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

Vishal V. Agrawal
McDonough School of Business, Georgetown University, Washington DC 20057
Vishal.Agrawal@georgetown.edu
Stylianos Kavadias
Judge Business School, University of Cambridge, Cambridge 30332
s.kavadias@jbs.cam.ac.uk
L. Beril Toktay
Scheller College of Business, Georgia Institute of Technology, Atlanta, GA 30332
Beril.Toktay@scheller.gatech.edu

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 $\max_{0\leq\delta\leq 1} \Pi(\delta)$, where

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

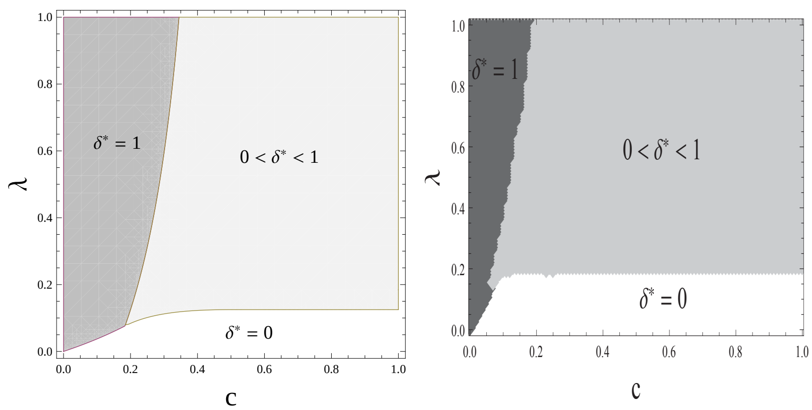
Let $c(\delta) = 0$ and $\rho = 1$. $\widetilde{\Pi}_a(\delta)$ and $\widetilde{\Pi}_b(\delta)$ are both convex in δ and $\widetilde{\Pi}(\delta)$ is continuous at $\delta = \bar{d}$. $\widetilde{\Pi}(0) - \widetilde{\Pi}(1) = \frac{-(\beta\lambda_h+\lambda_l(3-\beta))}{4(1+2\beta\lambda_h+4\lambda_l-2\beta\lambda_l)(1+\beta\lambda_h+\lambda_l(1-\beta))}$, 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. □

References

Desai, P., D. Purohit. 1998. Leasing and Selling: Optimal Marketing Strategies for a Durable Goods Firm. *Management Sci.* **44**(11) S19–S34.

Hendel, I., A. Lizzeri. 1999. Adverse Selection in Durable Goods Markets. *Amer. Econom. Rev.* **89**(5) 1097–1115.

Katz, M., C. Shapiro. 1985. Network Externalities, Competition and Compatibility. *Amer. Econom. Rev.* **75**(3) 424–440.