The Limits of Planned Obsolescence for Conspicuous Durable Goods

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An extensive body of literature argues for the benefits of planned obsolescence, the strategy of designing products with low durability to induce repeat purchases from the consumers, and allow the firm to sell a larger volume. Yet, several firms avoid planned obsolescence and instead offer products with high durability. In this paper, we offer a demand-side rationale for a high-durability product design strategy: the exclusivity-seeking consumer behavior associated with conspicuous consumption. In the presence of consumers who value exclusivity, we find that firms benefit from designing products with higher durability in conjunction with a high-price, low-volume introduction strategy. A higher durability in such a context leads to greater resale value, allowing the firm to charge a higher price and lower the sales volume to achieve the product exclusivity valued by the consumers. This contrasts with the planned obsolescence strategy that capitalizes on the high sales volume achieved by setting a low new product price. We also show that offering higher durability and charging a higher price are complementary levers to respond to consumers who value exclusivity. Our analysis unearths insights regarding the effect of exclusivity-seeking behavior on a firm's demand and pricing. We show that firms' durability choice may explain the joint increase in price and demand for conspicuous goods.

Key words: Durable products; Product design; Product obsolescence; Exclusivity-seeking consumers; Demand externalities

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1. Introduction and Related Literature

Planned obsolescence is a well-established strategy utilized by firms selling durable products, where they design products of low durability that are characterized by rapidly diminishing consumer value over time. The adoption of planned obsolescence dates back to the early 1900's, when Dupont reduced the durability of early versions of nylon stockings to induce replacement (Slade 2006). Xerox and Kodak lowered the durability of products such as photocopiers and micrographic equipment by designing their core components to become obsolete faster (Borenstein et al. 1995). Planned obsolescence still remains a popular strategy in practice (The Economist 2009). A large body of academic literature provides support for this practice (see Waldman 2003 for an overview).

Yet, some firms eschew planned obsolescence in favor of a high durability strategy. For example, BMW ensures the high durability of its products with a combination of design choices, free maintenance services and extended warranty for the first four years (BMW 2008), and even promotes this feature using the tagline "holds its value like it holds a corner" (BMW 2012). Similarly, the Swiss watch manufacturer Patek Philippe designs high durability products (Patek Philippe 2012a) and advertises: "You never actually own a Patek Philippe, you merely look after it for the next generation" (Patek Philippe 2012b). We observe that these products are *conspicuous* in nature, i.e., their ownership and use is public. Prior research in social psychology has established that for such products, consumers may exhibit a desire for *exclusivity* - the more consumers own a product, the less value each derives from owning it (Worchel et al. 1975, Snyder and Fromkin 1977, Lynn 1991, Snyder 1992, Simonson and Nowlis 2000, Tian and Hunter 2001); a "BMW in every driveway" dilutes the value of the car (cf., Bagwell and Bernheim 1996). The seminal work of Leibenstein (1950) dubs exclusivity-seeking consumers as "snobs." In this paper, we pose the following question: Does exclusivity-seeking or snobbish consumer behavior help explain why firms adopt high-durability product design strategies for conspicuous products?

The effect of exclusivity-seeking consumer behavior on whether the firm prefers high durability vs. planned obsolescence is not straightforward. A key factor is the dependence of the consumers' utility on the total number of consumers who own a product (i.e., the level of product exclusivity). Consider the impact of planned obsolescence on product exclusivity. Planned obsolescence limits the trade on the secondary market, preventing the product from being traded to lower-valuation consumers, thereby limiting total ownership, and maintaining its exclusivity. This suggests that planned obsolescence should continue to be attractive in the presence of snobs. On the other hand, planned obsolescence leads to a lower new product price and higher new product sales. This may lead to more consumers owning the product, and this drop in exclusivity may hurt the firm's profits. Overall, therefore, it is not clear whether planned obsolescence is the optimal design choice in the presence of snobbish consumers. We shed light on this question by analyzing a firm's joint durability and pricing decisions in the presence of snobs. To the best of our knowledge, this is the first work to address durability choice in the context of conspicuous consumption.

A body of literature in operations investigates how a firm's decisions are influenced by different consumer behavioral traits such as forward-looking or strategic consumers (Su 2007, Cachon and Swinney 2009, Su and Zhang 2009), social comparisons (Roels and Su 2014), hyperbolic discounting (Plambeck and Wang 2013), mental accounting (Erat and Bhaskaran 2012), and procrastination (Wu et al. 2014) (see Netessine and Tang 2009 for an overview). An emerging stream in this literature examines the effect of snobbish consumer behavior on a firm's production, rationing and pricing decisions (Tereyağoğlu and Veeraraghavan 2012, Arifoğlu et al. 2012). We contribute to this literature by analyzing a firm's new product introduction strategy in the presence of snobbish and forward-looking consumers. Another stream of literature in operations investigates pricing in service systems with congestion (see Hassin and Haviv 2003, Randhawa and Kumar 2008, Anand et al. 2011, Cachon and Feldman 2011, and references therein). The effect of congestion is similar to snobbish consumer behavior in that as more consumers join the system, they derive lower utility. This literature focuses on pricing and capacity as two primary levers to regulate consumer decisions under congestion (see Hassin and Haviv 2003). To affect consumer purchase behavior for conspicuous durable goods, product design becomes relevant. In this paper, we provide an in-depth analysis of durability choice in the presence of snobbish consumers.

Our paper is also related to the literature in operations that studies how a firm's choice of quality, i.e., the value of the product to the customers, is influenced by product line and architecture decisions (Kim and Chhajed 2002, Heese and Swaminathan 2006, Krishnan and Zhu 2006, Netessine and Taylor 2007, Agrawal and Ülkü 2013), supply chain structure and decentralization (Xu 2009, Shi et al. 2013, Kim and Swinney 2013), capacity investments (Chayet et al. 2011), and environmental regulation (Chen 2001, Plambeck and Wang 2009). This stream of literature mostly focuses on non-durable products and does not consider snobbish consumer behavior. We contribute to this stream of literature by studying the effect of snobbish consumer behavior on durability choice, a design decision that also influences the customers' value for the product.

There is an extensive literature in social psychology that identifies the existence of exclusivity-seeking consumer behavior and examines how these behaviors impact purchasing (Snyder and Fromkin 1977, Lynn 1991, Snyder 1992, Simonson and Nowlis 2000, Tian and Hunter 2001). However, this literature does not focus on how exclusivity-seeking consumer behavior influences the demand at the aggregate level or the decisions of a firm. In marketing, Corneo and Jeanne (1997), Amaldoss and Jain (2005a,b) investigate the effect of a firm's pricing decisions on the aggregate demand in the presence of snobbish consumer behavior. These papers focus on non-durable products, and therefore do not consider durability choice. Our results offer an alternative explanation for the unconventional price-demand relationship discussed in the context of conspicuous consumption, namely that price and demand may be observed to jointly increase: Amaldoss and Jain (2005a) show that both snobs and followers (i.e., conformity-seeking consumers) must coexist for price and demand to jointly increase for a non-durable product. We show that this joint increase may take place due to the change in the underlying durability choice of the firm as long as some snobbish consumers are present. In a recent paper that is closest to our work, Rao and Schaefer (2013) examine a firm's pricing decisions for a durable product in the presence of snobbish consumer behavior. They show that a higher quality indirectly leads to greater exclusivity through pricing. However, they do not examine the firm's durability choice and instead assume the product is perfectly durable. In addition, they do not consider the presence of a secondary market, which is critical to the firm's durability choice and its incentive to practice planned obsolescence. We explicitly investigate the firm's durability choice in the presence of snobbish consumers and incorporate a secondary market in our analysis.

An established body of work discusses the benefits of planned obsolescence (see Waldman 2003 and references therein). An early stream of papers in this literature compared the durability choice of a monopolist with that of a firm in a perfectly competitive market (Kleiman and Ophir 1966, Levhari and Srinivasan 1969, Swan 1970, Goering 1992). These papers find that a monopolist will produce a product with lower durability than the competitive firm. Muller and Peles (1990) extend this stream of literature by examining this question in a dynamic context and show that the optimal durability decreases over time. Another stream of papers in this literature focus on investigating whether a monopolist firm has an incentive to practice planned obsolescence (Bulow 1986, Hendel and Lizzeri 1999b). A fundamental insight from this literature is that when a firm does not control the secondary market or cannot eliminate it by a mechanism such as leasing, it benefits from lowering product durability to reduce the cannibalization of new products by used products. As summarized by Waldman (2003) (p. 138), "The general point is that a durable goods producer with market power wants to lower the quality of the used units.... One way to achieve this is by reducing the physical quality of the product by reducing the durability built into new units." In other words, planned obsolescence is the strategy of choice for a durable goods monopolist.

Our key contribution is to show that this well-established strategy is ill-suited for conspicuous durable goods where exclusivity-seeking behavior matters. We develop a durable goods monopolist model closely aligned with the existing literature, and verify that, even when durability is costless, the firm prefers to practice planned obsolescence in the absence of snobbish consumer behavior. However, when snobbish consumer behavior exists in the market, this result is reversed and the firm instead adopts a high durability strategy because of the demand-side effects that snobbishness introduces. In particular, we identify the strength of the resale value response to a change in durability as the primary mechanism at work. We describe this fundamental mechanism and show that it is robust to different modeling choices for snobbishness. When durability is costly, planned obsolescence may persist even under snobbish behavior, but only when this supply-side effect (cost of durability) is sufficient to dominate the resale value response effect. Our results also show that offering higher durability and charging a higher price are complementary levers in the presence of snobbish consumer behavior. In sum, our analysis uncovers the limitations of planned obsolescence for conspicuous products and offers theoretical support for the existence of high durability strategies in practice. Moreover, our analysis identifies a new product introduction strategy specific to conspicuous durable goods: a low-volume, high-price strategy that relies on the resale value effect to drive profit, rather than the repeat purchase effect highlighted by the extant literature.

2. The Model

We model the problem as a discrete-time, infinite-horizon game, where the firm and consumers move sequentially in each period. The firm is a profit-maximizing monopolist who introduces a durable product in every period. The quality of a new product is fixed and without loss of generality, normalized to one. We discuss the effect of product quality on the firm's durability choice in §4. Each product has a maximum useful lifetime of two periods and depreciates with use. Consumers that purchase the product derive utility from two different factors: consumption and exclusivity. Consumers' valuations are heterogeneous along both these dimensions.

Consumption utility is θ for a new product and $\delta\theta$ for a used product, where θ is the per-period consumer valuation for product quality and θ is uniformly distributed in $[0,1]$. Here $\delta \in [0,1]$ represents the product durability (Desai and Purohit 1998), where $\delta = 0$ represents a product that only lasts for one period, whereas $\delta > 0$ implies that the product lasts for two periods and the depreciation after one period of use is $1 - \delta$. Thus, we have a vertical differentiation model, where ceteris paribus, every consumer (weakly) prefers a new product over a used product, i.e., $\delta\theta \leq \theta$. This allows us to formally define planned obsolescence as $\delta = 0$, which renders the useful life of the product to be just one period. Without loss of generality, the size of the market is normalized to one. A consumer uses at most one product in a given period.

Utility from exclusivity is given by $-\lambda Q_e$, where Q_e is the expectation of the total volume of products in use by consumers in that period, and $\lambda \geq 0$ represents a consumer's sensitivity to exclusivity (or "snobbishness") (cf., Amaldoss and Jain 2005a,b). $-\lambda Q_e$ decreases in Q_e and consequently captures exclusivity-seeking behavior, i.e., a consumer experiences a greater disutility from the same product as more consumers own it. Modeling the consumers' valuation for product exclusivity through a linear negative externality is consistent with a dating or a matching scenario as in Balachander and Stock (2009), and yields similar insights as a model where product exclusivity yields a positive benefit as in Pesendorfer (1995) and Rao and Schaefer (2013) (see §4 for a detailed discussion). This specification also makes the implicit assumption that consumers are equally sensitive to the presence of new and used products. Our findings are valid even if we relax this assumption (see the discussion in §4 for details).

We model heterogeneity in consumers' sensitivity to product exclusivity as follows: A fraction $\beta \in [0,1]$ of the consumers (independent of θ) have sensitivity to product exclusivity (or snobbishness) $\lambda_h > 0$; the rest have lower sensitivity λ_l, where $0 \leq \lambda_l \leq \lambda_h$. Consumers with $\lambda_l = 0$ are referred to as indifferent consumers.

Putting the two components of consumer utility together, the per-period gross utility of consumer type θ of snobbishness λ from using a new product in period t is given by $u_n^t(\theta, \lambda, Q_e^t) = \theta - \lambda Q_e^t$ and that from a used product in period t is given by $u_u^t(\theta, \lambda, Q_e^t) = \delta^{t-1}\theta - \lambda Q_e^t$. The consumers are forward-looking and form perfect expectations of price and product durability in the future. Finally, the analysis uses a rational expectations framework where each consumer has the same expectation about the volume of products in use (Q_e) and this expectation is correct in equilibrium.

2.1 Sequence of Events and Specification of the Game

The firm first chooses the durability (δ^t), followed by the price of a new product (p_n^t) in every period. The firm determines the durability of the product through the design process, which involves several actions such as using higher performance components, more durable materials, more reliable interfaces between those components, or better production equipment (Saleh 2008). A product with higher durability requires a higher per-unit cost of production, denoted by $c(\delta) = c\delta^2$, where $c'(\delta) \geq 0$.

Observing the firm's pricing and durability decisions, the consumers form rational expectations regarding the total volume of consumers who will own the product, and make their purchasing decisions (cf., Amaldoss and Jain 2005a,b, Balachander and Stock 2009). We assume that the firm can commit to its pricing decision before the consumers make their purchasing decisions (cf., Desai and Purohit 1998, Hendel and Lizzeri 1999b). Our main results continue to hold if we relax this assumption (see §A4 in the online supplement for details).

At the end of every period, consumers who own a product that still has useful life left may choose to sell the used product on the secondary market and purchase a new one. Since there is typically a large number of individual sellers and buyers in the secondary market, we assume that the secondary market is competitive and the resale value of a used product is given by the market-clearing price p_u^t. Note that although the firm does not have direct control of the secondary market, it can indirectly influence it through the product durability and the price of the new product.

We restrict our attention to rational expectations, stationary equilibria, where $p_n^t = p_n$ and $\delta^t = \delta$ (cf., Debo et al. 2005, Plambeck and Wang 2009). This allows us to rule out transient effects due to only new products being present in the first period. The time inconsistency effect is not present in our model since we consider a product with finite durability in an infinite-horizon setting (Huang et al. 2001). Nevertheless, our qualitative insights can be shown to hold under a two-period model where time inconsistency is present (see §A3 in the online supplement for details). We also assume that all information regarding the cost structures and preferences are common knowledge, and all players have a common discount factor $0 < \rho < 1$. In order to eliminate the uninteresting cases where the business is never profitable for the firm, we assume $c(\delta) < 1 + \rho\delta$.

3. Analysis and Results

In order to analyze our model, we solve for the subgame perfect equilibrium of the game by using backward induction. We begin by focusing on the setting where the firm faces homogenously snobbish consumers in §3.1 for the sake of expositional clarity. Subsequently, we generalize to the heterogenous snobbishness setting in §3.2.

3.1 Homogenous Snobbishness

In order to focus on the setting with homogenous snobbishness, let $\lambda_h = \lambda_l = \lambda$. For a given expectation of the total volume of products in use and the price of the new product, there are at most three undominated consumer strategies (cf. Hendel and Lizzeri 1999a): In decreasing order of the consumer type θ that adopts them, always buy a new product and sell the used product on the secondary market, always buy a used product from the secondary market, and do not purchase either product (see §A1 in the online supplement for details).

The market-clearing price for used products p_u is determined by equating the supply and demand for used products. Aggregating over consumer types that adopt each strategy yields the new product demand $D_n(p_n, \delta; Q_e)$, the used product demand $D_u(p_n, \delta; Q_e)$, and the total volume of products in use $D(p_n, \delta; Q_e) = D_n(p_n, \delta; Q_e) + D_u(p_n, \delta; Q_e)$. For a rational expectations equilibrium, we require that consumer expectations about the volume of products in use are correct in equilibrium, i.e., $D(p_n, \delta; Q_e) = Q_e$. Let $D(p_n, \delta)$ and $D_n(p_n, \delta)$ denote the equilibrium quantities for the total volume of products in use and the new product demand, respectively. It can be shown that there exists a unique rational expectations equilibrium for the total volume of products in use, which is given by $D(p_n, \delta) = \frac{2(1-p_n+\rho\delta)}{1+\delta+2\rho\delta+2(1+\rho)\lambda}$ (see §A2 in the online supplement for details).

We next analyze the firm's pricing strategy that maximizes its profits for a given durability level δ. Under stationarity, the firm's problem reduces to $\max_{p_n \geq 0} \Pi(p_n, \delta) = (p_n - c(\delta)) D_n(p_n, \delta)$, where $\Pi(p_n, \delta)$ is the firm's per-period profit for a given product durability and new product price. Let the optimal price for a given δ be denoted by $p_n^*(\delta)$, and $\widetilde{\Pi}(\delta) \doteq \Pi(p_n^*(\delta), \delta)$ and $\widetilde{D}_n(\delta) \doteq D_n(p_n^*(\delta), \delta)$ denote the profit and new product demand evaluated at this price, respectively.

PROPOSITION 1. *For a given product durability δ,*

i. $\widetilde{D}_n(\delta)$ weakly decreases in consumer snobbishness λ.

ii. $p_n^*(\delta)$ increases in δ and is independent of λ.

iii. $\widetilde{D}_n(\delta)$ is increasing in δ if and only if $\rho > c'(\delta)$ and $\lambda > \widetilde{\Lambda}(\delta)$, where $\widetilde{\Lambda}(\delta) > 0$ and $\widetilde{\Lambda}'(\delta) > 0$.

iv. When $\widetilde{D}_n(\delta)$ decreases in δ, the decrease in the new product demand is lower for higher consumer snobbishness ($d^2\widetilde{D}_n(\delta)/d\delta d\lambda \geq 0$).

As expected, the demand for the new product decreases as consumers become more snobbish (i) because the externality they face increases, decreasing their net utility from owning a product. The new product price is increasing in δ (ii) because a higher durability product offers greater utility to consumers purchasing a new product due to its higher resale value. Substituting $\lambda = 0$ in (iii), we see that in the absence of snobbish consumer behavior, the new product demand decreases in durability. This is consistent with the existing literature (Waldman 2003). A revealing finding in Proposition 1 (iii) is that in the presence of snobbish consumer behavior ($\lambda > 0$), the new product demand increases in durability, provided consumers are sufficiently forward-looking ($\rho > c^{'}(\delta)$), and sufficiently snobbish ($\lambda > \widetilde{\Lambda}(\delta)$). Even when the demand decreases in durability, its rate of decrease is moderated by λ (iv).

This contrast stems from the combination of three different effects that a more durable product has on a consumer's net utility from owning a new product ($\theta - p_n^*(\delta) + \rho p_u^*(\delta,\lambda) - \lambda Q^e$) as opposed to a used product ($\delta\theta - p_u^*(\delta,\lambda) - \lambda Q^e$), i.e., $(\theta - p_n^*(\delta) + \rho p_u^*(\delta,\lambda) - \lambda Q^e) - (\delta\theta - p_u^*(\delta,\lambda) - \lambda Q^e) = \theta(1-\delta) - p_n^*(\delta) + p_u^*(\delta,\lambda)(1+\rho)$. First, the drop in the intrinsic utility from owning a used product instead of a new product $\theta(1-\delta)$ decreases in δ. In other words, a used product is a closer substitute for the new product when the durability is higher. Second, the firm charges a higher new product price for a more durable product, i.e., $p_n^*(\delta)$ is increasing in δ. Third, the resale value $p_u^*(\delta,\lambda)$ is higher for a more durable product. The first two effects exert a negative pressure on the new product demand, while the third has the opposite effect.

In the absence of snobbish consumer behavior, the former effects dominate the latter, and the new product demand decreases in durability. In the presence of snobbish consumer behavior, the magnitude of the first two effects is independent of the consumer snobbishness level. However, the third effect becomes stronger as the consumer snobbishness increases, i.e., as the consumers become more snobbish, the increase in the resale value due to higher durability is larger ($d^2 p_u^*(\delta,\lambda)/d\delta d\lambda > 0$). The reason for this is as follows: As the snobbishness level λ increases, the externality faced by consumers increases, decreasing their net utility from owning a product. Consequently, only the consumers who have sufficiently high valuations θ purchase a new or a used product, i.e., the covered market shifts to the higher end. This implies that the marginal consumer who dictates the market-clearing price is a higher θ consumer and therefore, has a more pronounced increase in its intrinsic utility $\delta\theta$ from an increase in δ. Consequently, for a higher snobbishness level, there is a greater increase in the resale value in response to an increase in durability. When the snobbishness level is sufficiently high, the increase in the resale value is sufficiently large to dominate the first two effects, and a higher durability leads to an increase in the demand in conjunction with a price increase. When the snobbishness level is low, the consequence of this resale value response is to slow down the rate of decrease in demand as λ increases.

Amaldoss and Jain (2005a) show that both snobs and followers (i.e., conformity-seeking consumers) must coexist for price and demand to jointly increase for a non-durable product. Our result shows that this effect can be observed for durable products even in the absence of followers, and is attributed to the resale value response in the secondary market, which is unique to the context of durable products.

We now analyze the firm's optimal product durability δ^* that maximizes the firm's profit, i.e., we solve $\max_{0\leq\delta\leq 1}\widetilde{\Pi}(\delta)$. Recall that the firm is said to practice planned obsolescence when it offers a non-durable product, i.e., $\delta^*=0$. For the rest of our analysis, we assume no discounting, i.e., $\rho=1$. This simplifies our expressions and helps us to obtain analytical results for the design strategy. Nevertheless, it can be shown that $\rho<1$ provides similar qualitative insights.

To establish a benchmark and relate to the existing literature on durable goods, we first consider the setting where consumers are not snobbish, i.e., $\lambda=0$.

PROPOSITION 2. *If $\lambda=0$, then the firm practices planned obsolescence ($\delta^*=0$).*

The above proposition shows that in the absence of snobbish behavior, the firm prefers to practice planned obsolescence by making the product non-durable. The reason for this is as follows: As discussed in Proposition 1, in the absence of snobbish behavior, the demand for new products decreases with product durability. This negative volume effect on profit is significant enough to dominate the positive price effect from higher durability. Therefore, the firm prefers to offer a non-durable product. This result is similar to that from the literature on durable goods in economics, which discusses that the firm has an incentive to practice planned obsolescence by reducing the product durability to reduce the substitution between new and used products (cf. Waldman 2003, pg. 138). It is also the same as that can be obtained by solving for the profit-maximizing durability in the model of Desai and Purohit (1998).

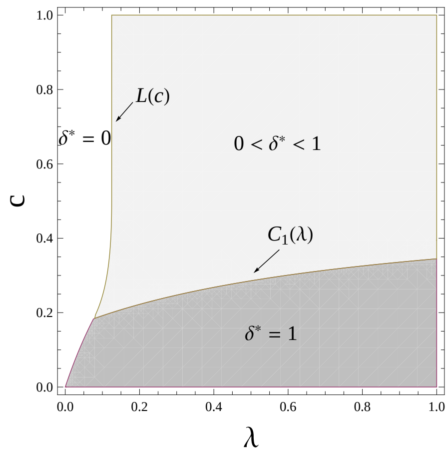
Next we account for the effect of snobbish consumer behavior on the firm's durability choice and show that planned obsolescence may be suboptimal.

PROPOSITION 3. *$\delta^*>0$ if and only if $\lambda>L(c)$, where $L(c)$ is increasing in c and $L(0)=0$.*

As stated in Proposition 3 and illustrated in Figure 1, the firm still practices planned obsolescence when the consumers' snobbishness is below a threshold, i.e., $\lambda\leq L(c)$. To understand what drives this result, we consider the implications of increasing durability on the firm's margin and demand. Recall from Proposition 1 that the demand can increase or decrease in the durability. In particular, when consumer snobbishness is low ($\lambda\leq\widetilde{\Lambda}(\delta)$), the new product demand is monotonically decreasing in durability. Otherwise, the demand first increases and then decreases in the durability, where the increase in the demand is due to the resale value response as discussed before.

It can be shown that the margin $p_n(\delta)-c(\delta)$ locally increases in δ at $\delta=0$. When the consumer snobbishness is low, the demand is locally decreasing at $\delta=0$ but at a faster rate, resulting in the profit to also decrease locally. In fact, we can show that the profit in this case is convex with another local optimum at $\delta=1$. The firm is in effect choosing between two locally optimal strategies: $\delta=0$ – a low-price, high-volume strategy, and $\delta=1$ – a high-price, low-volume strategy. The negative

Figure 1 Design strategy in the presence of homogenously snobbish consumers ($\lambda_h = \lambda_l = \lambda$).



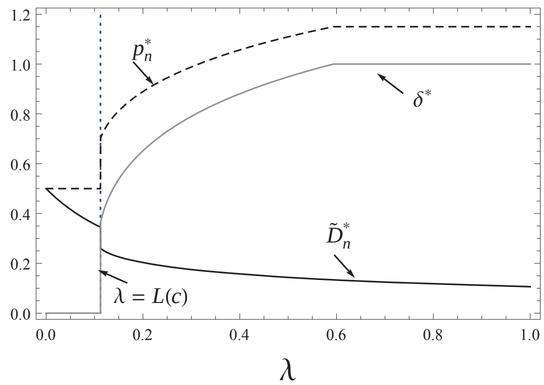
Note. In panel (a), offering a durable product is optimal in the gray and black regions (defined by $\lambda > L(c)$), with maximum durability $\delta^* = 1$ in the black region (where $c < C_1(\lambda)$ holds) and $0 < \delta^* < 1$ in the gray region.

externality due to snobbish consumer behavior favors the low-volume strategy except when cost is prohibitive. This can be observed in Figure 1 where for low λ, $\delta^* = 1$ for low cost of durability and 0 otherwise. In contrast, when the consumer snobbishness is high, the demand is locally increasing at $\delta = 0$ due to the resale value response discussed earlier, resulting in the profit to increase locally. Consequently, $\delta^* > 0$, i.e., the firm prefers to offer a durable product if the consumers are sufficiently snobbish. This is clearly driven by the way in which consumer snobbishness shapes the demand change in response to an increase in durability.

Proposition 4. *In equilibrium, the optimal durability δ^* and the new product price $p_n^*(\delta^*)$ (weakly) increase in the consumer snobbishness λ, and the new product demand $\widetilde{D}_n(\delta^*)$ strictly decreases in λ.*

Proposition 4 and Figure 2 illustrate the firm's new product introduction strategy in the presence of snobbish consumers. Recall that as consumers become more snobbish, the negative externality increases, which has a negative impact on the firm's profits. The firm would like to moderate the higher negative externality by making the product more exclusive. The firm can do so by offering a more durable product and charging a higher price. However, this is not optimal when the consumer snobbishness is sufficiently low ($\lambda \leq L(c)$) and both durability and price remain unchanged as λ increases. As the consumer snobbishness increases beyond $L(c)$, the firm begins to utilize durability as a lever to moderate the negative effect of a higher λ, until maximum durability. Increasing the product durability is costly, but consumers are also willing to pay a higher price for the product (due to a higher resale value). This enables the firm to increase the price to exploit this additional value. In fact, the firm has an additional reason to increase the price: it makes the product more exclusive. If the firm increased its price to only exploit the additional value inherent in a more durable product, one would expect the demand to remain unchanged. However, the new product demand strictly decreases with increased consumer snobbishness, implying that the firm increases the new product price further to benefit from the value of a more exclusive product. Thus, the main insight emerging from these results is that offering higher durability and charging a higher price are complementary levers to moderate the negative effect of an increase in the consumer snobbishness.

Figure 2 **New Product Introduction Strategy in the presence of homogeneously snobbish consumers ($\lambda_h = \lambda_l = \lambda$).**



Note. In the above figure, $c(\delta) = 0.3\delta^2$. Durability δ^* and new product price p_n^* weakly increase in λ and the new product demand $\widetilde{D}_n$ decreases in λ.

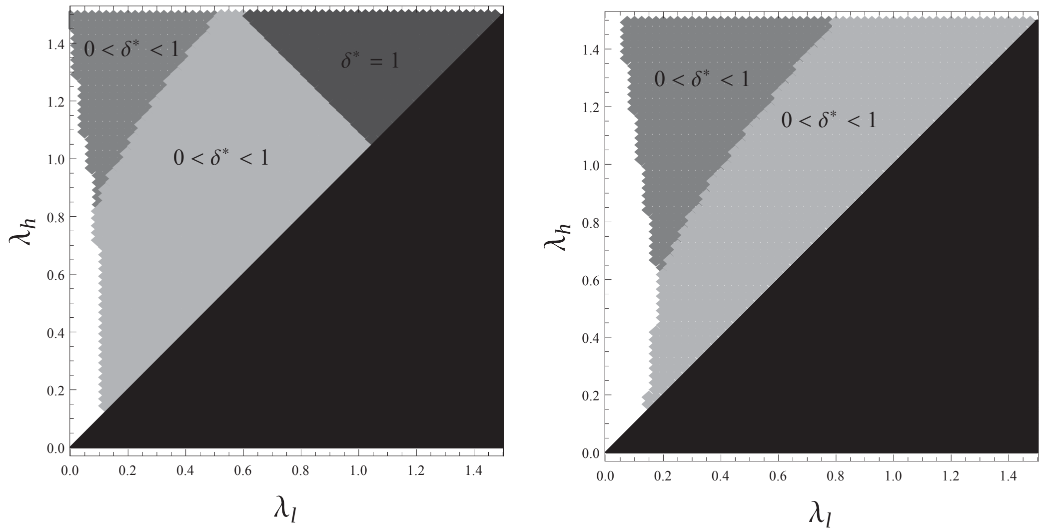
3.2 Heterogeneous Snobbishness

We next analyze the firm's design strategy in the presence of heterogeneously snobbish consumers (i.e., $\lambda_h > \lambda_l \geq 0$). We denote the expression $2(1-\beta)(\lambda_h - \lambda_l)$ by $\bar{d}$, which can be interpreted as a heterogeneity measure with respect to exclusivity-seeking behavior: The more unbalanced the mix and the larger the difference in snobbishness, the larger the value of $\bar{d}$. There exists a unique rational expectations equilibrium for the total volume of products in use, which is characterized as follows when $c(\delta) < 1 + \rho\delta$ (the condition for the business to be profitable):

$$D(p_n, \delta) = \begin{cases} \frac{2(1-\beta)(1-p_n+\rho\delta)}{(1-\beta)(1+\delta)+\rho\delta(2-\beta-\beta\delta)+2(1-\beta)(\beta\lambda_h(1+\rho\delta)+\lambda_l(1-\beta+\rho(1-\beta\delta)))} & \text{if } 0 \leq \delta \leq \bar{d}, \\ \frac{2(1-p_n+\rho\delta)}{1+\delta+2\rho\delta+2(1+\rho)(\beta\lambda_h+(1-\beta)\lambda_l)} & \text{if } \bar{d} < \delta \leq 1. \end{cases}$$

There is demand for the new product from both the more and less snobbish consumers for all δ. Both segments buy the used products if and only if $\delta > \bar{d}$. Otherwise, the more snobbish consumers do not purchase a used product. The reason for this is as follows: As the fraction of the less snobbish consumers grows (β decreases) or they become less snobbish (λ_l decreases), more of them purchase

Figure 3 Design and product introduction strategy in the presence of heterogeneous consumer snobbishness ($\lambda_h > \lambda_l \geq 0$).



(a) $c = 0.35$ (b) $c = 0.5$

Note. In both panels, $\beta = 0.5$ and the black region represents the parameter region ($\lambda_l \geq \lambda_h$) that is not valid in our model. Planned obsolescence ($\delta^* = 0$) is optimal in the white region. When $0 < \delta^* < 1$, both consumer types own a used product in the light gray region, but only the less snobbish consumers own a used product in the gray region. When $\delta^* = 1$ (the dark gray region), both types own a used product.

a product and therefore, the volume of products in the market increases. A higher total volume increases the negative externality. If this effect is strong enough, i.e., $\bar{d} > \delta$, the net utility of the more snobbish consumers decreases to the point that they abstain from the secondary market.

The structural results discussed in Proposition 1 hold for the heterogenous setting (the proof in §A2 in the online supplement is for this general setting). Analytically characterizing δ^* when $c > 0$ and $\lambda_l \neq \lambda_h$ is intractable, but we can analyze the case where durability is costless ($c = 0$).

PROPOSITION 5. *If $\lambda_h > \lambda_l \geq 0$ and providing durability is costless ($c = 0$), then $\delta^* = 1$.*

Recall that in the absence of snobbish consumer behavior, planned obsolescence is optimal. The above proposition shows that this result is also reversed for any degree of heterogeneity in consumer snobbishness when durability is costless. In addition, we observe consumer self segmentation in the following manner: When $\bar{d} > 1$, the more snobbish consumers do not purchase a used product because $\delta^* < \bar{d}$ holds. Otherwise, both types of consumers purchase a used product.

Figure 3 demonstrates the results regarding the firm's design choice for the heterogenous case when durability is costly: The firm chooses planned obsolescence only when the snobbishness of both consumer types is sufficiently low. Otherwise, the firm prefers to offer a durable product. When the consumer snobbishness levels are high, the firm may even choose to offer a perfectly durable product ($\delta^* = 1$). In addition, Figure 3 depicts the resulting consumer self segmentation: When the firm chooses $\delta^* > 0$, both consumer types purchase the used products only if the heterogeneity in their snobbishness is low, i.e., λ_h and λ_l are not too different (light gray region). On the other hand, when the heterogeneity is high (large λ_h and low λ_l), the more snobbish consumers do not purchase a used product. Therefore, as heterogeneity increases, the less snobbish consumers have a greater influence on the firm's decisions, leading to lower durability. Finally, the effect of durability cost can be observed by comparing the two panels in Figure 3. It can be seen that as the cost increases, planned obsolescence becomes more attractive and the region where the firm chooses planned obsolescence increases. The region where both types of consumers own a used product (light gray region or $\delta > \bar{d}$) shrinks at the expense of the region where only the less snobbish consumers own a used product (gray region or $\delta \leq \bar{d}$).

4. Extensions and Discussion of Assumptions

Our model captures snobbish consumer behavior through an exogenous, linear externality, and assumes that the sensitivity to the exclusivity is the same for new and used products. We now discuss the implications of relaxing these assumptions.

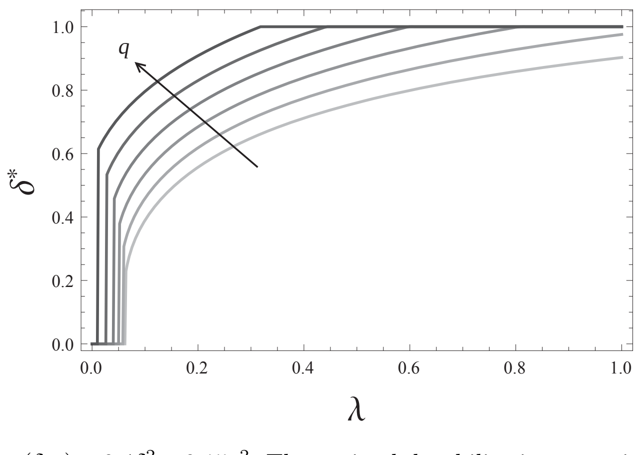
Robustness of the linear negative externality assumption. We can endogenize the externality by accounting for the underlying phenomena that lead to such consumer behavior. For example, we can consider a matching or dating scenario as in Balachander and Stock (2009) (also see Pesendorfer 1995), where a consumer is randomly matched with another consumer and incurs a disutility from being matched with a consumer who owns the same product. The expected disutility of a consumer θ is given by $\lambda\widetilde{p}$, where $\widetilde{p}$ is the probability of meeting another consumer who owns the same product. Since Q_e is the total number of consumers who own the product and the total number of consumers in the market is 1 in our model, $p = Q_e/1$, yielding a linear negative externality.

Alternatively, we can also consider a framework where product exclusivity yields a positive benefit to consumers (cf., Pesendorfer 1995, Rao and Schaefer 2013). Consider a model where the utility from exclusivity is given by $+\lambda(1-Q_e)$. A consumer enjoys a positive benefit λ if no other consumer owns the product (i.e., $Q_e = 0$) and there is no benefit due to the exclusivity if all consumers own the product (i.e., $Q_e = 1$). Note that this model also exhibits a linear utility loss in volume, similar to our analysis, but is a positive term in the consumers' utility. For this alternative model, our case with heterogenous snobbishness is analytically intractable, therefore we focus on the results for the homogenous snobbishness case. Our results in Proposition 1 (ii) and (iii) change slightly. Under this alternative model, the new-product price increases in λ and the new-product demand decreases in δ. Nevertheless, we find that our main results in Propositions 2-4 regarding the firm's durability choice hold (details available on request). That is, when consumers are not snobbish, the firm prefers planned obsolescence. However, the firm prefers to offer a durable product when the consumer's snobbishness level is above a threshold. In addition, the optimal durability and the new product price are increasing in λ and the new product demand strictly decreases in λ.

Differential in the sensitivity to the exclusivity of new and used products. In our analysis, we assume that the consumers are equally sensitive to the presence of other consumers who own the new product versus those who own a used product. We can extend our model to relax this assumption: Consider the setting where the sensitivity of a consumer to the used and new products is different and denoted by λ_u and λ_n, respectively. The externality is then given by $\lambda_u D_u^e + \lambda_n D_n^e$, where D_u^e and D_n^e are the consumers' expectations of the total volume of used and new products in use. Under stationarity, we have that $D_u^e = D_n^e = Q_e/2$. Thus, the externality is given by $Q_e(\lambda_u + \lambda_n)/2$, which can be rewritten as λQ_e, where $\lambda = (\lambda_n + \lambda_u)/2$. It is straightforward to then see that all our structural and qualitative insights hold in this setting.

Role of Product Quality. We now relax the assumption that the new product quality is normalized to one and examine its effect on the firm's durability choice. Let $q > 1$ denote the quality of a new product. The per-period gross utility of consumer type θ of snobbishness λ from using a new product is then given by $u_n(\theta, \lambda, Q_e) = q\theta - \lambda Q_e$ and that from a used product is given by $u_u(\theta, \lambda, Q_e) = \delta q\theta - \lambda Q_e$. We assume that the per-unit production cost is given by $c(\delta, q) = c\delta^2 + kq^2$. We focus on the case with homogenous snobbishness $\lambda_h = \lambda_l = \lambda$. We find that for a given durability, the new product demand and price are both increasing in the new product quality.

Figure 4 **The effect of product quality on the optimal durability δ^*.**



Note. In the above figure, $c = (\delta, q) = 0.4\delta^2 + 0.15q^2$. The optimal durability increases in the new product quality.

It is analytically intractable to investigate the effect of product quality on the optimal durability choice. Therefore, we conduct an extensive numerical analysis; a subset of the results from which are illustrated in Figure 4. We find that the optimal durability is increasing in the new product quality. The reason for this is as follows: The intrinsic consumption utility for a customer is increasing in the new product quality, which would imply a higher demand for the new product. The firm can moderate the higher negative externality by increasing the durability to make the product more exclusive. Therefore, the firm offers higher durability for a product with higher quality.

5. Conclusions

Articles in the academic literature and the business press have long argued for the benefits of a planned obsolescence strategy that induces consumers to make repeat purchases (Bulow 1986, Waldman 1996, Desai and Purohit 1998, Hendel and Lizzeri 1999b, Waldman 2003, The Economist 2009). While there are firms pursuing such planned obsolescence strategies in practice (Slade 2006), others take the opposite approach and emphasize the highly durable nature of their designs. We posit that the conspicuous nature of some product categories, where consumers value product exclusivity, may explain this dichotomy. To the best of our knowledge, this paper is the first to account for exclusivity-seeking behavior as an explanatory factor in firms' durable product strategies. Our results carry significant managerial implications along two dimensions:

Implications for design. We outline conditions that render a high-durability design strategy more profitable than the planned obsolescence strategy. As in the prior literature, we find that a firm should design products of low durability in the absence of exclusivity-seeking behavior. This explains the planned obsolescence strategy adopted by firms like Kodak or Xerox for products such as copiers or printers that are bought by consumers primarily based on their functionality and not exclusivity. However, for conspicuous products, the high-volume, low-price new product introduction strategy associated with planned obsolescence imposes an indirect cost because the consumer desire for exclusivity results in a utility loss due to the high volume. In a broad range of settings, designing a more durable product allows for a high-price, low-volume introduction strategy that maintains exclusivity and benefits the firm. This result provides theoretical support for some high durability strategies observed in practice (BMW 2008, NYT 2008, 2010).

Implications for demand and pricing. We offer a mechanism that explains the unconventional price-demand relationship that the price *and* demand increase jointly in the context of conspicuous consumption (cf. Amaldoss and Jain 2005a). We show that this is driven by the underlying durability choice made by firms. In other words, rather than treating this relationship as a property of certain product categories, we find that such ex-post observations may be attributed to the combined effect of the underlying durability choice and the exclusivity-seeking consumer characteristic. In particular, when consumers exhibit a high enough snobbishness, price *and* demand jointly increase in product durability. In the absence of exclusivity-seeking behavior, this effect does not exist; demand decreases in durability. This discussion highlights the importance of accounting for the different dimensions of consumer valuation and product durability in understanding the demand implications of pricing strategies.

Finally, our results advocate a need for greater alignment between product design choices and consumer behavior to increase the effectiveness of the product development process. They also reinforce the importance of focusing managerial attention on consumers earlier in the design process and using empathic design approaches to identify such latent behavioral traits (Leonard-Barton and Rayport 1997, Thomke and Von Hippel 2002, Business Week 2004).

We conclude with a discussion of directions for future research. An interesting direction of research is to empirically test the predictions from our model, which offer the following testable hypothesis: A firm offers higher durability products to consumers with higher snobbishness. One can carry out a field experiment by focusing on dealers that differ from each other based on the durabilities of cars they sell, and the treatment would be to have some dealers indicate low quantities of cars (which will serve as the more exclusive condition in the treatment). A difference-in-difference analysis on the final negotiated prices while controlling for the market, dealer, and other factors would reveal the consumers snobbishness. One can further extend this analysis by considering the heterogeneity in snobbishness in different markets as it may differ based on different demographic factors (such as occupational status, age, education, see Chao and Schor 1998). Finally, a comparison of the durability of cars for markets with different levels of snobbishness would show whether firms offer higher durability products to markets that have higher snobbishness in practice. Another approach would involve testing whether cars which are perceived to be more exclusive in practice have higher durability than other cars, using data on reliability ratings (Desai and Purohit 1998) or used car prices (Desai and Purohit 1999) as proxies of durability.

We also focused on the setting where a monopolist firm sells products directly to end consumers. However, some durable goods may be sold through a retailer (Bhaskaran and Gilbert 2009, 2014). A promising direction for future research is to consider the effect of snobs on the firm's durability choice in such a decentralized setting, or in the presence of competition between manufacturers (Desai and Purohit 1999). We focused on one dimension of product durability, i.e., the quality of the used product in this paper. It remains a future research direction to consider two different durability dimensions viz., usable and physical life, as in Koenigsberg et al. (2011). It may also be a promising direction to consider correlation between consumer valuations for quality and snobbishness to analyze how this influences the firm's durability choice. Another interesting direction for future research is to analyze a firm's new product introduction and design strategies in the presence of reference groups, i.e., where consumers experience a higher negative externality not only due to more consumers buying the same product, but also based on the identity of the consumers buying the product (Pesendorfer 1995, Amaldoss and Jain 2008).

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Online Supplement for The Limits of Planned Obsolescence for Conspicuous Durable Goods

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A1. Derivation of demand functions

We only need to consider two-period strategies because a product lasts only for two periods. Therefore, there are nine potential strategies: BNBN, BNBU, BUBN, BNX, XBN, BUX, XBU, BUBU, XX. Note that in our model, holding onto a used product is equivalent to selling the used product and buying it back. Therefore, under stationarity, the per-period net utility from purchasing a new product (BN) is $\theta - p_n + \rho p_u$, that from purchasing a used product (U) is $\delta\theta - p_u$, and from remaining inactive (X) is 0. The net utility from any of these actions is independent of the action in the previous period. Therefore, any strategy where a consumer chooses an action different than its action in the previous period is dominated. For example, a strategy where the consumer purchases a new product and continues to hold onto it for the next period is dominated (cf. Hendel and Lizzeri 1999, p. 1099-1100 for an intuitive explanation for this). This leaves only three potentially undominated strategies: BNBN (always buy a new product), BUBU (always buy a used product), and XX (never purchase a product). The net present values for these strategies are given by $\frac{\theta-\lambda_x Q_e - p_n + \rho p_u}{1-\rho}$ for consumers playing BNBN, $\frac{\delta\theta - p_u - \lambda_x Q_e}{1-\rho}$ for consumers playing BUBU, and 0 for consumers playing XX.

It is straightforward to see from the net present values that consumers who play BNBN will have higher θ than those who play BUBU, who have higher θ than those who play XX. Let the marginal consumer who is indifferent between BNBN and BUBU, BUBU and XX, be denoted by $\Theta_1(\lambda_x)$ and $\Theta_2(\lambda_x)$, respectively. Consumers in $\theta \in (\Theta_1(\lambda_x), 1]$ will always buy new products (BNBN), consumers in $\theta \in (\Theta_2(\lambda_x), \Theta_1(\lambda_x)]$ buy used products from the secondary market in every period (BUBU) and consumers in $\theta \in (0, \Theta_2(\lambda_x)]$ never purchase a product

(XX). Using the derived net present value functions, $\Theta_1(\lambda_x)$ and $\Theta_2(\lambda_x)$ can be found by solving $\frac{\Theta_1(\lambda_x)-\lambda_x Q_e-p_n+\rho p_u}{1-\rho} = \frac{\delta\Theta_1(\lambda_x)-p_u-\lambda_x Q_e}{1-\rho}$, and $\frac{\delta\Theta_2(\lambda_x)-p_u-\lambda_x Q_e}{1-\rho} = 0$, respectively. $\Theta_1(\lambda_x) = \frac{p_n-p_u(1+\rho)}{1-\delta}$ and $\Theta_2(\lambda_x) = \frac{p_u+\lambda_x Q_e}{\delta}$. Note that if $\Theta_2(\lambda_x) \geq \Theta_1(\lambda_x)$, then BUBU is dominated, leaving only BNBN and XX as the undominated strategies. Under this situation, the marginal consumer who is indifferent between BNBN and XX can be found by solving $\frac{\widetilde{\Theta}_1(\lambda_x)-\lambda_x Q_e-p_n+\rho p_u}{1-\rho} = 0$, and is given by $\widetilde{\Theta}_1(\lambda_x) = p_n - \rho p_u + \lambda_x Q_e$.

A2. Proofs

Proof of Proposition 1. We first begin by obtaining the rational expectations equilibrium for a given price and product durability for our general heterogenous case.

Θ_1 is independent of λ_x, and $\Theta_2(\lambda_x)$ & $\widetilde{\Theta}_1(\lambda_x)$ is increasing in λ_x. Let D_n denote the demand for new products and D_u^x denote the demand for used products, where $x \in \{l, h\}$. Then $D_u^h = \max(\beta(\Theta_1 - \Theta_2(\lambda_h)), 0)$, and $D_u^l = \max((1-\beta)(\Theta_1 - \Theta_2(\lambda_l)), 0)$. Since $\Theta_2(\lambda_x)$ is increasing in λ_x, we have that if $D_u^h > 0$, then $D_u^l > 0$ always holds. Therefore, we can have three different cases: a. $D_u^h, D_u^l > 0$ (or $\Theta_2(\lambda_l) \leq \Theta_2(\lambda_h) < \Theta_1$), b. $D_u^l > 0$ and $D_u^h = 0$ (or $\Theta_2(\lambda_l) < \Theta_1 \leq \Theta_2(\lambda_h)$), and c. $D_u^h = D_u^l = 0$ (or $\Theta_1 \leq \Theta_2(\lambda_l) \leq \Theta_2(\lambda_h)$).

First, consider the setting where $D_u^h, D_u^l > 0$, i.e., there is demand for used products from both the more snobbish and the less snobbish consumers. The aggregate volume of products in use is then given by $D(p_n, \delta; Q_e) = 1 - \Theta_1 + (1-\beta)(\Theta_1 - \Theta_2(\lambda_l)) + \beta(\Theta_1 - \Theta_2(\lambda_h))$. The market-clearing price under this setting can be found by solving $D_n = D_u^h + D_u^l$, and is given by $p_u = \frac{\delta(-1+2p_n+\delta)-Q_e(1-\delta)(\beta\lambda_h+(1-\beta)\lambda_l)}{1+\delta+2\rho\delta}$. Now consider the setting where $D_u^h = 0$ and $D_u^l > 0$, i.e., there is demand for used products only from the less snobbish consumers. $D(p_n, \delta; Q_e)$ is then given by $\beta(1-\widetilde{\Theta}_1(\lambda_h))+(1-\beta)(1-\Theta_1)+(1-\beta)(\Theta_1-\Theta_2(\lambda_l))$. The market-clearing price under this setting can be found by solving $D_n = D_u^l$, and is given by $p_u = \frac{\delta(p_n(2-\beta-\beta\delta)-(1-\delta)(1-\beta\lambda_h Q_e))-\lambda_l Q_e(1-\beta)(1-\delta)}{(1-\beta)(1-\delta)+\rho\delta(2-\beta-\beta\delta)}$. Finally, if $D_u^h = D_u^l = 0$, then $D(p_n, \delta; Q_e) = \beta(1-\widetilde{\Theta}_1(\lambda_h)) + (1-\beta)(1-\widetilde{\Theta}_1(\lambda_l))$ and $p_u = 0$.

By substituting the value of $p_u = \frac{\delta(-1+2p_n+\delta)-Q_e(1-\delta)(\beta\lambda_h+(1-\beta)\lambda_l)}{1+\delta+2\rho\delta}$ in D_u^h, we get that $D_u^h > 0$ if and only if $Q_e < Q_x \doteq \frac{\delta(1-p_n+\rho\delta)}{\lambda_h(1+\delta+2\rho\delta)-(1+\rho\delta)(\lambda_h\beta+(1-\beta)\lambda_l)}$, and $D_u^l > 0$ under this condition. Similarly, substituting the value of $p_u = \frac{\delta(p_n(2-\beta-\beta\delta)-(1-\delta)(1-\beta\lambda_h Q_e))-\lambda_l Q_e(1-\beta)(1-\delta)}{(1-\beta)(1-\delta)+\rho\delta(2-\beta-\beta\delta)}$, $D_u^l > 0$ if and only if $Q_e < Q_y \doteq \frac{1-p_n+\rho\delta}{\beta\lambda_h+(1-\beta)\lambda_l+\beta\delta\rho\lambda_h+\rho\lambda_l(1-\beta\delta)}$, where $Q_x < Q_y$. Therefore, we can characterize $D(p_n, \delta; Q_e)$ as follows: If $0 \leq Q_e < Q_x$, then $D_u^h, D_u^l > 0$ (there is demand for used products from both consumer types) and $D(p_n, \delta; Q_e) = \frac{2(1-p_n+\rho\delta-Q_e(1+\rho)(\beta\lambda_h+(1-\beta)\lambda_l))}{1+\delta+2\rho\delta}$. If $Q_x \leq Q_e < Q_y$, then $D_u^l > 0$ and $D_u^h = 0$ (only less snobbish consumers purchase the used products), and $D(p_n, \delta; Q_e) = \frac{2(1-\beta)(1-p_n+\rho\delta-Q_e(\lambda_l(1+\rho)+\beta(\lambda_h-\lambda_l)(1+\rho\delta)))}{(1-\beta)(1-\delta)+\rho\delta(2-\beta-\beta\delta)}$. Finally, if $Q_y \leq Q_e$, then $D_u^h = D_u^l = 0$ (there is no demand for used products) and $D(p_n, \delta; Q_e) = 1 - p_n - Q_e(\beta\lambda_h + (1-\beta)\lambda_l)$.

Let $\sigma(Q_e) = D(p_n, \delta; Q_e) - Q_e$. $\sigma(Q_e)$ is non-increasing in Q_e, $\sigma(0) > 0$ and $\sigma(Q_y) < 0$. Therefore, there exists a unique rational expectations equilibrium which is given by the value of Q_e between 0 and Q_y such that $\sigma(Q_e) = 0$ (or $D(p_n, \delta; Q_e) = Q_e$). The condition for whether this value of Q_e is smaller than Q_x is $\sigma(Q_x) < 0$, which is given by $\delta \geq 2(1-\beta)(\lambda_h - \lambda_l)$. Therefore, let $\bar{d} \doteq 2(1-\beta)(\lambda_h - \lambda_l)$ and we can characterize the rational expectations equilibrium as follows:

$$D(p_n,\delta) = Q_e = \begin{cases} \frac{2(1-\beta)(1-p_n+\rho\delta)}{(1-\beta)(1+\delta)+\rho\delta(2-\beta-\beta\delta)+2(1-\beta)(\beta\lambda_h(1+\rho\delta)+\lambda_l(1-\beta+\rho(1-\beta\delta)))} & \text{if } 0 \le \delta \le \bar{d}, \\ \frac{2(1-p_n+\rho\delta)}{1+\delta+2\rho\delta+2(1+\rho)(\beta\lambda_h+(1-\beta)\lambda_l)} & \text{if } \bar{d} < \delta \le 1. \end{cases}$$

At the rational expectations equilibrium, the new-product demand is given by $D_n(p_n,\delta) = D(p_n,\delta)/2$ and is strictly positive (i.e., $\Theta_1 < 1$ or $\widetilde{\Theta}_1 < 1$), which implies that both consumer types purchase the new product. However, note that when $\delta < \bar{d}$, we have that $Q_x < Q_e = D(p_n,\delta) < Q_y$, which implies that used products are purchased only by the less snobbish consumers ($D_u^h = 0$).

For a given δ, $\Pi(p_n,\delta) \doteq (p_n - c(\delta))D_n(p_n,\delta)$ is strictly concave in p_n for both forms of D_n (i.e., whether $\delta \le \bar{d}$ or $\delta > \bar{d}$). Solving the first-order condition with respect to p_n, we obtain $p_n^*(\delta) = \frac{1+\rho\delta+c(\delta)}{2}$ for both forms of D_n. $p_n^*(\delta)$ is independent of λ_h and λ_l, and increasing in δ.

Let $\widetilde{\Pi}(\delta) = \Pi(p_n^*(\delta),\delta)$ and $\widetilde{D}_n(\delta) = D_n(p_n^*(\delta),\delta)$. $\widetilde{D}_n(\delta)$ is given by $\frac{1+\rho\delta-c(\delta)}{2(1+\delta+\rho\delta+2(1+\rho)(\beta\lambda_h+(1-\beta)\lambda_l))}$ for $\bar{d} < \delta < 1$ and $\frac{(1-\beta)(1+\rho\delta-c(\delta))}{2((1-\beta)(1+\delta)+\rho\delta(2-\beta-\beta\delta)+2(1-\beta)(\beta\lambda_h(1+\rho\delta)+\lambda_l(1-\beta+\rho(1-\beta\delta))))}$ otherwise. It is straightforward to see that $\widetilde{D}_n(\delta)$ is weakly decreasing in λ_h and λ_l. Differentiating $\widetilde{D}_n(\delta)$ with respect to δ gives that $\widetilde{D}_n(\delta)$ is increasing in δ if $\rho > c'(\delta)$ and $\beta\lambda_h + (1-\beta)\lambda_l > \widetilde{\Lambda}(\delta) \doteq \frac{(1+\rho)(1+c(\delta))+c'(\delta)+\rho c(\delta)}{2(1+\rho)(\rho-c'(\delta))}$ for $\delta > \bar{d}$ and $\lambda_l > \widetilde{\widetilde{\Lambda}}(\delta) \doteq \frac{2+\beta-\beta\delta(2-\rho^2\delta)+c'(\delta)(1-\beta)(1+2\beta\lambda_h)+c(\delta)(3-2\beta+2(1-\beta)\lambda_h)}{2(1-\beta)(\rho(1+\rho+\beta c(\delta))-c'(\delta)(1+\rho-\beta))}$ for $\delta \le \bar{d}$. For the homogenous case ($\lambda_h = \lambda_l = \lambda$), we have $\bar{d} = 0$. Therefore, $\widetilde{D}_n(\delta)$ is increasing in δ for $\rho > c'(\delta)$ and $\lambda > \widetilde{\Lambda}(\delta)$. □

Proof of Proposition 2. Let $\lambda_h = \lambda_l = 0$ and $\rho = 1$. $\widetilde{\Pi}(\delta)$ is then given by $\frac{(1+\delta-c(\delta))^2}{4(1+3\delta)}$. $\widetilde{\Pi}(0) - \widetilde{\Pi}(\delta) = \frac{\delta(1-\delta)+c(\delta)(2-c(\delta)+2\delta)}{4(1+3\delta)}$, which is strictly positive for all $\delta \in (0,1]$ and $c(\delta) < 1+\delta$. Therefore, $\delta^* = 0$. □

Proof of Proposition 3. The firm's profit evaluated at $\rho = 1$ and $\lambda_h = \lambda_l = \lambda$ is given by $\widetilde{\Pi}(\delta) = \frac{(1+\delta-c(\delta))^2}{4(1+3\delta+4\lambda)}$. The firm's problem is to maximize $\widetilde{\Pi}(\delta)$ by choosing $\delta \in [0,1]$. By solving the first-order condition for the unconstrained problem, $\widetilde{\Pi}'(\delta) = 0$, we get four roots given by $r_1 = \frac{1-\sqrt{1+4c}}{2c}$, $r_2 = \frac{1+\sqrt{1+4c}}{2c}$, $r_3 = \frac{3-4c(1+4\lambda)-\sqrt{9+4c(-15+48\lambda+4c(1+\lambda)^2)}}{18c}$ and $r_4 = \frac{3-4c(1+4\lambda)+\sqrt{9+4c(-15+48\lambda+4c(1+\lambda)^2)}}{18c}$. It is straightforward to show that $r_1 < 0$ and $r_2 > 1$ for $c \in [0, 1+\delta]$ and r_3 is a local minimizer because $\widetilde{\Pi}''(r_3) > 0$. Thus, we have only three candidate solutions for δ^*: 0, r_4 and 1.

We will characterize δ^* in the λ-c space. We begin by finding the condition when $\widetilde{\Pi}(1) > \widetilde{\Pi}(0)$. Let $x_1(c,\lambda) \doteq \widetilde{\Pi}(0) - \widetilde{\Pi}(1)$. $dx_1(c,\lambda)/dc = \frac{2c}{4+4\lambda} > 0$, $x_1(0,\lambda) = -3\lambda/(2+10\lambda+8\lambda^2) < 0$ and $x_1(1,\lambda) = 3/(8+40\lambda+32\lambda^2) > 0$. Thus, there is a unique indifference curve defined by $c = C_2(\lambda) \doteq 2 - \frac{2(1+\lambda)}{\sqrt{(1+\lambda)(1+4\lambda)}}$ where $\widetilde{\Pi}(0) = \widetilde{\Pi}(1)$; $\widetilde{\Pi}(1) > \widetilde{\Pi}(0)$ only if $c < C_2(\lambda)$ and $\widetilde{\Pi}(1) \le \widetilde{\Pi}(0)$ otherwise. The condition $c < C_2(\lambda)$ can be rewritten as $\lambda > l_1(c) \doteq \frac{c(4-c)}{4(3-c)(1-c)}$. We are now going to divide the λ-c space in three different collectively exhaustive and mutually exclusive regions: $c < C_1(\lambda) \doteq \frac{2+8\lambda}{13+16\lambda}$, $C_1(\lambda) \le c \le 1/2$ and $1/2 < c$. The reason for choosing these regions is as follows: If $c < C_1(\lambda)$ and r_4 is real-valued, $r_4 \ge 1$ and can be ruled out. Moreover, $\lim_{\lambda\to\infty} C_1(\lambda) = 1/2$. In each of these regions, we will determine δ^* from the three candidate solutions (0, r_4 and 1) by comparing $\widetilde{\Pi}(0)$, $\widetilde{\Pi}(r_4)$ and $\widetilde{\Pi}(1)$.

First, if $c < C_1(\lambda)$, then $r_4 \geq 1$ and is ruled out. We only need to compare 0 and 1. We know that $\widetilde{\Pi}(1) > \widetilde{\Pi}(0)$, i.e., $\delta^* = 1$ if $\lambda > l_1(c)$ (or $c < C_2(\lambda)$) and $\delta^* = 0$ otherwise.

Second, if $C_1(\lambda) \leq c \leq 1/2$, then we can show that $\widetilde{\Pi}(0) > \widetilde{\Pi}(1)$. Thus, we only need to compare r_4 and 0. However, $r_4 > 0$ if and only if $\lambda > \frac{-6-4c+3\sqrt{3}\sqrt{1+4c}}{16c}$. If $\lambda < \frac{-6-4c+3\sqrt{3}\sqrt{1+4c}}{16c}$, then r_4 is ruled out and $\delta^* = 0$. If $\lambda > \frac{-6-4c+3\sqrt{3}\sqrt{1+4c}}{16c}$, then $\widetilde{\Pi}(r_4) > \widetilde{\Pi}(0)$ only if $\lambda > l_2(c) \doteq \frac{3\sqrt{1+18c+108c^2+216c^3}-3-29c-16c^2}{8c(1+8c)}$, where $l_2(c) > \frac{-6-4c+3\sqrt{3}\sqrt{1+4c}}{16c}$. Thus, if $C_1(\lambda) \leq c \leq 1/2$, then $\delta^* = 0$ for $\lambda < l_2(c)$ and $\delta^* = r_4$ otherwise.

Finally, consider $1/2 < c$: If $\lambda < 1/8$, then r_4 is not real valued and is ruled out. We only need to compare 0 and 1. We can show that $1/8 < l_1(c)$, which implies $\lambda < l_1(c)$. Thus, $\widetilde{\Pi}(0) > \widetilde{\Pi}(1)$ for $\lambda < 1/8$, i.e., $\delta^* = 0$. If $1/8 \leq \lambda$, then we can show that $\widetilde{\Pi}(r_4) > \widetilde{\Pi}(0)$ and $\widetilde{\Pi}(r_4) > \widetilde{\Pi}(1)$, i.e., $\delta^* = r_4$. Thus, if $1/2 < c$, then $\delta^* = 0$ for $\lambda < 1/8$ and $\delta^* = r_4$ otherwise.

Putting all three cases from above together: $\delta^* = 0$ if and only if $\lambda \leq L(c)$, where $L(c)$ is defined as follows:

$$L(c) \doteq \begin{cases} l_1(c) & \text{if } c < C_1(\lambda), \\ l_2(c) & \text{if } C_1(\lambda) \leq c \leq 1/2, \\ 1/8 & \text{if } c < 1/2. \end{cases}$$

If $\lambda > L(c)$, then $\delta^* > 0$. If $c < C_1(\lambda)$ also holds, then $\delta^* = 1$, otherwise $\delta^* = r_4$.□

Proof of Proposition 4. Let $\rho = 1$ and $\lambda_h = \lambda_l = \lambda$. From Proposition 3, $\delta^* = 0$ for $\lambda \leq L(c)$, $\delta^* = r_4$ for $\lambda > L(c)$ and $c > C_1(\lambda)$ (where $C_1(\lambda)$ increases in λ) and $\delta^* = 1$ otherwise. Since r_4 increases in λ, δ^* is non-decreasing in λ. It is straightforward to see that $p_n^*(\delta)$ is increasing in δ (since $c(\delta)$ increases in δ). Thus, $p_n^*(\delta^*)$ is non-decreasing in λ. When $\delta^* = 0$, $\widetilde{D}_n(0) = 1/(2+8\lambda)$, which strictly decreases in λ. When $\delta^* \in (0,1)$, it is straightforward to show that $d\widetilde{D}_n(\delta^*)/d\lambda < 0$. Finally, when $\delta^* = 1$, $\widetilde{D}_n(1) = \frac{1-c}{8+4\lambda}$, which strictly decreases in λ. Thus, $\widetilde{D}_n(\delta^*)$ strictly decreases in λ.□

Proof of Proposition 5. When $\lambda_h > \lambda_l \geq 0$, the firm's design problem is given by $\max_{0\leq\delta\leq1} \Pi(\delta)$, where

$$\widetilde{\Pi}(\delta) = \begin{cases} \widetilde{\Pi}_a(\delta) \doteq \frac{(1-\beta)(1+\rho\delta-c(\delta))^2}{4((1-\beta)(1+\delta)+\rho\delta(2-\beta-\beta\delta)+2(1-\beta)(\beta\lambda_h(1+\rho\delta)+\lambda_l(1-\beta+\rho(1-\beta\delta))))} & \text{if } 0 \leq \delta \leq \bar{d}, \\ \widetilde{\Pi}_b(\delta) \doteq \frac{(1+\rho\delta-c(\delta))^2}{4(1+(1+2\rho)\delta+2(1+\rho)(\beta\lambda_h+(1-\beta)\lambda_l))} & \text{if } \bar{d} < \delta \leq 1. \end{cases}$$

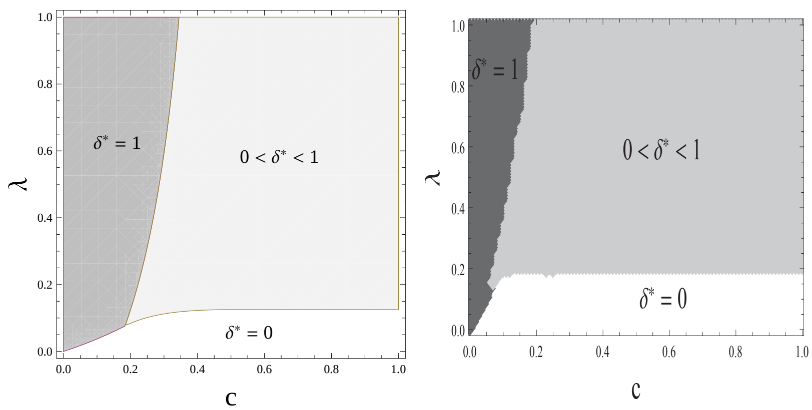
Let $c(\delta) = 0$ and $\rho = 1$. $\widetilde{\Pi}_a(\delta)$ and $\widetilde{\Pi}_b(\delta)$ are both convex in δ and $\widetilde{\Pi}(\delta)$ is continuous at $\delta = \bar{d}$. $\widetilde{\Pi}(0) - \widetilde{\Pi}(1) = \frac{-(\beta\lambda_h+\lambda_l(3-\beta))}{4(1+2\beta\lambda_h+4\lambda_l-2\beta\lambda_l)(1+\beta\lambda_h+\lambda_l(1-\beta))}$, which is negative for all $\beta \in [0,1]$ and $\lambda_h > \lambda_l \geq 0$. Therefore, $\widetilde{\Pi}(0) < \widetilde{\Pi}(1)$, i.e., $\delta^* = 1$. □

A3. The role of time inconsistency

We can consider a two-period model similar to the one in Desai and Purohit (1998), where time inconsistency is present. We generalize their model to incorporate the exclusivity-seeking behavior and cost of durability as in our main model (details about this are available on request). In such a two-period model, the firm offers new products in the first period. However, in the second period, consumers who purchased a new product earlier, can choose to sell the used product on the secondary market. Therefore, while only new products are available in the first period, both new and used products may be available in the second period. It can be shown that there can be at most four consumer strategies in the two-period model: a consumer can buy a new product in both periods (by selling the old product on the secondary market in the second period), a consumer can buy a new product in the first period and hold onto it in the second period, a consumer can choose to not purchase a new product in the first period and buy a used product from the secondary market in the second period (if available).

While the optimal pricing decisions can be found analytically, finding the optimal durability is analytically intractable. However, it can be found by numerical optimization (details available on request) and is depicted in panel b of Figure 1. By comparing the panels in Figure 1, it can be seen that our results also hold in the presence of time inconsistency: The firm may prefer to not practice planned obsolescence in the presence of snobbish consumers, and the firm's optimal design strategy is similar under the infinite-horizon and two-period models.

Figure 1: Comparison of the optimal design strategy with $\lambda_h = \lambda_l = \lambda$ under an infinite-horizon model (panel A) and a two-period model (panel B)



(a) (b)

A4. Alternative model where the firm cannot commit to its pricing decision.

In our main analysis, we assumed that the firm can commit to its pricing decision, which is also a conventional assumption in the durable goods literature. Under this assumption, we imposed the conditions for the rational expectations equilibrium before solving for the firm's pricing decision. We now consider an alternative assumption, where the firm cannot commit to its pricing decision (i.e., the conditions for the rational expectations equilibrium are imposed while solving for the firm's optimal price (see Katz and Shapiro (1985), who also compare two such formulations in a different context). We will show that even under such a formulation, our main result that the firm may prefer to offer a higher durability product and avoid planned obsolescence remains unchanged. For brevity, we focus on the homogeneous case to demonstrate this (i.e., $\lambda_h = \lambda_l = \lambda$). The above change in assumption does not change that there are three undominated consumer strategies and the marginal consumers also remain the same. The market-clearing price can be found by equating $1-\Theta_1(\lambda)=\Theta_1(\lambda)-\Theta_2(\lambda)$ and is given by $p_u=\frac{\delta(-1+2p_n+\delta)-\lambda Q_e(1-\delta)}{1+\delta+2\rho\delta}$. The demand for new products is given by $D_n(p_n|Q_e,\delta)=1-\Theta_1(\lambda)=\frac{1+\rho\delta-p_n-\lambda Q_e(1+\rho)}{1+\delta+2\rho\delta}$.The firm's pricing problem is then given by $\max_{p_n}(p_n-c(\delta))D_n(p_n|Q_e,\delta)$ subject to the condition for rational expectations, i.e., $Q_e=D(p_n|Q_e,\delta)=1-\Theta_2(\lambda)$, as a constraint, which evaluated at the marketing clearing price is given by $Q_e=\frac{2(1-p_n+\delta\rho-\lambda Q_e(1+\rho))}{1+\delta+w\rho\delta}$. Note that under this formulation, the firm's problem is a function of Q_e, and the condition for rational expectations is solved along with the first-order conditions for the firm's problem to optimize p_n.

Solving for the firm's optimal price, we get $p_n^*(\delta)=\frac{1+\delta(1+\rho(3+\delta+2\delta\rho)+c\delta(1+\delta+2\lambda+2\rho(\delta+\lambda)))}{2(1+\delta+\lambda+2\delta\rho+\lambda\rho)^2}$ and $D_n(\delta)=Q_e/2=\frac{1-c(\delta)+\rho\delta}{2(1+\delta+2\rho\delta+\lambda(1+\rho))}$. The firm's profit optimized at these values is given by $\Pi(\delta)=\frac{(1+\delta+2\delta\rho)(1-c(\delta)+\rho\delta)^2}{4(1+\delta+2\delta\rho+\lambda(1+\rho))^2}$. We now solve for δ^*. For brevity, we will restrict our attention to the special case where durability is costless to provide ($c=0$) and as in our main analysis for the firm's design strategy, we will assume $\rho=1$. First, if $\lambda=0$, there is no difference in the firm's profit under the two formulations, i.e., even under this formulation if $\lambda=0$, then $\delta^*=0$. Therefore, to find δ^*, we focus on the case where $\lambda>0$. While the profit is not strictly convex in δ, there are no local maximizers between 0 and 1. This implies that there are only two potential solutions: $\delta^*=0$ or $\delta^*=1$. $\Pi(0)-\Pi(1)=\frac{-3\lambda(4+5\lambda)}{4(2+\lambda)^2(1+2\lambda)^2}<0$ for $\lambda>0$. Therefore, $\delta^*=1$ for $\lambda>0$. This implies that our result that the firm may prefer to avoid planned obsolescence and offer products with high durability is robust to our assumption that the consumers form their expectations after the firm has committed to the new-product price. □

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