Component Goods and Innovation

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Abstract

We consider the research and development (R&D) decisions of a durable good monopolist that can only engage in partial physical obsolescence—the obsolescence of component parts. We show that if the durable good producer does not have a monopoly in the component good market then it invests in less than the socially efficient level of R&D, with the level of R&D decreasing as the market becomes more competitive. If the component good market is perfectly competitive then the monopolist gets practically no benefit from partial physical obsolescence.

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1 Introduction

The planned obsolescence literature has always assumed that the monopolist can limit the durability of the whole product. However for most durable goods—such as cellphones, printers, automobiles, computers, and stereo systems—it is not the whole product that becomes obsolete, but a component. It is the battery not the cellphone, the toner cartridge not the photocopier, the car parts not the car that dies first. Furthermore the consumer can often buy the replacement good from many different suppliers. Fishman and Rob (2000) show that a durable good monopolist can use planned obsolescence of the whole product to achieve the socially optimal research and development (R&D) level. In contrast this paper shows that if only a component can be made obsolete and there are other suppliers of this component then the amount of innovation in the primary good market is often significantly less than optimal.

There have been many court cases involving firms like Kodak, Data General, Unisys and Xerox about aftermarket monopolization.[1] In response, a literature has developed analyzing the static welfare impacts of aftermarket monopolization (Chen and Ross (1993, 1998), Borenstein, Mackie-Mason and Netz (2000)). However, this is the first paper to examine the dynamic impact—the impact of component good market monopolization on research and development.

Within the framework of Fishman and Rob (2000) we assume that the monopolist can only make a component obsolete and analyze its R&D incentives when it does not monopolize the component good market. Fishman and Rob (2000) show that if the monopolist does not use planned obsolescence then the old generation acts as a competitor for the new generation and the monopolist does not innovate efficiently. In contrast if the monopolist uses obsolescence then it can extract the full social surplus from each generation and will innovate efficiently. In practice it might be quite difficult if not impossible to make the whole product obsolete at once. If the monopolist can only make a component obsolete then the competition previously provided by the last generation is now provided by firms supplying the component. Thus the monopolist is only able to charge consumers for the incremental utility and the price of the component, and if the component good market is competitive this is essentially the same as not being able to use obsolescence.

In section 2 we describe our model, in section 3 we analyze how the competi-

[1] The term "aftermarket" refers to markets for any complementary goods and services that may be needed after purchase of a durable good.

tive environment of the component goods market will affect innovation. Section 4 concludes.

2 Model

The basic model in our analysis is essentially the same as Fishman and Rob (2000) except that we must make stronger concavity assumptions for our comparative statics. Time is continuous and all parties have the same instantaneous interest rate of $r > 0$.

There is a continuum of infinitely lived homogenous consumers of measure one that consume either zero or one unit of the good, consuming one unit of a product of quality q delivers q units of utility per time, consuming zero delivers zero.

The firm provides a durable good with an infinite life, and may introduce new generations periodically. Before the introduction of a new model there must be an R&D or *gestation* stage. This stage has length t and the flow of R&D expenditure is x—which is constant during the stage. The quality improvement from this R&D is given by an *innovation function* $g(x,t)$. The new generation then has the quality of $q + g(x,t)$, and the next gestation period is triggered. A new generation has a fixed cost of F, a constant marginal cost of c, and the R&D expenditure of $x\frac{1-e^{-rt}}{r}$. We assume that:

Assumption 1 g is strictly concave, bounded, increasing in x and t, twice continuously differentiable, $g(x,0) = g(0,t) = 0$, and there exists an $\{x_p, t_p\}$ such that

$$r(F+c) < \left(1-e^{-rt_p}\right)\left[g(x_p,t_p) - e^{rt_p}x_p\right] \ . \tag{1}$$

Furthermore

$$\left(1-e^{-rt}\right)g_{xt} \leq rg_x \tag{2}$$

and

$$2\left(e^{rt}-1\right)g_{xx}\left(g_{tt}-rg_t\right) \geq \left[\left(1-e^{-rt}\right)g_{xt} - rg_x\right]^2 \ . \tag{3}$$

The condition 1 guarantees the monopolist will innovate. It and condition 2 differ from Fishman and Rob (2000) because in our paper x and t will not be constant. Condition 2 guarantees that x and t are substitutes at the optimum, and condition 3 guarantees that the objective function is strictly concave at the optimum. These conditions can all be met by Cobb-Douglass innovation functions. Condition 3 requires that the coefficient on x is smaller than the coefficient on t. Intuitively the marginal benefit of investment per unit of time must be lower than the marginal benefit of time.

Unlike Fishman and Rob (2000) we assume there is a finitely durable component good which is a perfect compliment to the primary good. As the new model of the primary product is introduced, the component becomes obsolete. The component good is produced at a marginal cost of αc, where $\alpha \in [0, 1]$.

The component good market may or may not be monopolized by the primary good monopolist. The cost of buying a component is determined by a reduced form inverse demand curve $(p^c(g, q, t', \alpha c))$. Including q and g and t' (the length of time until the next generation is introduced) allows the price to be a function of both the last and new generation's value; αc is included since price can not be below the cost of production. Most of the simplifying assumptions for g are also made for p^c.

Assumption 2 $p^c(g, q, t', \alpha c)$ is strictly concave, increasing, and twice continuously differentiable.

Notice that if the product degrades over time this would be equivalent to increasing $p^c(g, q, t', \alpha c)$, thus our model can handle this variation though we do not explicitly analyze this case.

In our model there is no price discrimination or secondhand market. When indifferent consumers will buy the new generation rather than replace the component, and replace the component rather than not consume the good. We look at Markov perfect equilibria that are only a function of q, and if a given strategy is optimal at multiple q's then the same strategy will be chosen at all such q's.

3 The Market for Component Goods

The price of the new model, p, will be a function of the value of the good and the component. If a consumer has a good of quality q he will buy the new generation if $(q+g)\frac{1-e^{-rt_e}}{r} - p \geq q\frac{1-e^{-rt_e}}{r} - p^c \geq 0$ and $(q+g)\frac{1-e^{-rt_e}}{r} - p \geq 0$. Thus

$$p = g\frac{1-e^{-rt_e}}{r} + \min\left\{q\frac{1-e^{-rt_e}}{r}, p^c\right\} \tag{4}$$

we will assume $p_c \leq q\frac{1-e^{-rt_e}}{r}$ without loss of generality. The Bellman equation is

$$\Pi(q)=\max_{x,t}\left\{-x\frac{1-e^{-rt}}{r}+e^{-rt}p^{c}\left(g,q,t_{e},\alpha c\right)+e^{-rt}\frac{1-e^{-rt_{e}}}{r}g\left(x,t\right)-e^{-rt}\left(F+c\right)+e^{-rt}\Pi\left(q+g\left(x,t\right)\right)\right\}. \tag{5}$$

We can immediately show that increasing competition decreases innovation.

Proposition 1 *If the competitiveness in the component good market increases at any point in the future (p^c decreases) then the amount of innovation decreases.*

Proof. *Let $p^c(k)$ be the price of the component good of the model k stages from now. Then it is immediate that $\Pi_{p^c(k)} = e^{-rt}e^{-r\Sigma_{j=1}^{k}t(j)} > 0$ where $t(j)$ is the value of t j stages from now. Thus $\Pi_{xp^c(k)} = 0$ and $\Pi_{tp^c(k)} = -r\ \Pi_{p^c(k)}$. Using Cramer's rule:*

$$\begin{aligned}\frac{\partial x}{\partial p^{c}(k)} &= \frac{-r\Pi_{p^{c}(k)}\Pi_{xt}}{\Pi_{xx}\Pi_{tt}-\Pi_{xt}^{2}}\\ \frac{\partial t}{\partial p^{c}(k)} &= \frac{r\Pi_{p^{c}(k)}\Pi_{xx}}{\Pi_{xx}\Pi_{tt}-\Pi_{xt}^{2}}\ .\end{aligned}$$

In Lemma 2 we show that $\Pi_{xx} < 0$, $\Pi_{xx}\Pi_{tt} - \Pi_{xt}^2 > 0$ thus $\frac{\partial t}{\partial p^c(k)} < 0$. For $\frac{\partial x}{\partial p^c(k)} > 0$ to be true we need

$$\Pi_{xt}=-1+\frac{1}{g_{x}}\frac{1-e^{-rt}}{r}g_{xt}+e^{-rt}\left(p_{gg}^{c}+\Pi_{qq}\left(q+g\right)\right)g_{x}g_{t}<0\ .$$

Now $p^c_{gg} < 0$ and $\Pi_{qq}(q) = e^{-rt}p^c_{qq} + \Pi_{qq}(q+g) < 0$ and by assumption $(1-e^{-rt})\,g_{xt} \leq rg_x$. Thus this is true. ■

The critical element for this proposition is the constant sign of $\Pi_{tp^c(k)}$ and $\Pi_{xp^c(k)}$, thus it should generalize to markets where the degree of competitiveness increases in discrete amounts. Furthermore this proposition shows that expecting competition in the future will reduce innovation today. Notice that if the primary good does degrade some this is equivalent to the price of the component rising, which increases the amount of innovation. The monopolist would like to make the good as close to completely obsolete as possible.

In the following lemma we establish the upper and lower bounds on innovation. Each of these cases simplifies to a case in Fishman and Rob (2000).

Lemma 1 *If the component good market is a monopoly then the monopolist chooses the socially optimal level of innovation, if the component good market is perfectly competitive then the monopolist acts as if it can not make the good obsolete but has a constant marginal cost of $(1-\alpha)c$.*

Proof. If the component good market is monopolized then obviously $p_c \geq q\frac{1-e^{-rt_e}}{r}$. In this case the objective function is the same as in Fishman and Rob (2000) when the monopolist can make its good completely obsolete, and this leads to the socially optimal level of innovation. If the component good market is perfectly competitive then $p_c = \alpha c$, and then the objective function is the same as in Fishman and Rob (2000) when the monopolist can not make the good obsolete except that the marginal cost is lowered by αc. ∎

When the component good market is competitive planned obsolescence has a trivial impact on the amount of innovation. If the component good market is monopolized by the durable good producer innovation increases the price of every future model. If the component good market is competitive the only benefit is to increase the price of the current model. Thus a benefit previously reaped from every model is now only reaped from one. Competition in the component market essentially removes all the advantage from planned obsolescence.

4 Conclusion

Previous work on durable goods theory has modelled planned obsolescence as reduction in the durability of the whole of the product. However, it is typically a component that becomes physically obsolete rather than the whole unit. In the antitrust literature it is an open question whether a firm with a patent in a primary good should also be able to control the component good market. We show that if the firm does not control the component good market then its incentive to innovate is dramatically reduced.

References

[1] Borenstein, S.; Mackie-Mason, J.K. and J. Netz, 2000, Exercising Market Power in Proprietary Markets, Journal of Economics & Management Strategy 9, 157-188.

[2] Chen, Z. and T.W. Ross 1993, Refusals to deal, price discrimination and independent service organizations, Journal of Economics and Management Strategy 2, 593-614.

[3] Chen, Z. and T.W. Ross 1998, Refusals to deal and orders to supply in competitive markets, International Journal of Industrial Organization 17, 399-417.

[4] Fishman, A. and R. Rob, 2000, Product Innovation by a Durable-Good Monopoly, RAND Journal of Economics 31, 237-252.

5 Appendix

Lemma 2 *The Monopolist's objective function is strictly concave at the optimum.*

Proof. *The first order conditions are*

$$\Pi_x = -\frac{1-e^{-rt}}{r} + e^{-rt}\left(p_g^c + \frac{1-e^{-rt_e}}{r} + \Pi_q\left(q+g\right)\right) g_x$$
$$\Pi_t = -r\left(\Pi\left(q\right) + \frac{x}{r}\right) + e^{-rt}\left(p_g^c + \frac{1-e^{-rt_e}}{r} + \Pi_q\left(q+g\right)\right) g_t$$

from these one can derive that the second derivatives at the optimum are:

$$\Pi_{xx} = \frac{1}{rg_x} g_{xx} + e^{-rt} g_x^2 \left(p_{gg}^c + \Pi_{qq}\left(q+g\right)\right)$$
$$\Pi_{tt} = \left(g_{tt} - rg_t\right)\frac{1}{rg_x}\left(e^{rt}-1\right) + e^{-rt} g_t^2 \left(p_{gg}^c + \Pi_{qq}\left(q+g\right)\right)$$

these are both strictly negative since $p_{gg}^c < 0$ *and* $\Pi_{qq}\left(q\right) = e^{-rt}p_{qq}^c + e^{-rt}\Pi_{qq}\left(q+g\right) < 0$. *Now*

$$\Pi_{xt} = -1 + \frac{1-e^{-rt}}{r}\frac{g_{tx}}{g_x} + e^{-rt} g_x g_t \left(p_{gg}^c + \Pi_{qq}\left(q+g\right)\right)$$

and for strict concavity we also need:

$$\begin{aligned}\Pi_{xx}\Pi_{tt} - \Pi_{xt}^2 &= \left(\frac{1}{rg_x}\right)^2 \left(\left(e^{rt}-1\right) g_{xx}\left(g_{tt} - rg_t\right) - \left(\left(1-e^{-rt}\right) g_{tx} - rg_x\right)^2\right) \\ &\quad + \frac{e^{-rt}}{rg_t}\left(p_{gg}^c + \Pi_{qq}\left(q+g\right)\right)\left(\frac{g_x}{g_t}\left(e^{rt}-1\right)\left(g_{tt} - rg_t\right) + \frac{g_t}{g_x} g_{xx} - 2\left(\left(1-e^{-rt}\right) g_{tx} - rg_x\right)\right) >\end{aligned}$$

This is true if

$$\left(e^{rt}-1\right) g_{xx}\left(g_{tt} - rg_t\right) > \left(\left(1-e^{-rt}\right) g_{tx} - rg_x\right)^2$$

which is guaranteed by our assumption that $\left(e^{rt}-1\right) g_{xx} g_{tt} \geq 2\left(\left(1-e^{-rt}\right) g_{xt} - rg_x\right)^2$. *We also need*

$$\frac{g_x}{g_t}\left(e^{rt}-1\right)\left(g_{tt} - rg_t\right) + \frac{g_t}{g_x} g_{xx} - 2\left(\left(1-e^{-rt}\right) g_{tx} - rg_x\right) < 0$$

by assumption 2 we know that $\left(1-e^{-rt}\right) g_{tx} - rg_x \leq 0$ *so we need*

$$g_{xx}\frac{g_t}{g_x} + \left(g_{tt} - rg_t\right)\left(e^{rt}-1\right)\frac{g_x}{g_t} < 2\left(1-e^{-rt}\right) g_{xt} - rg_x \leq 0$$

If we square both sides this means the left hand side needs to be larger than the right hand side, and one of the terms on the left hand side is $2\left(e^{rt}-1\right) g_{xx}\left(g_{tt} - rg_t\right) \geq 4\left(\left(1-e^{-rt}\right) g_{tx} - rg_x\right)^2$ *by assumption.* ■