first period. For option (i), consumer i's surplus is $v_{i1} + v_{i2} - p = (v_{i1} - p_1) + (v_{i2} - (1-\alpha)p_2) + m$; for option (ii), the surplus is $v_{i1} + (1-\alpha)p_2 - m - p = v_{i1} - p_1 > 0$; for option (v), the surplus is $v_{i1} - p_1 > 0$. When $v_{i2} - (1-\alpha)p_2 + m \geq 0$, option (i) gives the highest surplus; when $v_{i2} - (1-\alpha)p_2 + m < 0$, both option (ii) and (v) are the optimal choice. So consumers in segment *1b* will choose option (i), while consumers in segment *2* will choose (ii) or (v). Third, similarly, consumers in segment *1c* will choose option (i) whereas consumers in segment *3* will choose option (iii) or (vi). Fourth, clearly, consumers in segment *1d* will not rent the product from the sharing market in any period. For option (i), consumer i's surplus is $v_{i1} + v_{i2} - p > 0$; for option (ii), the surplus is $v_{i1} + (1-\alpha)p_2 - m - p = v_{i1} - p_1 < 0$; for option (iii), the surplus is $v_{i2} + (1-\alpha)p_1 - m - p = v_{i2} - p_2 < 0$. So consumers in segment *1d* will choose option (i). Lastly, consumers in segment *4* will not use the product in either period, and they also find it unprofitable to buy the product and rent it out in the sharing market. In summary, consumers in segment *1* (i.e., *1a*, *1b*, *1c*, *1d*) will choose to buy and use the product themselves in both periods. For consumers in segments *2* and *3*, the best option is not unique. However, we know that in the first period, all consumers in segment *2* will use the product but consumers in segment *3* will not; in the second period, all consumers in segment *3* will use the product but consumers in segment *2* will not. That is, the demand in the sharing market is "segment *2*" in the first period and "segment *3*" in the second period. Note that the supply for the sharing market in each period comes from the products that consumers in segment *2* and segment *3* buy from the firm. Since in equilibrium the product-sharing demand in each period should be equal to the supply in each period, we obtain that in equilibrium half of all consumers in segments *2* and *3* will buy the product and the other half will rent from the product-sharing market. From Lemma A, by symmetry we get $p_1 = p_2 = \frac{p+m}{2-\alpha}$. Thus the firm's total demand is easily computed by summing up all consumers in segment *1* (including sub-segments *1a*, *1b*, *1c*, and *1d*) and half of the consumers in segments *2* and *3*: $d(p,q) = \left(1 - \frac{p_1}{q}\right)\left(1 - \frac{p_2}{q}\right) + \left(\frac{\alpha p_2}{q} + \frac{m}{q}\right)\left(1 - \frac{p_1}{q}\right) + \left(\frac{\alpha p_1}{q} + \frac{m}{q}\right)\left(1 - \frac{p_2}{q}\right) + \frac{1}{2}\left(\frac{\alpha p_2}{q} + \frac{m}{q}\right)\left(\frac{\alpha p_1}{q} + \frac{m}{q}\right) + \left(1 - \frac{p_1}{q}\right)\left(\frac{(1-\alpha)p_2}{q} - \frac{m}{q}\right)$. Plugging in $p_1 = p_2 = \frac{p+m}{2-\alpha}$, we have $d(p,q) = 1 - \frac{\alpha}{2(2-\alpha)}\frac{p^2}{q^2} - \left(\frac{1-\alpha}{2-\alpha} + \frac{1}{2-\alpha}\frac{m}{q}\right)\frac{p}{q} + \frac{1}{2-\alpha}\frac{m}{q}$. □

PROOF OF PROPOSITION 1. For the firm's pricing strategy, taking derivative gives $\frac{\partial p^S}{\partial m} = \frac{1}{q}\frac{\partial p^S}{\partial \tilde{m}} = \frac{2}{3\alpha}\left(\frac{[2(1-\alpha+\tilde{m})-\alpha\tilde{c}\,]+\frac{3}{2}\alpha(1+\tilde{c})}{\sqrt{[2(1-\alpha+\tilde{m})-\alpha\tilde{c}\,]^2+6\alpha[(2-\alpha+\tilde{m})+(1-\alpha+\tilde{m})\tilde{c}]}} - 1\right) < 0$. For other non-monotonic results, we just need to prove them in the $\alpha = 0$ case, where $\pi^S = \frac{[(2+\tilde{m})-(1+\tilde{m})\tilde{c}]^2}{8(1+\tilde{m})}q$, $cs^S = \left[1 - \frac{3(2+\tilde{m})^2}{16(1+\tilde{m})} + \frac{\tilde{m}^2}{4} - \frac{\tilde{m}^3}{12} - \frac{\tilde{c}(2+\tilde{m})}{8} + \frac{\tilde{c}^2(1+\tilde{m})}{16}\right]q$, and $sw^S = \left[1 - \frac{(2+\tilde{m})^2}{16(1+\tilde{m})} + \frac{\tilde{m}^2}{4} - \frac{\tilde{m}^3}{12} - \frac{3\tilde{c}(2+\tilde{m})}{8} + \frac{3\tilde{c}^2(1+\tilde{m})}{16}\right]q$. Note that $\frac{\partial \pi^S}{\partial m} =$

$\frac{1}{q}\frac{\partial \pi^S}{\partial \widetilde{m}} = \frac{(2+\widetilde{m})-(1+\widetilde{m})\tilde{c}}{8(1+\widetilde{m})^2}[(1-\tilde{c})\widetilde{m}-\tilde{c}]$. There is $\frac{\partial \pi^S}{\partial m} < 0$ when $m < \frac{\tilde{c}}{1-\tilde{c}}q$ (i.e., $\widetilde{m} < \frac{\tilde{c}}{1-\tilde{c}}$), and $\frac{\partial \pi^S}{\partial m} > 0$ when $m > \frac{\tilde{c}}{1-\tilde{c}}q$ (i.e., $\widetilde{m} > \frac{\tilde{c}}{1-\tilde{c}}$). It can be shown that $\frac{\tilde{c}}{1-\tilde{c}}q < m^*$ given $0 \le c < \frac{q}{2}$. Meanwhile, $\frac{\partial cs^S}{\partial m} = \frac{1}{q}\frac{\partial cs^S}{\partial \widetilde{m}} = \frac{8\widetilde{m}-4\widetilde{m}^2+\frac{3}{(1+\widetilde{m})^2}-3-2\tilde{c}+\tilde{c}^2}{16}$ and $\frac{\partial sw^S}{\partial m} = \frac{1}{q}\frac{\partial sw^S}{\partial \widetilde{m}} = \frac{8\widetilde{m}-4\widetilde{m}^2+\frac{1}{(1+\widetilde{m})^2}-1-6\tilde{c}+3\tilde{c}^2}{16}$. One can show $\frac{\partial cs^S}{\partial m} \le 0$ and $\frac{\partial sw^S}{\partial m} \le 0$ at $m = 0$, and $\frac{\partial cs^S}{\partial m} > 0$ and $\frac{\partial sw^S}{\partial m} > 0$ at $m = m^*$ given $0 \le c < \frac{q}{2}$. □

Note that because of continuity of functions, we can complete the proof by simply proving the result in the $\alpha = 0$ case for Proposition 2, 3, and 4.

PROOF OF PROPOSITION 2. Note $\frac{\partial p^S}{\partial m} = \frac{1}{q}\frac{\partial p^S}{\partial \widetilde{m}} = \frac{-1}{2(1+\widetilde{m})^2} < 0$. It can be shown that $p^S > p^N$ at $m = 0$, $p^S < p^N$ at $m = m^*$. Thus, $\exists\, m_1 \in (0, m^*]$ such that $p^S > p^N$ if $m \in [0, m_1)$, $p^S < p^N$ if $m \in (m_1, m^*)$. □

PROOF OF PROPOSITION 3. Let us first examine the case $0 \le c < \frac{q}{2}$, i.e., $0 \le \tilde{c} < \frac{1}{2}$. Defining $\Delta_1 \equiv \pi^S|_{m=0} - \pi^N = \frac{(2-\tilde{c})^2}{8}q - \frac{\tilde{c}^3+(\tilde{c}^2+6)\sqrt{\tilde{c}^2+6}-18\tilde{c}}{27}q$, we have $\frac{\partial \Delta_1}{\partial c} = \frac{1}{q}\frac{\partial \Delta_1}{\partial \tilde{c}} = \frac{1}{6} + \frac{\tilde{c}}{4} - \frac{\tilde{c}^2+\tilde{c}\sqrt{\tilde{c}^2+6}}{9} > 0$. If $c = 0$ (i.e., $\tilde{c} = 0$), $\Delta_1 = \left(\frac{1}{2} - \frac{2\sqrt{6}}{9}\right)q < 0$; if $c = \frac{q}{2}$ (i.e., $\tilde{c} = \frac{1}{2}$), $\Delta_1 = \left(\frac{9}{32} - \frac{1}{4}\right)q > 0$. Thus, there exists some $c_1 \in (0, \frac{q}{2})$ such that $\pi^S|_{m=0} < \pi^N$ if $0 \le c < c_1$ and $\pi^S|_{m=0} > \pi^N$ if $c_1 < c < \frac{q}{2}$. Note that there is $\frac{\partial \pi^S}{\partial m} < 0$ when $m < \frac{\tilde{c}}{1-\tilde{c}}q$, and $\frac{\partial \pi^S}{\partial m} > 0$ when $m > \frac{\tilde{c}}{1-\tilde{c}}q$ (see the proof of Proposition 1). If $0 \le c < c_1$ (i.e., $0 \le \tilde{c} < \tilde{c}_1$), then $\pi^S < \pi^N$ at $m = 0$, and $\pi^S < \pi^N$ at $m = m^*$. Hence, we can conclude that $\pi^S < \pi^N$. If $c_1 < c < \frac{q}{2}$ (i.e., $\tilde{c}_1 < \tilde{c} < \frac{1}{2}$), then $\pi^S > \pi^N$ at $m = 0$, $\pi^S < \pi^N$ at $m = m^*$. Thus, $\exists\, m_3 \in (0, m^*]$ such that $\pi^S > \pi^N$ if $m \in [0, m_3)$, $\pi^S < \pi^N$ if $m \in (m_3, m^*)$.

Second, we consider the case $\frac{q}{2} \le \tilde{c} < 2q$, i.e., $\frac{1}{2} \le \tilde{c} < 2$. Note $\frac{\partial \pi^S}{\partial m} < 0$ since $(1-\tilde{c})\widetilde{m} - \tilde{c} < 0$. Since $\pi^S = \pi^N$ when $m = m^*$, we conclude that $\pi^S > \pi^N$. □

Proof of Proposition 4. First, we consider the consumer surplus. Given $0 \le c < \frac{q}{2}$ (i.e., $0 \le \tilde{c} < \frac{1}{2}$), we have shown that $\frac{\partial cs^S}{\partial m} \le 0$ at $m = 0$, and $\frac{\partial cs^S}{\partial m} > 0$ at $m = m^*$ (see the proof of Proposition 1). Note $\frac{\partial^2 cs^S}{\partial m^2} = \frac{1}{q}\frac{\partial^2 cs^S}{\partial m \partial \widetilde{m}} = \frac{8-8\widetilde{m}-\frac{6}{(1+\widetilde{m})^3}}{16q}$. Plugging in $\frac{\partial cs^S}{\partial m} = 0$, we have $\frac{\partial^2 cs^S}{\partial m^2} = \frac{8-4\widetilde{m}^2+\frac{3}{(1+\widetilde{m})^2}-\frac{6}{(1+\widetilde{m})^3}-3-2\tilde{c}+\tilde{c}^2}{16q} > \frac{8-4\widetilde{m}^2+\frac{3}{(1+\widetilde{m})^2}-\frac{6}{(1+\widetilde{m})^3}-4}{16q} = \frac{4(1+\widetilde{m})(1-\widetilde{m})-\frac{3(1-\widetilde{m})}{(1+\widetilde{m})^3}}{16q} > 0$. One can easily show that $cs^S < cs^N$ at $m = 0$, $cs^S > cs^N$ at $m = m^*$. Thus, $\exists\, m_4 \in (0, m^*]$ such that $cs^S < cs^N$ if $m \in [0, m_4)$, $cs^S > cs^N$ if $m \in (m_4, m^*)$.

Second, we consider the social welfare. We first show that $\exists\, c_2 \in (0, \frac{q}{2})$ such that $sw^S|_{m=0} < sw^N$ if $0 \le c < c_2$. For $0 \le c < \frac{q}{2}$, defining $\Delta_2 \equiv sw^S|_{m=0} - sw^N = \left[\frac{3(2-\tilde{c})^2}{16} - 1 - \frac{5\tilde{c}^3+(5\tilde{c}^2-6)\sqrt{\tilde{c}^2+6}-72\tilde{c}}{81}\right] q$, we have $\frac{\partial \Delta_2}{\partial c} = \frac{1}{q}\frac{\partial \Delta_2}{\partial \tilde{c}} = \frac{5}{36} + \left(\frac{3}{8} - \frac{5}{27}\right)\tilde{c}^2 - \frac{10\tilde{c}\sqrt{\tilde{c}^2+6}}{81} - \frac{\tilde{c}(5\tilde{c}^2-6)}{81\sqrt{\tilde{c}^2+6}} > \frac{5}{36} + \left(\frac{3}{8} - \frac{5}{27}\right)\tilde{c}^2 - \frac{10\tilde{c}\sqrt{\tilde{c}^2+6}}{81} \equiv H_1$. Since $H_1 > 0$ when $c = \frac{q}{2}$ (i.e., $\tilde{c} = \frac{1}{2}$) and $\frac{\partial H_1}{\partial c} = \frac{1}{q}\frac{\partial H_1}{\partial \tilde{c}} = \frac{1}{q}\left(\frac{41}{108}\tilde{c} - \frac{10\sqrt{\tilde{c}^2+6}}{81} - \frac{10\tilde{c}^2}{81\sqrt{\tilde{c}^2+6}}\right) < 0$, we have $H_1 > 0$ and $\frac{\partial \Delta_2}{\partial c} > 0$ for all $0 \le c < \frac{q}{2}$. Note that $\Delta_2 = \left(\frac{3}{4} - 1 + \frac{2\sqrt{6}}{27}\right) q < 0$ when $c = 0$ (i.e., $\tilde{c} = 0$), and $\Delta_2 = \left(\frac{27}{64} - \frac{5}{12}\right) q > 0$ when $c = \frac{q}{2}$ (i.e., $\tilde{c} = \frac{1}{2}$). Thus, $\exists\, c_2 \in (0, \frac{q}{2})$ such that $sw^S|_{m=0} < sw^N$ if $0 \le c < c_2$.

Given $0 \le c < c_2$, we have shown that $\frac{\partial sw^S}{\partial m} \le 0$ at $m = 0$, and $\frac{\partial sw^S}{\partial m} > 0$ at $m = m^*$ (see the proof of Proposition 1). Note that $\frac{\partial^2 sw^S}{\partial m^2} = \frac{1}{q}\frac{\partial^2 sw^S}{\partial m \partial \widetilde{m}} = \frac{8-8\widetilde{m}-\frac{2}{(1+\widetilde{m})^3}}{16q}$. Plugging in $\frac{\partial sw^S}{\partial m} = 0$, $\frac{\partial^2 sw^S}{\partial m^2} = \frac{8-4\widetilde{m}^2+\frac{1}{(1+\widetilde{m})^2}-\frac{2}{(1+\widetilde{m})^3}-1-6\tilde{c}+3\tilde{c}^2}{16q} > \frac{8-4\widetilde{m}^2+\frac{1}{(1+\widetilde{m})^2}-\frac{2}{(1+\widetilde{m})^3}-1-6+3}{16q} = \frac{4(1+\widetilde{m})(1-\widetilde{m})-\frac{(1-\widetilde{m})}{(1+\widetilde{m})^3}}{16q} > 0$. Note that $sw^S < sw^N$ at $m = 0$, $sw^S > sw^N$ at $m = m^*$. Thus, we conclude that $\exists\, m_5 \in (0, m^*)$ such that $sw^S < sw^N$ if $m \in [0, m_5)$, $sw^S > sw^N$ if $m \in (m_5, m^*)$. □

PROOF OF PROPOSITION 5. Note that $q_q^S - q_q^N = \frac{-3+3\alpha-3\tau+\sqrt{9\tau^2+(18-2\alpha)\tau-7\alpha^2+14\alpha+9}}{8k\alpha} - \frac{1}{2k} = \frac{1}{8k\alpha}H_2$, where $H_2 \equiv \sqrt{9\tau^2+(18-2\alpha)\tau-7\alpha^2+14\alpha+9} - (3+3\tau+\alpha)$. It can be easily shown that $H_2 \geq 0$ when $\alpha \leq 1-\tau$. The proof for $p_q^S \geq p_q^N$ is similar and therefore omitted here. One can easily show $d_q^S - d_q^N = \frac{1}{2} - \frac{\alpha(p_q^S)^2}{2(2-\alpha)(q_q^S)^2} - \frac{(1-\alpha+\tau)p_q^S}{(2-\alpha)q_q^S} + \frac{\tau}{2-\alpha}$. Since $\frac{p_q^S}{q_q^S} = \frac{-3+3\alpha-3\tau+\sqrt{9\tau^2+(18-2\alpha)\tau-7\alpha^2+14\alpha+9}}{4\alpha} \geq 1$ given $\alpha \leq 1-\tau$ and $d_q^S - d_q^N$ decreases in $\frac{p_q^S}{q_q^S}$, we have $d_q^S - d_q^N \geq \frac{1}{2} - \frac{\alpha}{2(2-\alpha)} - \frac{1-\alpha+\tau}{2-\alpha} + \frac{\tau}{2-\alpha} = 0$.

Because of continuity of functions, we can complete the proof by simply proving the result in the $\alpha = 0$ case. Noting that $\frac{\partial \pi_q^S}{\partial \tau} = \frac{(2+\tau)^2}{54(1+\tau)^3 k}(\tau - 1) < 0$ and $\pi_q^S = \pi_q^N$ at $\tau = 1$, we conclude $\pi_q^S > \pi_q^N$ for any $\tau \in (0,1)$. $\frac{\partial cs_q^S}{\partial \tau} = \frac{-\frac{\tau^5}{4}-\frac{5\tau^4}{12}+\frac{13\tau^3}{36}+\frac{13\tau^2}{12}-\frac{1}{9}}{3(1+\tau)^3 k} = \frac{H_3}{3(1+\tau)^3 k}$, where $H_3 \equiv -\frac{\tau^5}{4} - \frac{5\tau^4}{12} + \frac{13\tau^3}{36} + \frac{13\tau^2}{12} - \frac{1}{9}$. Note that $\frac{\partial H_3}{\partial \tau} = -\frac{5\tau^4}{4} - \frac{5\tau^3}{3} + \frac{13\tau^2}{12} + \frac{13\tau}{6} \geq 0$. One can show $H_3 < 0$ at $\tau = 0$, and $H_3 > 0$ at $\tau = 1$. Thus, cs_q^S first decreases and then increases in τ. Since $cs_q^S < cs_q^N$ at $\tau = 0$ and $cs_q^S = cs_q^N$ at $\tau = 1$, we can conclude $cs_q^S < cs_q^N$ for any $\tau \in (0,1)$. $\frac{\partial sw_q^S}{\partial \tau} = \frac{-\frac{\tau^5}{4}-\frac{5\tau^4}{12}+\frac{5\tau^3}{12}+\frac{5\tau^2}{4}-\frac{1}{3}}{3(1+\tau)^3 k} = \frac{H_4}{3(1+\tau)^3 k}$, where $H_4 \equiv -\frac{\tau^5}{4} - \frac{5\tau^4}{12} + \frac{13\tau^3}{36} + \frac{13\tau^2}{12} - \frac{1}{9}$. Note that $\frac{\partial H_4}{\partial \tau} = -\frac{5\tau^4}{4} - \frac{5\tau^3}{3} + \frac{5\tau^2}{4} + \frac{5\tau}{2} \geq 0$. It can be shown that $H_4 < 0$ at $\tau = 0$, and $H_4 > 0$ at $\tau = 1$. So sw_q^S first decreases and then increases in τ. Since $sw_q^S > sw_q^N$ at $\tau = 0$, and $sw_q^S = sw_q^N$ at $\tau = 1$, we can conclude that $\exists\, \tau_1 \in (0,1)$ such that $sw_q^S > sw_q^N$ if $\tau \in [0, \tau_1)$, and $sw_q^S \leq sw_q^N$ if $\tau \in (\tau_1, 1)$. □

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