# Product Pricing in a Peer-to-Peer Economy

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ABSTRACT: The emergence of a collaborative economy has been driven by advances in information technology that allow consumers to borrow and rent goods among peers on a secondary sharing market. In a dynamic setting, consumers make intertemporal decisions about purchases and their participation in the sharing market. This paper introduces an overlapping-generations model to analyze product pricing and consumer choice with and without a sharing market. The model quantifies the impacts of a peer-to-peer economy on the demand for ownership, the product price, and all participants' payoffs, including consumer surplus, profits, and social welfare. Given consumers that are heterogeneous with respect to their consumption needs and valuations, it illustrates which of them are prone to participate in a sharing economy and whether a retailer (or manufacturer) can benefit from the presence of a secondary exchange. A sharing market tends to increase the price of new products by a "sharing premium," which positively depends on the retailer's commitment ability. The price increment becomes relatively smaller for higher-cost products. Low-cost products and sufficiently impatient consumers together make a peer-to-peer economy *un*attractive for retailers. For high-cost products, however, the latter stand to gain from the existence of a sharing market. Most importantly, the introduction of a peer-to-peer economy increases consumer surplus and social welfare for high-cost products, thus creating an implicit imperative for a social planner to help promote collaborative consumption, at least for products which are demanding to manufacture, for instance by providing incentives for retailers and manufacturers that tend to offset possible expected negative payoff effects from consumer sharing.

KEY WORDS AND PHRASES: collaborative consumption, market equilibrium, monopoly pricing, overlapping generations, sharing economy.

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# Introduction

The emergence of sharing markets since the early 2000s is symptomatic for a paradigm shift, from ownership-based consumption to access-based consumption. The widening scope and increasing volume of the items that are being shared in the new peer-to-peer economy has been well documented [25].[1] With the possibility of sharing, consumers' flexibility increases, both in terms of managing the items they already own (because of the possibility of renting them out to peers who need them), and in terms of getting access to items they do not presently own (by borrowing them from their peers who do not currently need them). The resulting *a priori* ambiguous effect on the demand for ownership has been examined by [37]. Here we go a step further by analyzing the effects of sharing on the prices of the products, and the resulting welfare effects.

The growth of the peer-to-peer economy has largely been enabled by innovative intermediaries (such as AirBnB) who were able to create electronic platforms to match consumers and overcome market imperfections such as moral hazard, specific to collaborative consumption. Weber [34, 36] showed that a sharing intermediary may be able to resolve the moral-hazard problem for risk-neutral parties and extract a large portion from the gains of trade. In that view, sharing markets lead to a Pareto-improvement by increasing the surplus for *all* parties involved. However, there is already at least anecdotal evidence that prices of assets, for which active sharing markets exist, increase.[2] To paint a more complete picture of the effect that sharing markets have on the economy, we endogenize a monopolist's pricing decisions and examine the net impact of a sharing market by comparing the equilibrium outcomes with and without collaborative consumption. The monopolist can be thought of, interchangeably, as a retailer or a producer/manufacturer of a good. In the former case, the marginal cost corresponds to the invoice price, while in the latter it corresponds to the cost of producing an extra unit.

Since intermediaries have the potential to increase efficiency in sharing markets [36], we assume that sharing markets clear, and therefore allow for the discovery of an efficient market price without arbitrage. We then examine how prices are affected by sharing markets when the sellers of products can endogenously react. As in [37], we assume that agents can have different propensities for current and future needs. As a second dimension of heterogeneity, each agent has a value for the use of the item. The agents' need propensities and values are continuously distributed.

Models of sharing must be dynamic, because—at least from an economic viewpoint—collaborative consumption enables better intertemporal matching of consumption needs and access to goods. By means of overlapping generations of consumers, the model allows for the coexistence of individuals in different phases of their consumption lifecycle, so that some consumers (in an early consumption phase) decide about ownership while others (in a late consumption phase) can think about participating in the sharing economy, *either* as a lender *or* as a borrower, conditional on the need realization. Without sharing, a consumer at any stage can decide only about ownership, and it turns out that sharing markets can be used to correct temporary misallocations resulting from initial commitments by early purchase decisions. The

latter may not be met with the anticipated realization of a need for the product in the future. We show that a monopolist tends to increase product prices in response to sharing markets, thus extracting some of the extra allocational benefit consumers realize. This reflects the fact that sharing markets decrease the price elasticity of the demand for ownership (at least on average). Yet, a monopolist may sometimes be better off without a peer-to-peer economy because high-value non-owners in their late consumption phase cannot respond to a need for the item other than by buying it. The lack of sharing markets to those users creates a windfall for the monopolist. Depending on the cost of the product and the consumers' level of patience, we ask when this happens. A related question we address is how the volume of product sales and the distribution of surplus are affected by sharing markets.

The remainder of this paper is organized as follows. After a review of the pertinent literature, we introduce the main primitives of the model and establish the equilibrium choice behavior as well as the market price in a dynamic overlapping-generations economy with sharing. We then study the benchmark scenario ('base case') where consumers do not have access to a sharing market, and show that the firm's aggregate demand may in fact be higher. Next, we derive the equilibrium retail price with and without sharing market, under two possible commitment regimes. Finally, we characterize products for which sharing can be advantageous from the retailer's perspective and provide an analysis of the impact of a peer-to-peer market on both consumer surplus and social welfare. A discussion of the managerial implications is followed by a conclusion.

## Literature

Handlon and Gross [19] noted that sharing behavior is learned and its acceptability as a choice increases with chronological age. Doland and Adelberg [9] observed that the early learning of sharing by children is increased by social reinforcement; it also goes up with observation of such behavior by models [20].[3] More recently, Benkler [5] provides a careful discussion of "shareable goods," including case studies of carpooling and distributed computing, which may lead—more broadly—to a purely "access-based consumption" [3]. Despite the rich sociological motivations and textures of different types of sharing in various contexts, we are concerned here with "rational sharing," in the form of borrowing and lending, which Belk [4] describes as "borderline cases of sharing that generate an expectation that the object or some equivalent will be returned" (p. 1596).

Rational sharing amounts to realizing gains from trade from the collaborative consumption of durable goods.[4] The matching of sharing partners (i.e., borrowers and lenders) may take place directly or via intermediated marketplaces. Sharing markets are relatively recent. Zervas et al. [40] discuss the impact of AirBnB on the hotel industry. Other empirical studies concern car sharing [14], as well as general motivations for participating in collaborative consumption [26]. The absence of widespread sharing may be explained by market imperfections, such as the

informational asymmetries related to the moral hazard a renter might experience when choosing the effort of being careful with the shared property. Using an analytical model, Weber [34, 36] shows how intermediaries can eliminate moral hazard in sharing transactions and extract a large fraction of the gains from trade. Based on these findings, we neglect informational problems and focus on the agents' consumption decisions as well as the pricing of ownership with or without sharing markets. Our analysis shares aspects with early work on the decisions of whether to buy or rent a home [31] or land [29]. Einav et al. [11] provide a useful survey of the economics of peer-to-peer markets.

Arrow [2] introduced a market for contingent claims where agents provide mutual insurance to each other. Sharing markets do provide mutual insurance, which raises the value of ownership. As such, sharing markets allow for the transaction of short-term rental agreements which contain claims to the use of a certain good and insurance provisions in the case of damage or product failure. Our model builds on [37], who examines the question of ownership in a two-period model of agents, heterogeneous in their subjective needs for the item. In that setting, the sharing market does not necessarily clear, and the resulting supply-demand imbalance is resolved by random allocation and bilateral bargaining. Here we consider an infinite-horizon setting of overlapping generations, where agents are also heterogeneous with respect to their respective valuations for the use of the shared good. The idea of using overlapping generations as a model feature dates back at least to Fisher [13], and is common in economic growth models [22]. The advantage is stationarity of the equilibrium path, and in our setting, there is a unique clearing price for the sharing market which produces crisp conclusions about the agents' motivations to own and to share, as well as fairly clear predictions about the behavior of retail prices.

## Consumer Choice with Sharing Market

Let us consider a peer-to-peer economy with overlapping generations of finitely lived consumers (or "agents"). Each consumer generation exists for two periods, which are referred to as "early consumption phase" and "late consumption phase," respectively. The peer-to-peer economy operates in steady state at times $t \in \{0,1,\ldots\}$, and without loss of generality the number of consumers born in any given period $t$ is normalized to 1. At the end of the following period, $t+1$, these consumers born at the beginning of period $t$ exit the economy. One can interpret the overlapping generations of finitely lived consumers *either* literally, as consumers who enter and exit the economy, *or* in terms of two overlapping consumer preference classes (filled with long-lived agents), for each of whom the product becomes obsolete after two periods. In the remainder of this paper, we will use the first interpretation. Note that at any time $t$, the total number of consumers in the sharing economy is 2, corresponding to the sum of the two co-existing consumer generations. We refer to the respective consumption phases as $C_0$ (early consumption) and $C_1$ (late consumption).

Consumers have heterogeneous preferences for the durable consumption good in the economy. This could be any good worth sharing, such as a car, a party costume, or a power tool. Each

consumer is characterized by his (subjective) likelihood of need $\theta \in [0,1]$ and his value $v \in [0,1]$ for the item in case it is needed. Thus, any consumer's "type" is a point $(\theta, v)$ in the unit square $\mathcal{Q} = [0,1] \times [0,1]$. For simplicity, we assume that the type distribution for any generation is uniform on $\mathcal{Q}$.[5] Each consumer's type is persistent over his lifetime. The realizations of his need for the product are uncorrelated, and nothing can be learned from other consumers or his own past consumption about this need. If the item is not needed, its consumption utility drops to zero.

**Individual Consumption Decisions**

In any given consumption phase, a consumer of type $(\theta, v) \in \mathcal{Q}$ *either* needs the item *or* has no use for it at all. If he needs the item (which happens with probability $\theta$), his consumption value is $v$, otherwise the consumption benefit of the item vanishes. At any time $t$, the product can be bought from a retailer at a price $r > 0$; alternatively, the right for a one-time use of the product can be traded (i.e., acquired or relinquished) on a sharing market of peer consumers at the (nonnegative) price $p < r$.[6] As shown in the analysis below, for any given consumer generation ownership decisions are made in the early consumption phase $\mathcal{C}_0$: at the end of this phase, each agent is *either* an owner *or* a non-owner. In the late consumption phase $\mathcal{C}_1$, the borrowing/lending decisions on the sharing market become more important than ownership decisions, driven by the relatively high retail price $r$ compared to the clearing price $p$ for access to the product in the peer-to-peer economy. – In any consumption phase $\mathcal{C}_i$, for $i \in \{0,1\}$, the consumer is in a random need state $\tilde{s}_i \in \{0,1\}$, where by assumption

$$\text{Prob}(\tilde{s}_i = 1) = \theta.$$

This need state realizes at the beginning of each time period $t$. Given $p$ and $r$ (such that $0 < p < r$), we now consider the agents' decisions in their two consumption phases, starting with the last.

*Late Consumption Phase.* In $\mathcal{C}_1$, an agent of type $(\theta, v)$ observes the realization $s_1 \in \{0,1\}$ of the random need state $\tilde{s}_1$. As a non-owner, he can *either* not consume the product at all *or* rent it on the sharing market at the price $p$. Given his lack of consideration about the future in his late consumption phase, the option of renting dominates buying the product at the higher retail price $r > p$. The non-owner's resulting state-dependent payoff is

$$U_{s_1} = \max\{0, v s_1 - p\},$$

i.e., all $v \in [p,1]$ borrow in state $s_1 = 1$, and non-owners do nothing otherwise. On the other hand, an owner of type $(\theta, v)$ has the option to consume the product or else lend it out at the price $p$, with the state-dependent payoff

$$V_{s_1} = \max\{v s_1, p\},$$

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i.e., all $v \in [0, p)$ lend in state $s_1 = 1$ and all $v \in [0,1]$ lend in state $s_1 = 0$; otherwise no action is taken. The following result summarizes the state-contingent payoffs in $C_1$.

**Lemma 1.** *A type-$(\theta, v)$ agent's $C_1$-payoffs are $U_0 = 0$, $U_1 = \max\{0, v - p\}$ as non-owner, and $V_0 = p$, $V_1 = \max\{v, p\}$ as owner, respectively.*

As can be observed in Lemma 1, the payoff difference between owner and non-owner in any need state $s_i$ is equal to the price $p$ in the sharing market.

*Early Consumption Phase.* In $C_0$, an individual of type $(\theta, v)$, who is in need state $s_0 = 0$ or $s_0 = 1$, has the option to purchase the product from a retailer at the price $r$ to become an owner. In that case, the individual can use the item immediately. Alternatively, the agent can rent the item on the sharing market at the price $p$. Note that at this early stage in his life, the agent is concerned with his future, anticipating the expected utility ($\bar{V}$ as owner, or $\bar{U}$ as non-owner) in the next consumption phase as being influenced by his present choice. Any participant in the peer-to-peer economy discounts future payoffs at the common per-period discount factor
$$\delta \in (0,1].$$
Choosing the best of his three alternatives (do nothing / borrow on the sharing market / buy from the retailer) the agent's discounted state-dependent total payoff becomes
$$T_{s_0} = \max\{\delta \bar{U}, v s_0 - p + \delta \bar{U}, v s_0 - r + \delta \bar{V}\},$$
where $\bar{U} = (1-\theta)U_0 + \theta U_1$, $\bar{V} = (1-\theta)V_0 + \theta V_1$, and $U_i$, $V_i$, for $i \in \{0,1\}$, are given in Lemma 1. Combining the first two decision options yields the total expected payoff of non-ownership,
$$\max\{0, v s_0 - p\} + \delta \theta \max\{0, v - p\},$$
which needs to be compared with the total expected payoff of ownership,
$$v s_0 - r + \delta\big((1-\theta)p + \theta \max\{v, p\}\big).$$
In the low-need state $s_0 = 0$, an individual would purchase the product if and only if the retail price $r$ does not exceed the discounted price of sharing, $\delta p$. However, since $r > p$, this cannot happen in equilibrium, so that agents who do not need the product in their early consumption phase become non-owners. In the high-need state $s_0 = 1$, ownership is attractive for an agent if
$$r \le \min\{p, v\} + \delta p = \min\{(1+\delta)p, v + \delta p\}.$$
Conversely, if
$$p \le \min\{v, r/(1+\delta)\},$$
then the individual would prefer to borrow the item from the sharing market, even in the early consumption phase. Failing the last two inequalities, the individual is best off not consuming at all. The following result summarizes an individual's early consumption choice as a function of his type.

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**Lemma 2.** *In* $C_0$, *a type-* $(\theta, v)$ *agent in the need state* $s_0 = 1$ *becomes an owner if* $\min\{p, v\} \geq r - \delta p$, *and he borrows the item if* $p \leq v < r - \delta p$; *otherwise he does nothing.*

Note that in Lemma 2 it was implicitly assumed that in case of a tie between ownership and non-ownership payoff, an individual would opt for ownership, perhaps due to the residual claims that owners obtain from any asset, as opposed to non-owners who usually experience liability and some inconvenience when borrowing an item. As becomes clear below, the probability that a randomly drawn agent type experiences such indifference vanishes in equilibrium, so the tiebreaking rule is in fact immaterial.

## Equilibrium in the Sharing Market

Let $r > 0$ be a given retail price. Assuming that the sharing market clears, the price $p$ in the sharing market must be such that the demand for the shared product equals the supply.[7] Using Lemma 2, we can identify as potential suppliers in the exchange all agents in their late consumption phase $C_1$ who opted for ownership in their early consumption phase $C_0$. The number of owners is therefore

$$\Omega = (1 - G(\min\{p, r - \delta p\}))\bar{\theta} \, ,$$

where $\bar{\theta} \triangleq \int_0^1 \theta dF(\theta)$ denotes the *expected* likelihood of need, and $F, G$ are the distribution functions for $\theta$ and $v$, respectively (see note 5). As pointed out earlier, owners *always* lend in the low-need state ($s_1 = 0$), and they lend in the high-need state ($s_1 = 1$) *if* $v < p$. Thus, the actual sharing supply becomes

$$S = (1 - G(\min\{p, r - \delta p\}))\int_0^1 (1 - \theta)\theta dF(\theta) + \max\{0, G(p) - G(r - \delta p)\}\int_0^1 \theta^2 dF(\theta).$$

On the other hand, we also found earlier that non-owners in their late consumption phase $C_1$ borrow an item on the sharing market if they are in a high-need state and $v \geq p$. In the early consumption phase $C_0$, agents in the high-need state with $p \leq v < r - \delta p$ like to borrow on the sharing market. The resulting demand in the sharing market is

$$D = (1 - G(p))\int_0^1 (1 - \theta)\theta dF(\theta) + \max\{0, G(r - \delta p) - G(p)\}\int_0^1 \theta^2 dF(\theta).$$

Market clearing in the sharing market requires that the excess demand, $\Delta \triangleq D - S$, vanishes. Thus,

$$\Delta = G(r - \delta p) - G(p) = 0 \, ,$$

which implies the following result.

**Proposition 1.** *Given a retail price* $r \in (0, 1 + \delta)$, *the unique clearing price in the sharing market is* $p = r / (1 + \delta)$.

The clearing price in the sharing market satisfies a no-arbitrage condition in the sense that the present value of the cost of renting the product in successive consumption phases equals the retail price, i.e., $r = p + \delta p$. As a byproduct, Proposition 1 also determines the liquidity in the sharing market.

Corollary 1. *The transaction volume in the sharing market is*

$$S = D = (1 - G(r / (1 + \delta))) \int_0^1 (1 - \theta)\theta \, dF(\theta),$$

*for any given retail price* $r \in (0, 1 + \delta)$.

The transaction volume in the peer-to-peer economy is proportional both to the number of agents whose need states vary across consumption phases and to the number of agents with value above the clearing price $p = r / (1 + \delta)$ in the sharing market. Figure 1 illustrates the agents' choice behavior with the possibility of sharing, depending on their respective need states in the two consumption phases.
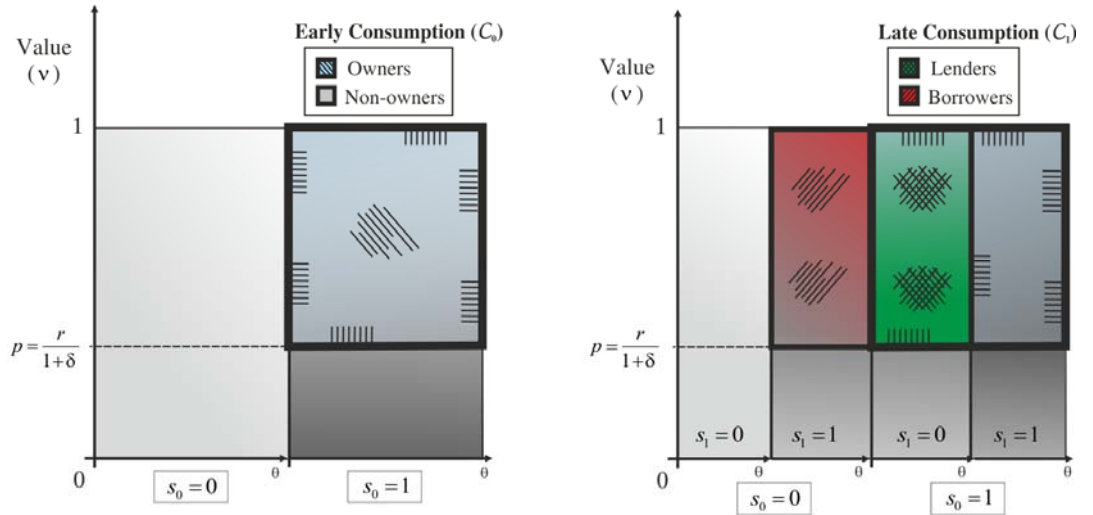


*Figure 1.* Equilibrium purchasing and sharing behavior *with* a peer-to-peer economy

Example 1. For the initially assumed uniform type distribution it is $F(\theta) = \theta$ and $G(v) = v$ for all $(\theta, v) \in \mathcal{Q}$. In this setting, Corollary 1 implies that

$$S = D = \frac{1}{6}\left(1 - \frac{r}{1 + \delta}\right) \in (0, 1/6),$$

for $r \in (0, 1 + \delta)$.

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**Equilibrium Concept and the Retailer's Price-Commitment Ability**

As mentioned at the outset, the firm's and all the agents' actions take place at the discrete time instances $t \in \{0,1,2,...\}$ over an infinite horizon. To arrive at fairly robust predictions about the outcome of these interactions, we consider the subgame-perfect Nash equilibrium by Selten [30] as the relevant equilibrium concept for the supergame.[8] It is clear that because of the coexistence of both consumer generations in each period and their finite lifetimes (which eliminates the conclusions of the various folk theorems, e.g., by Friedman [15]), there is no rationale for a nonstationary Nash equilibrium. Yet, depending on the exact sequence of actions within each period, the equilibrium can differ significantly. We consider the following two regimes, which define the retailer's commitment ability:

1. Stackelberg pricing (SP): at the beginning of each period, the retailer moves first by fixing the retail price $r$. Then the sharing market is opened and clears at the no-arbitrage price $p$, specified by Proposition 1. The intra-period leader-follower dynamic represents a Stackelberg stage game [33].[9] This is the sequence of actions implicit in the model by [38]. The Stackelberg setup is plausible if the sharing market is fairly slow to clear; it provides a benchmark of the best possible outcome for the monopolist.

2. Simultaneous-move pricing (SMP): the retailer's choice of $r$ and the market clearing happen virtually at the same time. In that setting, the retailer has to take the market price as given and cannot use the no-arbitrage condition in Proposition 1 to "backward-induct" the best retail price. To better understand the logic, note first that by the first fundamental welfare theorem (or "First Theorem of Pareto Optimality" [23]) the sharing market is efficient, in the sense that it implements a Pareto-optimal outcome among all consumers, enabling trade without any frictions. Hence, the market-clearing price can be thought of as a choice of a rational actor maximizing a weighted average of all consumers' payoffs. In other words, the relation $p = r / (1+\delta)$ can be viewed as the market's best response to any given retail price $r$. This setup is useful if the sharing market is very responsive to the retail price and/or the retailer's price-commitment ability is low. The simultaneous-move regime might be viewed as somewhat more purist with respect to the initial model, in the sense that at each time period everything really happens simultaneously, without the need for "sub-periods."

Because the solutions differ in several key aspects, in what follows we consider both *commitment regimes*, SP and SMP. Reality may lie somewhere in between the two extremes.

**Demand for Ownership with Sharing**

The commitment regime, together with the clearing price in Proposition 1, determines the stationary equilibrium demand $\Omega$ for ownership. The latter is positive only in the early consumption phase. Specifically, under *Stackelberg pricing* (SP), the retailer can anticipate the price formation in the market, so

$$\Omega_{SP} = \left(1 - G(r / (1+\delta))\right) \overline{\theta} \,,$$

given the retail price $r \in (0, 1+\delta)$. The corresponding price elasticity of the demand for ownership in a peer-to-peer economy is

$$\varepsilon_{SP} = -\frac{r}{\Omega_{SP}} \frac{\partial \Omega_{SP}}{\partial r} = \frac{r}{1+\delta} h\left(\frac{r}{1+\delta}\right),$$

where $h(v) \triangleq g(v) / (1 - G(v))$, for all $v \in [0,1]$, denotes the hazard rate of the value distribution $G$. Under *simultaneous-move pricing* (SMP), the clearing price $p$ in the sharing market is taken as given by the retailer, which implies that

$$\Omega_{SMP} = \left(1 - G(\min\{p, r - \delta p\})\right) \overline{\theta} \,.$$

The price elasticity $\varepsilon_{SMP}$ vanishes for $p < r / (1+\delta)$ and otherwise is

$$\varepsilon_{SMP} = r h(r - \delta p).$$

In this setting, the price formation $p = r / (1+\delta)$ in the market is viewed as a best response. At the no-arbitrage price in the equilibrium of the sharing market, the relationship between the price elasticities in the two commitment regimes is that $\varepsilon_{SMP}\big|_{p=r/(1+\delta)} = (1+\delta) \varepsilon_{SP}$. That is, the price elasticity of demand decreases if the retailer's price-commitment ability goes up (from the SMP-regime to the SP-regime).

Example 2. In the setting of Example 1, the hazard rate is $h(v) \equiv 1 / (1-v)$, and the price elasticities of the demand for ownership in the two commitment regimes become

$$\varepsilon_{SP} = \frac{r}{1+\delta-r} \quad \text{and} \quad \varepsilon_{SMP} = \frac{r}{1+\delta p - r},$$

respectively, for $r \in (0, 1+\delta)$ and $p \geq r / (1+\delta)$.

# Consumer Choice without Sharing Market

To measure the impact of the peer-to-peer economy, it is necessary to consider a base case without sharing. Thus, we now assume—in contrast to our preceding discussion—that no consumer generation has access to transactions on a sharing market, and therefore all agents have to make "isolated" consumption decisions, without the possibility of sharing.

**Isolated Retail Consumption**

In any given consumption phase ($\mathcal{C}_0$ or $\mathcal{C}_1$), a consumer of type $(\theta, \nu) \in \mathcal{Q}$ can respond to a high-need state by either doing nothing or else by purchasing the product at the price $r$ from the retailer. As before, we backward-induct ownership decisions at the beginning of the agent's lifecycle from the decisions in his late consumption phase.

*Purchase in Late Consumption Phase.* In $\mathcal{C}_1$, an agent of type $(\theta, \nu)$ first observes his need state $s_1 \in \{0, 1\}$. As a non-owner, he decides to purchase the product from the retailer if and only if $\nu s_1 \geq r$, resulting in the state-dependent payoff

$$\hat{U}_{s_1} = \max\{0, \nu s_1 - r\}.$$

As an owner, without sharing market there is no real choice available, thus implying the state-dependent payoff

$$\hat{V}_{s_1} = \nu s_1.$$

The following result summarizes the consumers' net benefits in $\mathcal{C}_1$ without a peer-to-peer economy.

Lemma 3. *A type-$(\theta, \nu)$ agent's isolated $\mathcal{C}_1$-payoffs are $\hat{U}_0 = 0$, $\hat{U}_1 = \max\{0, \nu - r\}$ as non-owner, and $\hat{V}_0 = 0$, $\hat{V}_1 = \nu$ as owner, respectively.*

A payoff difference between owner and non-owner is present only in the high-need state. Yet, comparing the consumers' payoffs for a fixed retail price $r$ suggests that the presence of a sharing market cannot decrease an agent's payoff, independent of his ownership status and need state. If one were to introduce a peer-to-peer economy holding $r$ constant, the consumers' surplus in $\mathcal{C}_1$ would have to therefore increase.

Lemma 4. *Given a fixed retail price, the difference between a type-$(\theta, \nu)$ agent's $\mathcal{C}_1$-payoffs with and without sharing market is nonnegative. More specifically: $V_0 - \hat{V}_0 = r / (1 + \delta)$, $V_1 - \hat{V}_1 = \max\{0, r / (1 + \delta) - \nu\}$, $U_0 - \hat{U}_0 = 0$, and*

$$U_1 - \hat{U}_1 = \begin{cases} \max\{0, \nu - (r / (1 + \delta))\}, & \text{if } \nu \leq r, \\ (\delta r) / (1 + \delta), & \text{otherwise,} \end{cases}$$

*for any retail price $r \in (0, 1 + \delta)$.*

Note that Lemma 4 does not imply that sharing markets are beneficial whenever the retail price is subject to optimization. In the next section ("Retail Price Optimization"), we show that the presence of a sharing market tends to substantially affect the retail price, positively or negatively, depending on the retailer's (or manufacturer's) commitment power in the dynamic setting.

*Purchase in Early Consumption Phase.* In $C_0$, when taking decisions a type- $(\theta, v)$ agent anticipates his expected payoffs, *either* as an owner *or* a non-owner, in his future consumption phase. In the high-need state ( $s_0 = 1$ ), the agent would make an isolated purchase if $v - r + \delta\theta\hat{V}_1 \geq \delta\theta\hat{U}_1$. In the low-need state ( $s_0 = 0$ ), it is clear that the agent would never buy the product because no immediate payoff is available and he will always have the option to purchase in the late consumption phase, should a need for the product arise then. The types seeking ownership in the early consumption phase can be characterized using Lemma 3.

**Lemma 5.** *In* $C_0$, *a type-* $(\theta, v)$ *agent in the need state* $s_0 = 1$ *becomes an owner in the absence of a sharing market if* $v \geq r / (1 + \delta\theta)$.

An equivalent representation for the ownership condition in Lemma 5 is that the probability of need $\theta$ exceeds a threshold that is decreasing in an agent's valuation $v$:

$$\theta \geq \frac{r - v}{\delta v}.$$

For $v \geq r$, this condition holds automatically (i.e., for all $\theta \in [0,1]$ ). However, it cannot be satisfied at all if $v < r / (1 + \delta)$. Figure 2 visualizes the consumers' choices in the absence of sharing, depending on their respective need states in the two consumption phases.
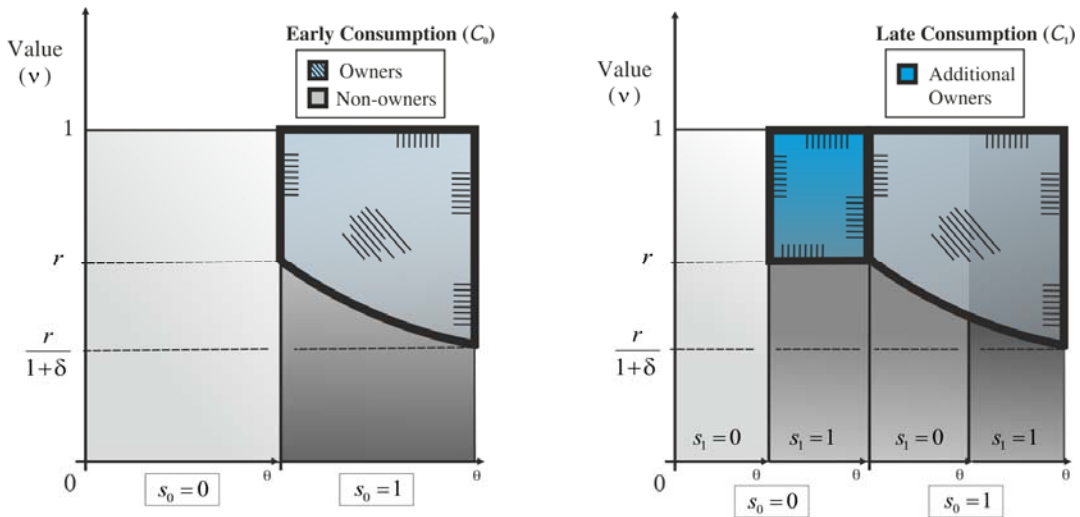


*Figure 2*. Equilibrium purchasing and sharing behavior *without* a peer-to-peer economy

**Demand for Ownership without Sharing**

As noted earlier in this section, without sharing markets ownership is acquired by some agents in their early and by other agents in their late consumption phase. In $\mathcal{C}_0$, the demand for ownership,

$$\hat{\Omega}_0 = \max\{0, 1 - G(r)\}\bar{\theta} + \int_{r/(1+\delta)}^{\min\{1,r\}} \left( \int_{(r-v)/(\delta v)}^{1} \theta \, dF(\theta) \right) dG(v),$$

depends on the perceived likelihood of future need, at least for intermediate valuations. In $\mathcal{C}_1$, the demand for ownership is

$$\hat{\Omega}_1 = \max\{0, 1 - G(r)\}\int_0^1 (1-\theta)\theta \, dF(\theta).$$

Thus, the total demand for ownership in the absence of a sharing market becomes

$$\hat{\Omega} = \hat{\Omega}_0 + \hat{\Omega}_1,$$

for any given retail price $r \in (0, 1+\delta)$. While in the late consumption phase ($\mathcal{C}_1$) demand follows a similar logic as in the presence of a peer-to-peer economy (non-owners purchase if and only if $s_1 = 1$ and $v \geq r$), in the early consumption phase ($\mathcal{C}_0$) there are consumers, with sufficiently high likelihood of need $\theta$ and with values $v$ below $r$ and above $r/(1+\delta)$, who accept a negative payoff in the present to ensure their future consumption benefits. For sufficiently low retail prices, the demand for ownership tends to be larger without than with a peer-to-peer economy. Figure 3 depicts, for all possible retail prices $r \in [0, 1+\delta]$, the aggregate demand for ownership with and without sharing ($\Omega$ and $\hat{\Omega}$), as well as the retailer's profit with and without sharing ($\Pi$ and $\hat{\Pi}$). Because $\hat{\Omega}(0) = 2/3 > 1/2 = \Omega(0)$ and $\hat{\Omega}(1+\delta) = \Omega(1+\delta) = 0$, *the demand without sharing is on average more elastic than the demand with sharing*: decreasing from a larger value to zero over the same retail-price interval (as $r$ varies from 0 to $1+\delta$), sales without collaborative consumption tend to be more responsive to price movements. Note also that for small retail prices (and sufficiently impatient consumers; here for $\delta = 0.6$) the firm's profit without sharing exceeds its profit with sharing. As we show below, the last observation continues to hold when substituting the respective equilibrium prices, as long as the marginal cost for the good remains small.

Example 3. Given a uniform type distribution as in the earlier examples, one obtains

$$\hat{\Omega}_1 = \max\{0, \frac{1-r}{6}\}.$$

To determine $\hat{\Omega}_0$, note first that for $r \in [0,1]$:

$$\int_{\frac{r}{1+\delta}}^{r} \left( \int_{\frac{r-v}{\delta v}}^{1} \theta \, d\theta \right) dv = \frac{r}{2\delta}\int_0^1 \frac{(1-x^2)\, dx}{((1/\delta)+x)^2}$$

is linear in $r$. The right-hand side of the preceding equation is equal to

$$\left( \frac{1}{2} - \frac{1}{\delta}\left(1 - \frac{\ln(1+\delta)}{\delta}\right) \right) r,$$

and it is increasing in $\delta \in (0,1]$. Thus, for $r \in [0,1]$:

$$\hat{\Omega}_0 = \frac{1}{2} - \left(1 - \frac{\ln(1+\delta)}{\delta}\right)\frac{r}{\delta}.$$

Similar computations yield

$$\hat{\Omega}_0 = \frac{(r-\delta)^2 - 1}{2\delta^2} - \left(\frac{\ln(r) - \ln(1+\delta)}{\delta}\right)\frac{r}{\delta},$$

for $r \in (1, 1+\delta)$. Finally, the demand for the product in the absence of a sharing market becomes

$$\hat{\Omega} = \begin{cases} \dfrac{2}{3} - \rho r, & \text{if } r \in [0,1], \\ \hat{\Omega}_0, & \text{if } r \in (1, 1+\delta), \end{cases}$$

where $\rho \triangleq \dfrac{1}{6} + \dfrac{1}{\delta}\left(1 - \dfrac{\ln(1+\delta)}{\delta}\right) \in [(7/6) - \ln(2), 2/3)$ is decreasing in $\delta \in (0,1]$; see Figure 3 for
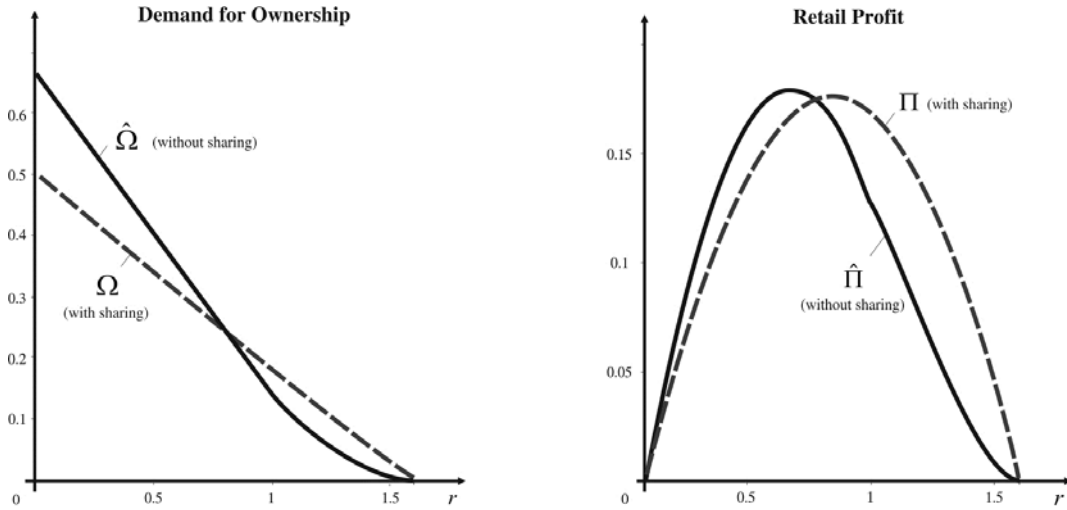
an illustration when $\delta = 0.6$.



*Figure 3.* Demand for ownership and retail profits, with and without sharing ( $c = 0.1$, $\delta = 0.6$ )

Example 4. Analogous to Example 2, one can determine the price elasticity of the product demand determined in Example 3:

$$\hat{\varepsilon} = \frac{\rho r}{(2/3) - \rho r},$$

for $r \in [0,1]$ and $\delta \in (0,1]$.[10]

# Retail Price Optimization

Consider now a monopolist retailer who is able to set the retail price so as to maximize (per-period) profits in the steady state of the overlapping-generations economy. Assuming that the retailer's cost of procurement is linear in the number of products, the corresponding marginal cost $c$ is constant and nonnegative. By the monopoly pricing rule [32], at the optimal rate $r$ the relative markup equals the inverse elasticity (Lerner index):[11]

$$\frac{r-c}{r} = \frac{1}{\varepsilon} \ .$$

Because the left-hand side of the preceding relation is less than 1, the monopolist retailer sets the optimal retail price in the elastic portion of the demand curve where $\varepsilon \geq 1$. If we denote by $r_{SP}^*, r_{SMP}^*$ the equilibrium prices with sharing for the two commitment regimens (SP and SMP), and by $\hat{r}^*$ the optimal retail price without peer-to-peer economy, respectively, then the last observation implies a lower bound for retail prices, based on the results in the earlier examples.

Lemma 6. *For any $c \geq 0$, the optimal retail prices are such that $r_{SP}^* \geq (1+\delta)/2$, $r_{SMP}^* \geq (1+\delta)/(2+\delta)$, and $\hat{r}^* \geq 1/(3\rho)$.*

The lower bound for the retail price in the economy without sharing market is majorized by the corresponding bound in the Stackelberg regime and minorized by the bound in the simultaneous-move regime. Provided that $\hat{r}^* \in [0,1]$, the equilibrium/optimal retail prices can be obtained explicitly.

Proposition 2. *(i) The equilibrium retail prices with sharing market are $r_{SP}^* = (1+\delta+c)/2$ and $r_{SMP}^* = (1+c)(1+\delta)/(2+\delta)$, respectively, for $c \geq 0$.[12] (ii) The optimal retail price without sharing market is $\hat{r}^* = \dfrac{1}{3\rho} + \dfrac{c}{2}$, for $c \in [0,1/2]$.[13]*

We can therefore conclude that the presence of a peer-to-peer economy has, at least for the Stackelberg regime, a unidirectional impact on retail prices, in terms of a positive "sharing premium."

Corollary 2. *For all $\delta \in (0,1]$, it is $\hat{r}^* \leq r_{SP}^*$, independent of $c$.*

Under price commitment by the retailer in the Stackelberg regime (SP), the retail price with sharing ($r_{SP}^*$) exceeds the retail price without sharing ($\hat{r}^*$). In the simultaneous-move regime (SMP), the retailer has no power of commitment, so the retail price with sharing ($r_{SMP}^*$) drops and becomes close to the retail price without sharing ($\hat{r}^*$), so that the sharing premium can in fact

become negative; see Figure 4. The price effect of a sharing market significantly depends on the retailer's price-commitment ability.[14] As an illustration: in the Stackelberg regime, the price $r_{SP}^*$ presents a "sharing premium" of up to 31% over $\hat{r}$ for medium-cost goods ($c = 1/2$) and up to 42% over $\hat{r}$ for a zero-cost good. In the simultaneous-move regime, on the other hand, the equilibrium retail price $r_{SMP}^*$ (compared to $\hat{r}$) includes a sharing premium of up to about 5% for medium-cost goods ($c = 1/2$) and a negative sharing premium of down to about -5% for a zero-cost good. The effects of sharing markets on retail prices can be considered significant. The direction of the price movement is determined by the retailer's commitment ability, or somewhat equivalently, by the speed of the price adjustment in the sharing market. The left panel in Figure 4 shows the different retail prices as a function of $c$ for $\delta = 0.6$. The "jump" (or rather set-valued transition) of the (upper-semicontinuous) price $\hat{r}$ occurs because the convexity of the demand function for high retail prices (greater than 1), which precludes certain prices (around 1) from being optimal. Note that the corresponding profit $\hat{\Pi}$ is continuous (i.e., without jump) because by the Berge maximum theorem [6] the price transition takes place only via indifference; see Figure 4.

**Profit Comparison**

Let $c \in [0, 1/2]$. Using the results in Proposition 2, the retailer's optimal profit with sharing market is

$$\Pi_{SP}^* \triangleq (r_{SP}^* - c)\,\Omega\big|_{r=r_{SP}^*} = \frac{(1+\delta-c)^2}{8(1+\delta)} \quad \text{and} \quad \Pi_{SMP}^* \triangleq (r_{SMP}^* - c)\,\Omega\big|_{r=r_{SMP}^*} = \frac{1}{2}\left(\frac{1+\delta-c}{2+\delta}\right)^2,$$

respectively, depending on the commitment regime. Without sharing market it becomes

$$\hat{\Pi}^* \triangleq (\hat{r}^* - c)\,\hat{\Omega}\big|_{r=\hat{r}^*} = \frac{(2-3\rho c)^2}{36\rho} .$$

As predicted by the Coase conjecture [8, 18], the retailer's profits in the presence of sharing are increasing in the ability to commit. The corresponding clearing prices in the sharing market, $p_{SP}^*$ and $p_{SMP}^*$, are such that $p_{SMP}^* < p_{SP}^*$, which in turn implies that, for low commitment ability by the retailer, the sharing market is an especially attractive option for consumers. This entails fiercer price competition, so $\Pi_{SMP}^* < \Pi_{SP}^*$. With commitment to its retail price at the beginning of each period, the firm obtains the highest possible profits, at least for high-cost products. Indeed, the ratio of the profits,

$$\eta_{SP} \triangleq \frac{\Pi_{SP}^*}{\hat{\Pi}^*} = \frac{9\rho}{2(1+\delta)}\left(\frac{1+\delta-c}{2-3\rho c}\right)^2,$$

is increasing (and convex) in $c$ and increasing in $\delta$. As shown in Figure 4, for low-cost products, the firm may be best off without a sharing market.
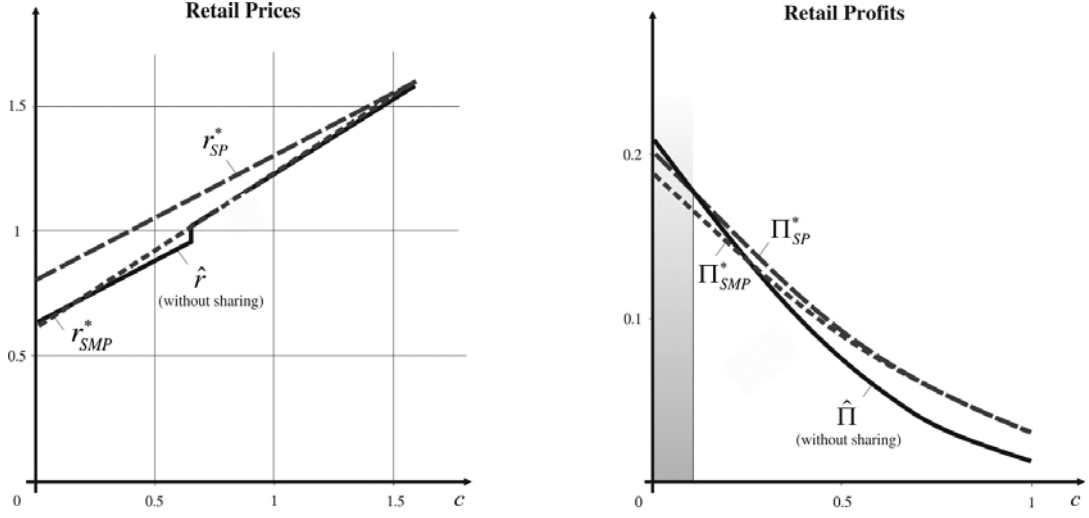
*Figure 4.* Equilibrium retail prices and profits ($\delta = 0.6$); shaded region: retailer prefers no sharing

**Proposition 3.** *For $c \in [0, 1/2]$, there exists $\bar{\delta}(c)$ in $(0,1)$ such that the retailer's optimal profit is larger with sharing market (in the Stackelberg regime) than without sharing market, for all $\delta \geq \bar{\delta}(c)$. The threshold $\bar{\delta}(c)$ is decreasing in $c$.*

As an example, for $c = 0$, one finds that $\eta_{SP} > 1$ if and only if $\delta$ exceeds $\bar{\delta}(0) \approx 0.7902$, while for $c = 1/2$ it is $\eta_{SP} > 1$ if and only if $\delta$ exceeds $\bar{\delta}(1/2) \approx 0.2646$. The threshold logic also applies in the cost dimension.

**Corollary 3.** *For $\delta \in (\bar{\delta}(1/2), \bar{\delta}(0))$, there exists a marginal-cost threshold $\bar{c}(\delta)$ in $[0, 1/2]$ such that the retailer's optimal profit is larger with sharing market than without sharing market, for all $c \geq \bar{\delta}(c)$. The threshold $\bar{c}(\delta)$ is decreasing in the discount factor $\delta$.*

To illustrate the latest findings, we consider some numerical examples. In the Stackelberg regime without discounting, i.e., for $\delta = 1$, a sharing market *increases* the retailer's profit by about 6.5% for zero-marginal-cost products ($c = 0$) and about 44.1% for medium-cost products ($c = 1/2$). Conversely, when there is substantial discounting ($\delta = 1/2$), then the sharing market *reduces* the retailer's profit by about 8% for zero-marginal-cost products and increases the retailer's profit by about 16.8% for medium-cost products. Conversely, in the simultaneous-move regime, a sharing market always reduces the retailer's profit, when $\delta = 1$ by about 41% for zero-marginal-cost products and by 100% (!) for medium-cost products ($c = 1/2$), and when there is substantial

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discounting ($\delta = 1/2$) by approximately 28% for zero-marginal-cost products and by about 58% for medium-cost products.

## Consumer Surplus and Social Welfare

To quantify the aggregate effect of a peer-to-peer market on consumers, it is necessary to compute the consumer surplus by summing over all agents' (net) payoffs in a given period. Because the equilibrium is stationary, it is enough to consider the consumer surplus for both generations in a single period.[15] For this, recall that in equilibrium, the retail price $r$ and the clearing price $p$ in the sharing market are related by the no-arbitrage condition $r = (1+\delta)p$. In $\mathcal{C}_1$, a non-owner gets the payoff $U_{s_1} = s_1 \max\{0, v-p\}$, while an owner obtains $V_{s_1} = p + s_1 \max\{0, v-p\}$, depending on the realized need state $s_1 \in \{0,1\}$. Given that (under our assumption of a uniform type distribution) for two-thirds of all consumers of a given generation the need-state realizations are the same in both consumption phases, a subset of the remaining third participates in the sharing market. Consequently, the realized consumer surplus of a given generation in $\mathcal{C}_1$ is

$$\mathrm{CS}_1(p) = \frac{1}{6}\int_p^1 (v-p)dv + \frac{(1-p)p}{6} + \frac{1}{3}\int_p^1 v\,dv = \frac{1-p^2}{4}.$$

In $\mathcal{C}_0$, consumers obtain $s_0(v-r)\mathbf{1}_{\{v \geq p\}}$ depending on the need-state realization $s_0 \in \{0,1\}$. Hence, the consumer surplus of a given generation in $\mathcal{C}_0$ is

$$\mathrm{CS}_0(p) = \frac{1}{2}\int_p^1 (v-r)dv = \frac{1-p}{2}\left(\frac{1-p}{2} - \delta p\right).$$

This yields the per-period consumer surplus in the presence of a sharing price,

$$\mathrm{CS}(p) = \mathrm{CS}_0(p) + \mathrm{CS}_1(p) = \frac{(1-p)(1-\delta p)}{2},$$

which is decreasing in the clearing price $p$. More specifically, in the Stackelberg regime (SP) where the retailer has relatively high commitment power, one obtains $\mathrm{CS}_{SP}^* = \mathrm{CS}(p_{SP}^*)$ at the equilibrium price $p_{SP}^* = (1+\delta+c)/(2(1+\delta))$. In the simultaneous-move regime (SMP), i.e., essentially without retail-price commitment, the per-period consumer surplus is $\mathrm{CS}_{SMP}^* = \mathrm{CS}(p_{SMP}^*)$ at the equilibrium price $p_{SMP}^* = (1+c)/(2+\delta)$.

Consider now the consumer surplus without sharing market. In $\mathcal{C}_0$, consumers in the high-need state with value $v \geq r/(1+\delta\theta)$ purchase, so that the surplus in the consumption phase becomes

$$\widehat{\mathrm{CS}}_0(r) = \int_0^1 \left(\int_{r/(1+\delta\theta)}^1 (v-r)dv\right)\theta\,d\theta = \frac{1}{4} + \frac{r}{\delta}\left(\frac{(3/2)+\delta}{1+\delta}r - \frac{\delta}{2}\right) - \frac{3}{2}\left(\frac{r}{\delta}\right)^2 \ln(1+\delta).$$

In $\mathcal{C}_1$, non-owners in the high-need state purchase the item, as long as $v \geq r$. Furthermore, owners in the high-need state obtain their value as payoff, so that the consumer surplus can be expressed in the form

$$\widehat{CS}_1(r) = \frac{1}{6}\int_r^1 (v-r)\,dv + \int_0^1 \left(\int_{r/(1+\delta\theta)}^1 v\,dv\right)\theta^2\,d\theta = \frac{(1-r)^2}{12} + \frac{1}{6} - \left(\frac{r}{\delta}\right)^2 \left(\frac{1+(\delta/2)}{1+\delta} - \frac{\ln(1+\delta)}{\delta}\right).$$

Combining the results for both consumption phases, the per-period consumer surplus in the absence of a peer-to-peer economy becomes

$$\widehat{CS}(r) = \frac{5+(1-r)^2}{12} - \frac{r}{2} - \left(\frac{r}{\delta}\right)^2 \left(\frac{1-\delta-\delta^2}{1+\delta} - \frac{1-(3/2)\delta}{\delta}\ln(1+\delta)\right).$$

Because a sharing market provides additional choice for consumers, its introduction—all else equal (i.e., at a constant retail price)—can be beneficial only for consumer surplus. From our earlier analysis,[16] we know that the retail price with sharing in the simultaneous-move regime is lower than without sharing, so that *a forteriori* the peer-to-peer economy increases the consumers' surplus. In the Stackelberg regime, the retail price increases over the base case, but one can show that this is not enough to compensate for the consumers' gains from trade in the peer-to-peer economy.

**Proposition 4.** *For $c \in [0,1/2]$ and $\delta \in (0,1]$, the introduction of a peer-to-peer economy increases consumer surplus, and $\widehat{CS} < CS_{SP}^* < CS_{SMP}^*$, where $\widehat{CS} \triangleq \widehat{CS}(\hat{r})$ is the consumer surplus without sharing.*

Based on the preceding result, it might be tempting to conclude that sharing markets are unequivocally good for society. Yet, one needs to check if a one-dollar improvement in consumer surplus does not cost more than a dollar of the retailer's profit to achieve. Using the closed-form expressions for the retailer's profit and the consumer surplus in each period, it is straightforward to check that this preliminary intuition proves to be correct: sharing markets not only increase the consumers' benefit, they also create value for society as a whole. Figure 5 depicts the social welfare $\hat{W} \triangleq \widehat{CS} + \hat{\Pi}$ without sharing as well as with sharing, both in the Stackelberg regime ($W_{SP}^* \triangleq CS_{SP}^* + \Pi_{SP}^*$) and the simultaneous-move regime ($W_{SMP}^* \triangleq CS_{SMP}^* + \Pi_{SMP}^*$), for $\delta = 0.6$ and $c \in [0,1]$. The "jump" in consumer surplus without sharing ($\widehat{CS}$) is due to the corresponding "jump" in the price $\hat{p}$ (shown in Figure 4) and is therefore also present in the social welfare $\hat{W}$.
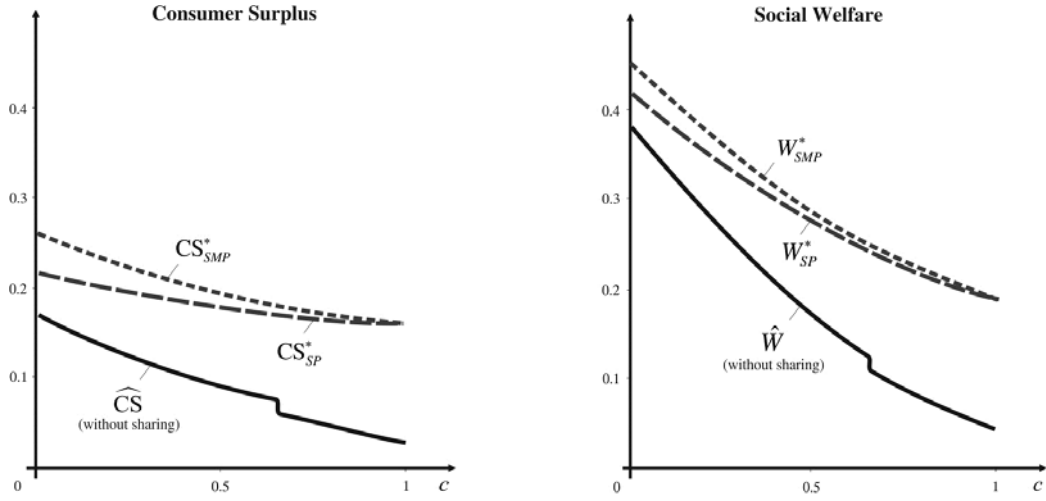
*Figure 5*. Consumer surplus and social welfare, with and without peer-to-peer economy, and for both commitment regimes ($\delta = 0.6$)

## Managerial Implications and Limitations

*Implications.* The recent advent of peer-to-peer economies, propelled by electronic intermediaries, begs the question of whether we are witnessing a temporary phenomenon or a paradigm shift from ownership-based to access-based consumption. The model provides economic intuition which sheds some light on this question. The effect of a peer-to-peer economy on retail prices depends on the retailer's ability to commit. Its positive effect on consumer surplus is unambiguous. On the other hand, its impact on retail profits may be negative for low-cost products, but increases in production cost and tends to be positive for high-cost products. The fact that goods are more expensive to purchase with a sharing economy when the retailer has commitment power, and sometimes cheaper when the retailer lacks this ability, has two practical consequences. First, the better the price discovery in a sharing market (possibly related to overcoming the problems of adopting electronic markets; see, e.g., [21]), the more responsive it can be to fluctuations in the retail price, thus diminishing the retailer's power to commit to a price, thus reducing the "sharing premium." Indeed, as sharing becomes more prevalent in society (see, e.g., [27] for an infinite-horizon model of sharing diffusion), retailers have to pay closer attention to competition from peer-to-peer markets. And as those markets become more liquid, the efficiency in the price discovery will increase. Second, a retailer benefits from a cost to change prices, just as in the classical durable-goods problem [8, 18]. This is somewhat surprising because the consumers' lifetime in the model is very limited but nonetheless allows for strategic purchasing behavior. A strong reputation may aid in improving the credibility of the retailer's price announcements.

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*Limitations.* The model rests on a number of limiting assumptions. While it does allow for two-dimensional consumer heterogeneity, in terms of use value and likelihood of need, the agents' lifetime is very limited. With longer (possibly random) consumer lifetimes, keeping track of the number of owners in the economy becomes more challenging, both explicitly, in terms of solving the model, and implicitly, in terms of stretching the realism of a rational-expectations assumption that requires each consumer, in equilibrium, to correctly anticipate the aggregate price path in order to make consistent forecasts and decisions [24]. It is unclear if introducing such complications could significantly enhance the qualitative insights obtained from the simpler version of the model.

# Conclusion

A peer-to-peer economy affects social welfare and changes the way the available surplus is distributed. Not all parties benefit from sharing. While consumer surplus always goes up with the introduction of an efficient sharing market, a retailer's (or producer's) profit may well decrease, particularly when the product's marginal cost is low. Thus, to realize the aggregate benefits of a peer-to-peer economy, a social planner may need to provide incentives to a manufacturer so as to encourage sharing. For high-cost goods, such incentives may not be needed because consumer sharing increases profits. For example, BMW recently introduced, on its own, a mobility service (at drive-now.com) to facilitate the shared use of its vehicles. However, for low-cost products the demand without sharing may well exceed the demand with sharing, driven by strategic consumer behavior (and lack of alternatives for high-need non-owners in their late consumption phase). Thus, even though sharing tends to decrease demand elasticity *on average*, the sharing-induced demand drop for new products (when they are relatively cheap) may lead to a negative net effect of collaborative consumption on a monopolist's profit; see Figure 3 and Figure 4.

The increase in consumer surplus follows from the Pareto-optimality of a market allocation: each consumer is free to participate and therefore ends up with a level of utility that is at least as high as without sharing. While the retailer may be able to appropriate some of this surplus given a positive "sharing premium," i.e., an increased retail price, it may be impossible to overcome a finite demand drop for low-price products. The comparison of the optimal retail prices and profits, with and without sharing, indicates that sharing markets are attractive for retailers with high-cost products and in situations where the future consumption of the product matters in the present. More broadly, retailers who are able to credibly commit to their prices in each period enjoy an advantage in rent extraction. For those, sharing markets can be *dis*-advantageous when products are fairly cheap to produce (relative to the consumer's average valuation). By extending the retailer's choice variables so as to include the product's *durability*, this conclusion may also hold for retailers with less commitment power. By actively decreasing the chance that a product survives the purchasing period, the retailer (or manufacturer) avoids competition with his own self in the future, thus decreasing the Coase problem by increasing the ability to commit. Planned obsolescence may also adjust the liquidity on the sharing market in the late consumption phase and thus increase profits (see [28]). The details are subject to further research. From a social

planner's viewpoint, the current results advocate sharing markets for high-cost products. To compensate retailers for a possible negative profit impact, a regulator may consider incentives that would encourage manufacturers and retailers to embrace the peer-to-peer economy in their product design and their marketing mix.

## Acknowledgements

## Notes

[1] See also [10]. As of May 2016, AirBnB, with more than 2 million listings in 34,000 cities, has served more than 60 million guests in more than 190 countries [1].

[2] The prices of apartments have increased in areas with increased use sharing intermediaries such as AirBnB, 9Flats, and Wimdu (personal communication by Roman Rochel, COO of 9Flats, Berlin, Germany; September 2013).

[3] Related to these studies, Furby [16] examines sharing decisions and moral judgments about sharing across different age groups and cultures (US vs. Israel).

[4] The idea of "collaborative consumption" was introduced by Felson and Spaeth [12] as an act of consuming while engaging in joint activities with others. Botsman and Rogers [7] drop the social context and use the notion equivalently to sharing.

[5] Some of our results hold under the more general assumption that the two attributes are independently distributed where $\theta$ follows the cumulative distribution function (cdf) $F$ and $v$ the cdf $G$, respectively, and $F, G : [0,1] \to [0,1]$ are continuously differentiable and increasing functions, i.e., their derivatives $f \triangleq F'$ and $g \triangleq G'$ are continuous on $[0,1]$ and positive almost everywhere.

[6] A situation where $p \geq r$ implies that the sharing market is inactive.

[7] In practice, there may be supply-demand imbalances [27, 37].

[8] The equilibrium, although sensitive with respect to the exact timing of the actions in each period (which determines the retailer's commitment ability), is robust in the sense that subgame perfection avoids noncredible threats and in our model leads to a unique strategy profile in equilibrium.

[9] Equivalently, in terms of the outcome of the supergame, the retailer could specify the retail price at the initial time $t = 0$, given sufficient ability to commit to this choice.

[10] The case where $r \in (1, 1+\delta)$ is more complicated and has been omitted.

[11] The inverse-elasticity rule generalizes to nonconstant marginal costs, but this complication is omitted here.

[12] In the simultaneous-move regime, the retailer's best response is $BR(p) = (1 + \delta p + c)/2$, which together with the no-arbitrage response by the sharing market in Proposition 1 implies the expression for $r_{SMP}^*$.

[13] The precise interval of validity for $c$ is $[0, (12\ln(2) - 10)/(6\ln(2) - 7)] \approx [0, 0.5921]$.

[14] As pointed out by Weber [35], rather than being either "on" or "off," commitment can be viewed on a continuum. Since $\hat{r}^*$ is bracketed by the retail prices with sharing for the two extreme commitment regimes, the retail price without sharing corresponds to a certain limited level of commitment by the retailer in the presence of a peer-to-peer economy. The relevant homotopy arguments are familiar in optimization theory [17] and have also been applied in the information-systems literature [39].

[15] The total consumer surplus is the present value of the per-period consumer surplus taken in perpetuity; by the geometric-series formula, for any given discount factor $\delta \in (0,1)$, the former and the latter are related by a proportionality factor of $1/(1-\delta)$.

[16] This follows from Proposition 1 and Corollary 2.

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