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Choice of Product Variety for the Durable-goods Monopolist

F. Javier Casado-Izaga and Ana I. Saracho

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This paper analyzes the strategic choice of variety by a monopolist seller of a durable good as a means to mitigate his commitment problem. The monopolist chooses his product variety with the goal of ensuring that a large reduction in future prices will not be profitable because it allows the firm to attract few additional consumers. The main result that emerges from considering product variety as an endogenous variable is that, contrary to the case in which it is exogenously determined, social welfare is always greater when the monopolist cannot commit than when he can.

Keywords: durable goods monopolist, commitment, product variety.

JEL classification: D42, L12.

1 Introduction

The power held by a monopolist in the production and sale of a durable good can be substantial, but is significantly less than the power held by a monopolist who produces a non-durable good. The monopolist seller of a durable good faces the problem of time inconsistency when deciding on his optimal production path. In the case of the durable-goods monopolist, the credibility problem rests on whether or not he can commit to a future schedule of production. By increasing his future production the monopolist induces a reduction in the capital value of the units sold before, and this fact is taken into account by consumers. As a result, the time path of prices will generally not be the one which, if a commitment to future prices were possible, would generate sales that maximize the present value of the monopolist's profits.

The present paper analyzes the strategic choice of product variety by a monopolist seller of a durable good as a means to mitigate his commitment problem. The literature has examined different possibilities which solve or mitigate this problem: renting rather than selling the good (Coase, 1972); capacity restrictions (Bulow, 1982); the establishment of exclusive contracts in serving the product (Bulow, 1982); the choice of product durability (Coase, 1972; Bulow, 1986); the use of best-price provisions (Butz, 1990); and the choice of quality (Chi, 1999). We consider a novel possibility in our analysis: the case of a monopolist who cannot commit to future production but instead chooses to produce a variety such that he credibly commits not to reduce future prices drastically. The monopolist produces a variety such that, in the future, he faces a residual demand with lower price elasticity when prices are low enough.

It is common in the literature on durable-goods monopolists to assume the existence of an exogenously given demand (see Bulow 1982; 1986; Kahn, 1986; Malueg and Solow, 1989). However, firms may frequently be able to choose the variety of the good they produce and, as a result, they are able to determine, at least in part, their own demand. For this reason, it may be relevant to analyze the monopolist's choice of variety from a strategic point of view. In principle, a tractable way to analyze this problem is to deal with the linear city model proposed by Hotelling (1929). This framework of analysis, which is often used for analyzing competition among rivals, may turn out to be particularly useful here because in the case of a durable-goods monopolist, the firm faces its own future competition. Moreover, this model provides locally linear demands, which allows us to compare the results with the existing results in the durable-goods monopolist literature.

The literature on durable goods has also analyzed the consequences that the ability or inability to commit to a future schedule of production has for social welfare in different scenarios (e.g., Bulow, 1982; Kahn, 1986; Malueg, Solow and Kahn, 1988; Malueg and Solow, 1987; 1989; Bond and Samuelson, 1987). Our paper analyzes the implications that the choice of product variety has for social welfare by comparing the cases of the monopolist renter and the monopolist seller. The main result to emerge from the analysis is that when product variety is considered an endogenous variable, contrary to an exogenously determined variable, social welfare is always greater when the monopolist cannot commit than when he can.

The paper is organized as follows. Section 2 describes the model and solves for the optimal choices of the monopolist who can commit (renter) and the monopolist who cannot (seller). Section 3 compares the implications for social welfare under endogenous and exogenous demand. Section 4 contains final remarks.

2 The Model

Consider a monopolist in the production and sale of a durable good. The monopolist must decide what variety and quantity of the good are to be produced. The good does not depreciate over time. There are two discrete periods of time ($j = 1, 2$) and production occurs only at the beginning of each period. For the sake of simplicity we assume that the marginal cost of production of the good in each period is zero and that the discount factor is one.[1]

Purchasers are assumed to be price takers and to have perfect foresight. Each consumer has a different preferred variety of the good (x) that does not change over time and consumers' tastes are distributed uniformly over the varieties interval $[0, 1]$. The number of consumers is normalized to one. There is perfect and complete information about the distribution of consumer tastes and the monopolist's production costs.

Consumers are modeled à la Hotelling (Hotelling, 1929). Each consumer wishes to make use of one unit of the durable good. The reservation price for the rental services provided by the good for the consumer whose preferred variety is x is $1 - t|x - a|$, where t is a positive constant and a is the variety of the good produced by the monopolist. The linear specification of transportation costs allows us to establish comparisons with some results obtained in the literature on durable goods.[2]

We assume that the monopolist's choice of product variety is irreversible, that is, it cannot be changed over time. One may think, for instance, that the firm must adopt a technology that will allow it to produce just that variety of the good but not a different one. Without loss of generality we consider $a \in [0, 0.5]$ and, for simplicity, we assume $t \geq 2$.[3]

1 The qualitative results of the paper do not change if the discount factor is assumed to be less than one. This point will be discussed below.

2 It is common in the literature on product differentiation to assume quadratic transportation costs to avoid the problem of non-existence of equilibrium in duopoly markets (see D'Aspremont, Gabszewicz, and Thisse, 1979). However, in the context considered here the problem does not exist because although the monopolist faces his own future competition, we do not study an oligopoly model.

3 Below we will discuss the results when $t < 2$.

The analysis is modeled as a game with two stages: First, the monopolist decides what variety of the good and what quantity are to be produced in period 1. Second, the firm decides what quantity is to be produced in period 2. The solution concept is that of the subgame-perfect Nash equilibrium. Hence, we proceed to solve the model by backward induction starting from the last stage of the game.

Let p be the rental price of the good, that is, the price for the services yielded by the good in each period. Consumers whose preferred variety (x) is such that $1 - t|x - a| - p \geq 0$ are interested in the services provided by the good in one period. Figure 1 shows the utility that these consumers derive $(1 - t|x - a| - p)$ from consuming the good in each period at three different rental prices: p_A, p_B and p_C $(p_A > p_B > p_C)$.

The consumer whose preferred variety is $\bar{x}$, such that $\bar{x} > a$, and who is indifferent between making use of one unit of the good in each period or not is determined by the equation: $1 - t(\bar{x} - a) - p = 0$. Consequently, $\bar{x} = \frac{1-p}{t} + a$. From Fig. 1, we obtain that the total amount demanded if $p \geq p_B$, that is if $\bar{x} \leq 2a$, is given by $q = 2(\bar{x} - a) = \frac{2}{t}(1 - p)$. If $p < p_B$, that is if $\bar{x} > 2a$, then the total amount demanded is given by $q = \min\{\frac{1-p}{t} + a, 1\}$.

As a result, the inverse demand function for the services yielded by the good in each period is:

$$p = \begin{cases} 1 - \frac{t}{2}q & \text{if } q \leq 2a \\ 1 + ta - tq & \text{if } 2a \leq q \leq 1 \end{cases}. \tag{1}$$

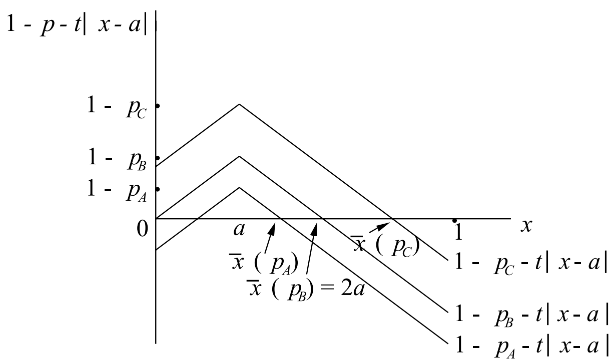

Fig. 1. Consumers' utility for making use of the good during one period

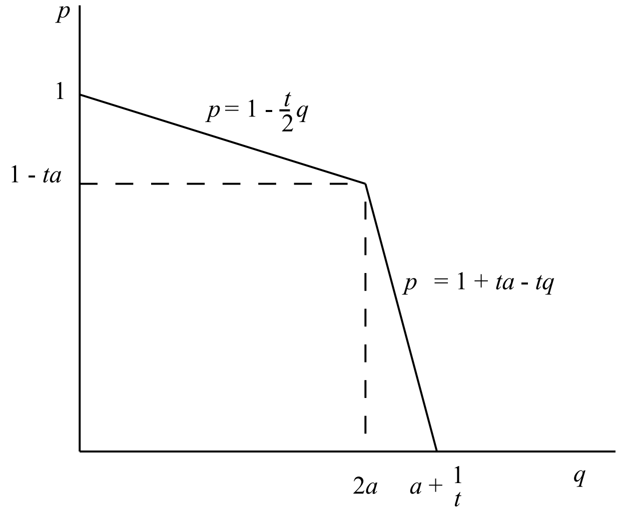

Fig. 2. Rental demand of the durable good

Figure 2 shows the rental demand:

It is important to note that the change in the shape of the demand curve (its kink) is due to the existence of potential buyers only on one side of the market when the quantity produced is greater than $2a$ (in Fig. 1 if $p < p_B$). In this case, an increase in production implies a large reduction in the price charged.

The following notation will be used in the formalization of the model: q_j^i denotes the quantity produced by the monopolist i (where $i =$ r for the monopolist renter and $i =$ s for the monopolist seller) in period j $(j = 1, 2)$; p_j^i denotes the corresponding price charged by monopolist i in period j and a^i denotes the product variety produced by monopolist i.

We first determine the demand functions for the monopolist renter and the monopolist seller. Obviously, the demand faced by the monopolist renter in both periods is given by (1). As to the demand of the monopolist seller, note that, given the good does not depreciate over time, those buyers who buy the good during the first period can use it also in the second period. As a result, p_2^s is such that the total quantity offered during the two periods $(q_1^s + q_2^s)$ is equal to the quantity demanded:

$$p_2^s = \begin{cases} 1 - \frac{t}{2}(q_1^s + q_2^s) & \text{if } q_1^s + q_2^s \leq 2a^s \\ 1 + ta^s - t(q_1^s + q_2^s) & \text{if } 2a^s \leq q_1^s + q_2^s \leq 1 \ . \end{cases} \tag{2}$$

The quantity produced in the second period (q_2^s) maximizes the monopolist's profits in that period, given the quantity sold in the first period. Consider now the first period. The price that the buyers are willing to pay depends on the expected price of the good in the second period. As consumers anticipate correctly the future price (p_2^s), the maximum additional amount that a consumer would pay to acquire the good in the first period, rather than in the second period, is equal to the difference between his valuation of the good when it is used in both periods and his valuation when it is used only in the second period. As a result, given that the discount factor is 1, we have

$$p_1^s = \begin{cases} 1 - \frac{t}{2}q_1^s + p_2^s & \text{if } q_1^s \leq 2a^s \\ 1 + ta^s - tq_1^s + p_2^s & \text{if } 2a^s \leq q_1^s \leq 1 \ . \end{cases} \tag{3}$$

Note that given q_1^s, p_1^s decreases as p_2^s decreases. For this reason the monopolist has an interest in committing to keep his second period price high. Next we consider the cases of the monopolist renter and the monopolist seller.

2.1 Monopolist Renter

This monopolist can commit to a future schedule of production. As mentioned above, the monopolist renter faces the same demand (and rents the same amount) in both periods. Thus, there will be no production in the second period. As a result, he will try to guarantee the highest demand for his product. We can solve the problem for $a = 0.5$. We then obtain the production level of the first period and the rental price (q_1^r, p_1^r). If this production is lower than 1, then the monopolist can guarantee himself the same profits by producing every variety such that, charging p_1^r, he obtains the same demand (q_1^r). Accordingly, he will be located close enough to the middle of the distribution of varieties. This firm solves the following problem:

$$\max_{a,\, q_1^r,\, q_2^r} \left(1 - \frac{t}{2}q_1^r\right)q_1^r + \left[1 - \frac{t}{2}(q_1^r + q_2^r)\right](q_1^r + q_2^r) \ .$$

Therefore, we have $q_1^{r^*} = \frac{1}{t}$, $q_2^{r^*} = 0$, $p_1^r = p_2^r = \frac{1}{2}$, $a^{r^*} \geq \frac{1}{2t}$ and the monopolist obtains profits $\pi^r = \frac{1}{t}$. The assumption that $t \geq 2$ guarantees that the monopolist will not cover the market.

2.2 Monopolist Seller

This monopolist will choose the intertemporally consistent plan of production that maximizes the present value of revenues. The following proposition can be established:

Proposition 1: If the monopolist cannot commit to a future schedule of production he will produce the variety $a^{s^*} = \frac{8}{13t}$, and the quantities $q_1^{s^*} = \frac{11}{13t}$, $q_2^{s^*} = \frac{5}{13t}$.

Proof: A monopolist who cannot commit to a future schedule of production will choose the intertemporally consistent plan of production that maximizes the present value of revenues. Note that the monopolist has four possibilities:

(I) $q_1^s + q_2^s < 2a^s$,

(II) $q_1^s < 2a^s = q_1^s + q_2^s$,

(III) $q_1^s < 2a^s < q_1^s + q_2^s$,

(IV) $q_1^s \geq 2a^s$.

Next, we proceed to solve the monopolist seller's problem in each of these cases. Note that since the firm is a monopolist, the solution where he chooses first a^s and then q_1^s is identical to the one where he chooses a^s and q_1^s simultaneously.

Case I: $q_1^s + q_2^s < 2a^s$.

The maximization problem of the monopolist must be solved by backward induction; that is, we first solve for the monopolist's optimal choice in period two (q_2^s) and then, given this optimal solution, we solve his problem in period one by finding the q_1^s that maximizes the present value of his revenues. Finally, we determine the value of a^s that maximizes his profits.

At time $j = 2$, taking into account (2) and given q_1^s, the monopolist solves:

$$\max_{q_2^s}\left[1 - \frac{t}{2}(q_1^s + q_2^s)\right]q_2^s \ .$$

From the first-order condition of this problem we obtain $q_2^s = \frac{1}{t} - \frac{q_1^s}{2}$, $p_2^s = \frac{1}{2} - \frac{tq_1^s}{4}$. Given the restriction $q_1^s + q_2^s < 2a^s$, we have $q_1^s < \frac{4ta^s - 2}{t}$.

When $j = 1$, the monopolist will solve for the q_1^s that maximizes the present value of his revenues. Taking into account the results above and (3), the monopolist solves:

$$\max_{q_1^s}\left(\frac{3}{2} - \frac{3tq_1^s}{4}\right)q_1^s + \left(\frac{1}{2} - \frac{tq_1^s}{4}\right)\left(\frac{1}{t} - \frac{q_1^s}{2}\right)$$

subject to $q_1^s < \frac{4ta^s - 2}{t}$.

The solution to this problem is $q_1^s = \frac{4}{5t}$, $q_2^s = \frac{3}{5t}$, $p_1^s = \frac{9}{10}$, $p_2^s = \frac{3}{10}$, and the monopolist obtains profits $\pi^s = \frac{0.9}{t}$. As $q_1^s < \frac{4ta^s - 2}{t}$, this is the solution if $a^s > \frac{0.7}{t}$. For $a^s \leq \frac{0.7}{t}$, the intertemporally consistent plan of production corresponds to the solution of some of the cases analyzed below.

Case II: $q_1^s < 2a^s = q_1^s + q_2^s$.

The consistent schedule of production such that $q_1^s + q_2^s = 2a^s$ must satisfy the following conditions:

First, given q_1^s, the q_2^s at which the marginal revenue corresponding to the rental demand $p_2^s = 1 + ta^s - tq_1^s - tq_2^s$ is zero must be smaller than or equal to $2a^s - q_1^s$;

Second, given q_1^s, the q_2^s in which the marginal revenue corresponding to the rental demand $p_2^s = 1 - \frac{tq_1^s}{2} - \frac{tq_2^s}{2}$ is zero must be greater than or equal to $2a^s - q_1^s$. These restrictions imply: $\frac{1}{3t} + \frac{q_1^s}{3} \leq a^s \leq \frac{1}{2t} + \frac{q_1^s}{4}$. Note that $q_1^s < 2a^s$ implies that $\frac{1}{3t} + \frac{q_1^s}{3} < \frac{1}{2t} + \frac{q_1^s}{4}$. Thus, taking into account (2) and (3), at $j = 1$ the monopolist solves:

$$\max_{q_1^s,\, a^s}\left(2 - ta^s - \frac{tq_1^s}{2}\right)q_1^s + (1 - ta^s)(2a^s - q_1^s)$$
$$+ \lambda\left(\frac{3ta^s - 1}{3t} - \frac{q_1^s}{3}\right) + \mu\left(\frac{-2ta^s + 1}{2t} + \frac{q_1^s}{4}\right) \ .$$

From the first-order conditions of this problem we obtain the following solution:

$$a^{s}=\frac{8}{13t},\ q_1^{s}=\frac{11}{13t},\ q_2^{s}=\frac{5}{13t},\ p_1^{s}=\frac{25}{26},\ p_2^{s}=\frac{5}{13},\ \pi^{s}=\frac{25}{26t}\ .$$

It can be easily checked that the first restriction is binding (the values of λ and μ are $\lambda=6/13$ and $\mu=0$).

Case III: $q_1^{s}<2a^{s}<q_1^{s}+q_2^{s}$.

At $j=2$, taking into account (2) and given q_1^{s}, the monopolist solves:

$$\max_{q_2^{s}}(1+ta^{s}-tq_1^{s}-tq_2^{s})q_2^{s}$$

subject to $q_1^{s}+q_2^{s}>2a^{s}$.

The solution to this problem is $q_2^{s}=\frac{1+ta^{s}-tq_1^{s}}{2t}$, $p_2^{s}=\frac{1+ta^{s}}{2}-\frac{tq_1^{s}}{2}$. Then, given the restrictions ($q_1^{s}<2a^{s}<q_1^{s}+q_2^{s}$), we have $\frac{3ta^{s}-1}{t}<q_1^{s}<2a^{s}$.

At time $j=1$ the monopolist will solve for the q_1^{s} that maximizes the present value of his revenues. Taking into account the previous results and (3) the monopolist solves the following maximization problem:

$$\max_{q_1^{s}}\left(\frac{3+ta^{s}}{2}-tq_1^{s}\right)q_1^{s}+\left(\frac{1+ta^{s}}{2}-\frac{tq_1^{s}}{2}\right)\left(\frac{1+ta^{s}}{2t}-\frac{q_1^{s}}{2}\right).$$

From the first-order condition we obtain

$$q_1^{s}=\frac{2}{3t},q_2^{s}=\frac{a^{s}}{2}+\frac{1}{6t},\ p_1^{s}=\frac{5}{6}+\frac{ta^{s}}{2},\ p_2^{s}=\frac{1}{6}+\frac{ta^{s}}{2},$$
$$\pi^{s}=\frac{7}{12t}+\frac{a^{s}}{2}+\frac{t(a^{s})^{2}}{4}\ .$$

Note that $q_1^{s}<2a^{s}<q_1^{s}+q_2^{s}$ implies that $\frac{1}{3t}<a^{s}<\frac{5}{9t}$. As a result, in case III the firm chooses the highest value of a^{s} and its profits have an upper limit in the value $\bar{\pi}^{s}=\frac{76}{81t}$.

Case IV: $q_1^{s}\geq 2a^{s}$.

At $j=2$ the monopolist solves the following problem:

$$\max_{q_2^s}(1 + ta^s - tq_1^s - tq_2^s)q_2^s \ .$$

Therefore, $q_2^s = \frac{1+ta^s-tq_1^s}{2t}$, $p_2^s = \frac{1+ta^s}{2} - \frac{tq_1^s}{2}$.

At time $j = 1$, taking into account the previous result, the restriction $q_1^s \geq 2a^s$ and (3), the monopolist will solve for the q_1^s that maximizes the present value of his revenues:

$$\max_{q_1^s}(2 + 2ta^s - 2tq_1^s - tq_2^s)q_1^s + (1 + ta^s - tq_1^s - tq_2^s)q_2^s + \lambda(q_1^s - 2a^s) \ .$$

subject to: $q_2^s = \frac{1+ta^s-tq_1^s}{2t}$.

From the first-order condition and solving for a^s we obtain

$$a^s = \frac{5}{11t}, \ q_1^s = \frac{10}{11t}, \ q_2^s = \frac{3}{11t}, \ p_1^s = \frac{9}{11}, \ p_2^s = \frac{3}{11}, \ \pi^s = \frac{9}{11t} \ .$$

Finally, note that by comparing the solutions obtained in the different cases it is straightforward to verify that the optimal variety and schedule of production are: $a^s = \frac{8}{13t}$, $q_1^s = \frac{11}{13t}$, $q_2^s = \frac{5}{13t}$. □

The monopolist seller chooses to produce a variety such that he credibly commits not to reduce future prices drastically. This can be guaranteed by moving away from the central varieties because by doing so the monopolist keeps the price elasticity of the residual demand sufficiently low (in absolute value) and, as a result, the second period price is high. The monopolist decides to produce a variety such that a large reduction in future prices is of no interest because it would allow the firm to attract fewer additional consumers that in the previous period (notice that $q_1^{s^*} + q_2^{s^*} = 2a^{s^*}$).

In other words, the monopolist chooses his variety in such a way that when the total production corresponds to the kink in the demand function, his marginal revenue function (discontinuous at this point) suffers a strong reduction. More precisely, at this point the marginal revenue is zero and the monopolist is not interested in increasing production beyond this point, given that marginal revenue would be negative.

In the first period the monopolist renter would produce a higher quantity than the monopolist seller, but in the end, the accumulated quantity produced between periods 1 and 2 would be lower than that chosen by the monopolist who cannot commit. Note also that even though both types of monopolists may produce the same variety, the monopolist renter does not face a residual demand in the second period. His demand in that period is identical to that of the first period. Therefore, the monopolist renter has no special interest in reducing price elasticity to maintain the second period prices at a high level.

The choice of product variety for the monopolist has not been considered in the extensive literature on durable goods. However, as this paper shows, from the monopolist seller's point of view the choice of product variety is a way to mitigate his commitment problem. More precisely, the monopolist seller has an incentive to locate himself far enough from the central variety ($a = 0.5$) to face a less elastic residual demand for the second period. He chooses a variety that guarantees an accumulated production such that all consumers with a preferred variety to the left of that chosen by the seller always buy the good. In this case, in order to produce an additional unit, the monopolist will have to reduce the price drastically because the potential buyers are located on only one side of the market. Although it increases the commitment ability, this drastic price reduction is, if we analyze the equilibrium variety chosen ($a^{s^*} = 8/13t$), never of interest from the monopolist seller's point of view.

We can compare two different situations to gain further insight: one in which the firm produces the central variety ($a = 0.5$) and a second one in which the producer can choose his product variety. This can be analyzed by comparing the results in cases I (which involves the value $a = 0.5$) and II (when the monopolist chooses his product variety) in the proof of Proposition 1. From the monopolist renter's point of view the quantities rented and prices charged are the same in both cases. However, if the monopolist has no commitment ability, there is a greater intertemporal reduction in prices when he cannot choose his product variety. With regard to the monopolist seller, when a is endogenous the monopolist sells more in the first period. However, his total production is lower than when variety is exogenous ($a = 0.5$), due to the lower elasticity of the residual demand. Thus, the monopolist who produces the central variety cannot avoid flooding the market during the second period, thereby inducing a large reduction in prices.

Let us now discuss the implications of some assumptions made in the formalization of the model.

First, consider the parameter t. If $t \leq 1$, it can be directly concluded that the monopolist renter covers the market ($q_1^{r^*} = 1$, $q_2^{r^*} = 0$) and produces the central variety ($a^{r^*} = 0.5$). In this case, there is no commitment problem because the monopolist seller also covers the market at $j = 1$ and there is no variety distortion ($a^{s^*} = 0.5$). If $1 < t < 2$, the monopolist renter does not cover the market ($q_1^{r^*} = \frac{1}{t} < 1,\ q_2^{r^*} = 0$) and the monopolist chooses the product such that he rents the same number of units to each side of the variety ($a^{r^*} \geq 1/2t$). From the monopolist seller's point of view, there are two different situations: on the one hand, he could choose the variety and production levels given by Proposition 1 (which is the case when t is high enough) and, on the other hand, he could cover the market in the second period by choosing the central variety (the solution when t is low enough).

Second, consider the role played by the discount factor, which has been assumed to be one in our analysis. It can be shown that even if the discount factor ($v > 0$) is lower than one, the monopolist seller will choose a variety such that the residual demand elasticity is low. The obvious solution is $a^{s^*} = \frac{6+2v}{(9+4v)t}$, $q_1^{s^*} + q_2^{s^*} = 2a^{s^*}$. Therefore, the distortion of the variety with regard to the central variety decreases as the discount factor diminishes. As to the monopolist renter, obviously his decision does not depend on the discount factor.

3 Social Welfare: Endogenous versus Exogenous Demand

Social welfare may be defined as the sum of the present value of consumer surplus and monopolist's profits. By comparing social welfare under both types of monopolists, the following proposition can be established:

Proposition 2: Social welfare is greater when the monopolist cannot commit to a future schedule of production than when he can.

Proof: In the case of the monopolist seller, social welfare (W^s) is $W^s = \frac{79}{52t}$, which corresponds to the sum of consumer surplus (29/52t) and monopolist's profits (50/52t). Social welfare in the case of the monopolist renter (W^r) is $W^r = \frac{3}{2t}$; that is, the sum of consumer surplus (1/2t) and monopolist's profits (1/t). Therefore, $W^s > W^r$. □

Consumers are better off when the monopolist cannot commit to future prices. On the other hand, the monopolist is better off when he can commit (he could always reproduce the solution for the monopolist seller). The monopolist seller makes less money because he has the ability to reduce the capital value of the outstanding stock of the good (via new sales) and no way of guaranteeing that this power will not be used.[4]

The result obtained in Proposition 2 is standard in the literature on durable goods when both linear demands and the assumption that the monopolist may only choose the quantities are considered simultaneously (e.g., Bulow, 1982; Kahn, 1986). However, it is often argued in the literature that this result relies crucially on these assumptions (see for instance, Bulow, 1982; Bond and Samuelson, 1984; Bulow, 1986, and Malueg and Solow, 1989). Malueg and Solow (1989), for example, show that the conclusion of higher social welfare when the monopolist cannot commit to a future schedule of production is not robust to changes from linear to kinked demands. This paper shows that Malueg and Solow's result may very well change when the monopolist is also allowed to choose the variety to be produced, that is, when the kinked demand is determined endogenously.

Malueg and Solow (1989, p. 523) find that the existence of a kink in the rental demand may imply that "social welfare may be raised or lowered by requiring the monopolist to sell, rather than rent, its output." In their analysis the kink and the shape of the demand curve are determined exogenously. The shape of the demand curve to the right of the kink is crucial to getting different results: social welfare is greater when the monopolist sells the good than when he rents it if and only if the change in the shape of the rental demand is mild enough.

Malueg and Solow (1989) consider the following inverse rental demand:

$$p = \begin{cases} 1 - q & \text{if } \; q \leq 1/2 \\ (n - q)/(2n - 1) & \text{if } \; 1/2 \leq q \leq n \end{cases} .$$

Figure 3 shows the rental demand:

Note that when $n = 0.75$ their rental demand coincides with the one in our model when $t = 2$ and the exogenous product variety is $a = 0.25$. For these parameter values, as Malueg and Solow conclude, social welfare is greater when the monopolist can commit to a future schedule of pro-

4 The result obtained in Proposition 2 that social welfare is greater when the monopolist cannot commit than when he can does not change if $1 < t < 2$ or the discount factor is lower than 1.

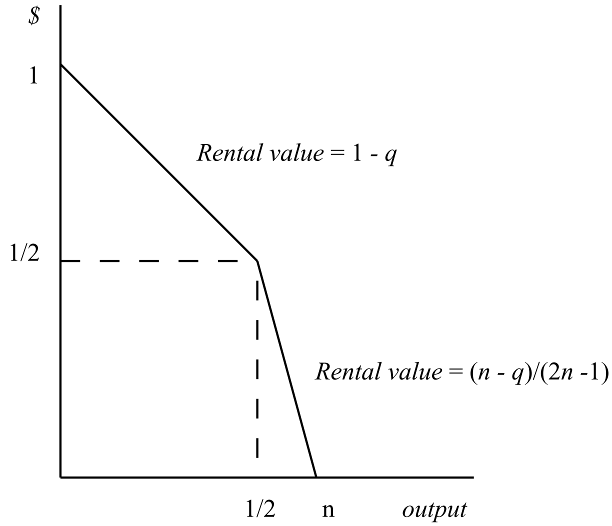

Fig. 3. Malueg and Solow's rental demand

duction than when he cannot. However, when the product variety is a choice of the monopolist, contrary to their result, social welfare will be greater for the monopolist seller than for the monopolist renter. In our model, for $t = 2$, the monopolist seller would choose $a^{s^*} = 4/13$ and the corresponding social welfare would be $W^s = 79/104$. The monopolist renter would choose $a^{r^*} \geq 0.25$ and social welfare would be $W^r = 0.75$.[5] This simple example shows how the consideration of an endogenous rental demand may play an important role in the implications for the analysis of social welfare with respect to the ability or inability to commit to a future schedule of production.

4 Concluding Remarks

We argue in this paper how the choice of product variety by a durable-goods monopolist can be very important from the point of view of its potential use to mitigate his commitment problem. When the monopolist decides on the variety of the good to be produced, he may choose

5 Note that the exogenously given product variety implicitly considered by Malueg and Solow (1989) is optimal for the monopolist renter but not for the monopolist seller.

between situations in which the demand (and its elasticity) is high and the firm cannot commit not to flood the market with the product in the future, setting low prices, and situations in which the demand (and its elasticity) is low but he can commit not to flood the market in the future, setting high prices.

Contrary to the case in which the monopolist who can commit produces a variety such that he has the highest demand (e.g., the central variety), the monopolist who cannot commit to a future schedule of production finds it more profitable to sell a variety of the durable good that allows him to mitigate his commitment problem. The reason is that, with respect to the central variety choice, this solution generates new intertemporally consistent production schedules, which increase the monopolist seller's profits. The monopolist chooses his product variety with the goal of assuring that a large reduction in future prices will not be profitable because marginal revenue in his residual demand is negative when prices are low.

This paper also shows a context where, contrary to the case in which product variety is exogenously determined, under endogenous choice of product variety social welfare is higher when the monopolist cannot commit to future production levels.

The simplest and most tractable way of analyzing the problem of a durable-goods monopolist when rental demand is not linear (which is usually the case studied in literature) is to consider kinked demands (as Malueg and Solow, 1989). In our context this is done by assuming linear transportation costs. The consideration of other formulations to model transportation costs will also imply kinked rental demands when the monopolist does not produce the central variety. Then, even in those cases the choice of product variety can mitigate the monopolist's commitment problem.

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References

Bond, E. W., and Samuelson, S. (1987): "Durable Goods, Market Structure and the Incentives to Innovate." *Economica* 54: 57–67.

Bulow, J. (1982): "Durable-goods Monopolists." *Journal of Political Economy* 90: 314–332.
—— (1986): "An Economic Theory of Planned Obsolescence." *Quarterly Journal of Economics* 101: 729–749.
Butz, D. A. (1990): "Durable-goods Monopoly and Best-price Provisions." *American Economic Review* 80: 1062–1076.
Chi, W. C. (1999): "Quality Choice and the Coase Problem." *Economics Letters* 64: 107–115.
Coase, R. (1972): "Durability and Monopoly." *Journal of Law and Economics* 15: 143–149.
D'Aspremont, C., Gabszewicz, J. J., and Thisse, J.-F. (1979): "On Hotelling's Stability in Competition." *Econometrica* 47: 1145–1150.
Hotelling, H. (1929): "Stability in Competition." *Economic Journal* 39: 41–47.
Kahn, C. M. (1986): "The Durable Goods Monopolist and Consistence with Increasing Costs." *Econometrica* 54: 275–294.
Malueg, D. A., and Solow, J. L. (1987): "On Requiring the Durable-goods Monopolist to Sell." *Economics Letters* 25: 283–288.
—— (1989): "A Note on Welfare in the Durable-goods Monopoly." *Economica* 56: 523–527.
Malueg, D. A., Solow, J. L., and Kahn, C. M. (1988): "Erratum to: The Durable Goods Monopolist and Consistency with Increasing Costs by Charles M. Kahn." *Econometrica* 56: 754.

Address of authors: – F. Javier Casado-Izaga and Ana I. Saracho, Department of Economics, University of País Vasco, Avenida L. Aguirre 83, E-48015 Bilbao, Spain (e-mail: jepcaizf@bs.ehu.es; jepsadea@bs.ehu.es)