GOVERNANCE AND THE EFFICIENCY OF ECONOMIC SYSTEMS
GESY

Discussion Paper No. 271

Monopoly Distortions in Durability and Multi-Dimensional Quality

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September 2009

Financial support from the Deutsche Forschungsgemeinschaft through SFB/TR 15 is gratefully acknowledged.

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September 3, 2009

Abstract

I show that Swan's (1970) independence result requires a multiplicative interaction between durability and all other quality attributes. Because there is no compelling argument for a multiplicativity in quality, monopolists tend to distort durability, even with constant marginal costs. Distortions in durability and other quality aspects are aligned exactly when the marginal cost of quality do not increase too much with durability.

Keywords: Durability, quality, monopoly
JEL Classification No.: L15

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1 Introduction

The seminal paper Swan (1970) demonstrates the surprising result that a standard monopolist has no incentive to distort durability. The result implies that durability choice is independent of market structure. Consequently, there is no reason for governmental intervention concerning durability choice even if markets are not competitive.

The result has found its way in most standard text books of industrial organization (e.g., Tirole, 1988, p.102ff; Carlton and Perloff, 1989, p.628ff; Scherer and Ross, 1990, p.608ff). It is well known however that Swan's independence result fails if marginal costs are not constant (e.g. Sieper and Swan 1973; Levhari and Peles 1973). More precisely, the independence result holds when the cost function displays a multiplicative structure between durability and quantity; constant marginal cost is but one example. Despite its specificity, a constant return to scale technology is nevertheless the appropriate benchmark for comparing the competitive outcome to a monopolistic one in the long run, because, in the long run, the industry's marginal cost equals the minimum average cost at a production plant and is therefore constant.

This note shows, however, that, in the presence of additional quality attributes, Swan's independence result requires that durability and these other attributes interact also multiplicatively. Yet, in contrast to the argument that marginal costs tend to be constant in the long run, there is no compelling reason why the interaction between durability and other quality characteristics should be multiplicative. The exact interaction depends on technological considerations alone.

To understand the intuition why additional quality attributes invalidate Swan's independence result, it is helpful to understand first why, without additional quality attributes, Swan's result holds. The first ingredient that drives Swan's result is that durability choice can be rephrased as a question about cost minimization only. Because the monopolist's incentive to reduce costs are undistorted, the monopolist picks, for a given output level, the efficient durability level. This by itself is, however, insufficient to guarantee an undistorted durability level, because the cost–minimizing durability level will, in general, depend on the firm's output level and a monopolist typically produces an inefficiently low output. For this reason, the second ingredient that drives Swan's independence result is the constant return to scale technology. It implies a multiplicative interaction between durability and output in the firm's cost function. This ensures that the cost–minimizing durability level is independent of the firm's output.

Now, for Swan's independence result to hold also in the presence of additional quality attributes, the cost–minimizing durability level must be independent of these quality attributes as well. Hence, just like in the case of the firm's output, durability must interact multiplicatively with all these attributes for durability to remain undistorted. Without multiplicativity, the direction of the distortion in durability follows the distortion in quality when a higher durability level lowers or does not raise the marginal cost of quality too much. In this case, it is optimal for the monopolist to choose an inefficiently high durability exactly when it is optimal for him to choose an inefficiently high quality level.

Durability in connection with additional quality attributes have been investigated in other economic contexts. Focusing on Coase's durable–good monopolist, Chi (1999) studies how quality choice alleviates the monopolist's problem and Inderst (2008) shows how the durable–good monopolist may offer different qualities to discriminate between different type of consumers. Strausz (2009) studies how, in a repeated games model, reduced durability acts as an incentive device to choose credible quality levels in other dimensions.

2 The Setup

I illustrate my arguments in a straightforward extension of Kleiman and Ophir (1966) to goods with two–dimensional product characteristics as used in Strausz (2009). In particular, I assume that the good is characterized by a durability level d and a second quality characteristic which I capture by a one–dimensional parameter $q > 0$. The durability level d describes the length of time that the product works. The quality q measures the utility which consumers derive from a functioning unit. For simplicity, I assume that durability is deterministic: it yields the consumer a constant utility for a time d and no utility thereafter.

Consumers have a total mass of one. Each consumer needs at most one functioning unit of the good. Consumers differ in their appreciation of quality q. In particular, a consumer of type $\alpha \in [0, 1]$ receives an instantaneous utility of αq from a good with quality q. Hence, a good with characteristics (q, d) yields consumer α a discounted utility of

$$v(q, d|\alpha) \equiv \int_0^d \alpha q e^{-rt} dt = \frac{(1 - e^{-dr})q\alpha}{r},$$

where r represents the common discount rate. The function $v(q, d|\alpha)$ represents consumer α's willingness to pay for a good (q, d); a consumer α buys the good (q, d) exactly when

$$p \leq v(q, d|\alpha). \tag{1}$$

Assuming that consumers are distributed according to the c.d.f. $F(\alpha)$, the buying decision (1) yields the inverse demand function

$$P(x|q, d) = F^{-1}(1 - x)(1 - e^{-dr})q/r,$$

where $F^{-1}(.)$ is the inverse of the c.d.f. $F(.)$.

Let $c(q, d, x)$ denote the cost of producing a quantity x of the good (q, d). In this case, profits equal

$$\Pi_t(q, d, x) = xP(x|q, d) - c(q, d, x).$$

For simplicity, I consider only stationary choices of q, d, and x. If the firm chooses durability d, consumers must repurchase the product every d periods. Hence, the firm's overall discounted profit from producing an infinite stream of x products (q, d) every d periods is

$$\Pi(q,d,x) = \sum_{i=0}^{\infty} \left(e^{-dr}\right)^i \Pi_t(q,d,x) = \frac{q}{r} x F^{-1}(1-x) - \frac{c(q,d,x)}{1-e^{-dr}}. \tag{2}$$

The main question is how the monopolistic solution compares to the efficient one. Because consumer surplus is the integral under the inverse demand function, an output x of goods (q, d) generates social welfare

$$W_t(q,d,x) = \int_0^x P(\tilde{x}|q,d)d\tilde{x} - c(q,d,x).$$

An infinite production of x units of goods (q, d) every d periods yields a social welfare of

$$W(q,d,x) = \sum_{i=0}^{\infty} \left(e^{-dr}\right)^i W_t(q,d,x) = \frac{q}{r} \int_0^x F^{-1}(1-\tilde{x})d\tilde{x} - \frac{c(q,d,x)}{1-e^{-dr}}. \tag{3}$$

3 Results

Let us first assume Swan's framework where quality q is fixed and the firm only chooses the output and durability level. A differentiation of (2) and (3) with respect to durability d yields the identical first order condition

$$c(q,d,x)e^{-dr}r = c_d(q,d,x)(1-e^{-dr}). \tag{4}$$

It illustrates that, when quality q is fixed, then for a *fixed* quantity level x, the monopolist's durability decision is undistorted. A closer inspection of (2) and (3) reveals the intuition behind this result: Durability choice only affects the cost of production and not the firm's revenue or the consumer's surplus. The optimal choice of d, therefore, follows from cost minimization considerations alone. With respect to cost minimization, the monopolist's incentives are aligned with efficiency.

Yet, the identical first order conditions do not guarantee that the monopolist's durability choice is undistorted. This is because they still depend on output x. But if we can express the cost function $c(q, d, x)$ as a product $\hat{c}(q, x)\tilde{c}(d)$, the term $\hat{c}(q, x)$ cancels out and the first order condition simplifies to

$$\tilde{c}(d)e^{-dr}r = \tilde{c}_d(d)(1 - e^{-dr}). \tag{5}$$

In this case, optimal durability d is independent of quantity x.

From a long run perspective, the case of constant marginal cost is a compelling benchmark and it underscores the relevance of Swan (1970)'s independence result.

Let us now consider that the case where quality q is no longer fixed, but is optimally set by the firm. In this case, Swan's independence result would still hold if durability δ interacts multiplicatively with quality q. Yet, we cannot make a compelling argument why this should be the case. Indeed, monopoly distortions in quality provision are well–studied in industrial organization. The direction of the distortion is, in general, ambiguous. Two effects distort the monopolist's quality choice. First, the monopolist's choice depends on the behavior of the marginal consumer, whereas, from a welfare perspective, the average effect over all consumers is the appropriate measure. Second, because the optimal quality choice depends on output x and the monopolist's output decision is distorted downwards, the quality choices are different due to differences in output choices. The direction of these two effects are indeterminate and, ultimately, depend on the firm's production technology. To make these observations more precise, let us compare the first order conditions

$$\frac{\partial \Pi}{\partial q} = 0 \;\Rightarrow\; c_q(q, d, x) = F^{-1}(1 - x)(1 - e^{-dr})/r; \tag{6}$$

and

$$\frac{\partial W}{\partial q} = 0 \;\Rightarrow\; c_q(q, d, x) = \int_0^x F^{-1}(1 - \tilde{x})d\tilde{x}(1 - e^{-dr})/r. \tag{7}$$

reveals the two types of distortions. The two first order conditions differ structurally and depend on the output level x.

From these first order conditions, we can investigate how the feedback effect distorts durability choice. Considering durability d as a function of quality q and differentiating (4) with respect to quality q yields, after a rearrangement of terms,

$$\frac{\partial d}{\partial q} = \frac{rc_q(q,d,x)e^{-dr} - (1-e^{-dr})c_{qd}(q,d,x)}{r^2c(q,d,x)e^{-dr} + (1-e^{-dr})c_{dd}(q,d,x)}.$$

The sign of $\partial d/\partial q$, which determines the direction of the feedback effect, depends on the cross partial derivative c_{qd}. If c_{qd} is negative, the sign is unambiguously positive, because at an optimal solution $c_{dd} > 0$ and $c_q > 0$. In this case, the sign of $\partial d/\partial q$ is positive and, as a result, the distortion in durability follows the distortion in quality: inefficiently high quality goes hand in hand with inefficiently high durability. In contrast, if the cross partial derivative c_{qd} is positive and relatively large in comparison to the derivative c_q, the distortions in quality and durability counteract each other.

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