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Measuring research benefits in an imperfect market: second comment

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Abstract

This note generalizes a finding about the necessary and sufficient conditions for research to generate greater benefits in the presence of distortions and highlights a significant source of bias in conventional cost-benefit calculations. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

That the benefits of research may be greater, the less competitive the market, is an intriguing notion. It has ramifications so substantial for public-project priority setting that it may inextricably alter the course of current research. It provides the basis for a recent contribution in this journal (Voon, 1994). During the subsequent debate (Sexton and Sexton, 1996; Voon, 1996) a finding occurs that is so fundamental to research-benefit calculations, has the ability to grossly enhance the efficacy of public funds, and, yet, lies grossly unexploited in the literature to date that it warrants closer scrutiny. The finding relates the optimal allocation of research effort to the structure of the market, and follows from the observation:

> The necessary and sufficient condition for the benefits of innovation under monopoly to be greater (respectively, less) than the benefits under perfect competition is that dead-weight losses due to the distortion decline (respectively, increase) as a result of the innovation (Sexton and Sexton, 1996, p. 202).

This result is elegant in its simplicity, yet powerful in its applicability, specifically in empirical situations in which market structure is at issue. Although an intuitive, geometric proof is available (Sexton and Sexton, 1996, Fig. 1, p. 202) a formal motivation will, later, prove useful. Let $\Psi(N)$ denote welfare defined with reference to some variable, N-for example, price or the level of output in the market. Let N^* denote the value of N that maximizes $\Psi(\bullet)$, and define by $\ell(N)$, the difference in the maximized value of $\Psi(\bullet)$ and its value at arbitrary N. Accordingly, $\ell(N) \equiv \Psi(N^*) - \Psi(N)$ denotes dead-weight loss and we have, from totally differentiating and rearranging terms:

$$\textbf{Lemma}: \Delta\Psi(N) \gtrless \Delta\Psi(N^*) \Leftrightarrow \Delta\ell(N) \lessgtr 0.$$

The principal purpose of this note is to highlight the appeal of this result as a guide for public investment

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when market structure is at issue[2]. Specifically, I consider the nature of the shift in the marginal costs function and the conditions that are necessary for research to generate greater benefits in the presence of a distortion. To do so, we recast the discussion in the context of a continuum of Cournot equilibria. The exercise is productive for three reasons. First, it is timely due to intense interest in research-benefit calculations (see Alston et al. (1995) for a thoughtful review). Second, because pure competition and monopoly provide inaccurate depictions of most agricultural sectors, the extension to Cournot adds a degree of realism to a potentially sterile debate. Third, the analysis clearly and unambiguously demonstrates that particular types of innovations give rise to greater benefits when the market structure is imperfect. Specifically, under conditions that are almost identical to the ones considered by Voon (1994) and Sexton and Sexton (1996), pivotal shifts in marginal costs generate strictly greater benefits under monopoly. The intuition for this result is presented mathematically and diagrammatically, and a fundamental problem with the welfare calculations Voon (1994) and Sexton and Sexton (1996) is highlighted.

2. Demand, costs, and dead-weight loss

Voon (1994) and Sexton and Sexton (1996) consider a model with linear demand $\mathrm{p}(Q) \equiv a - \alpha Q$ and linear marginal costs $\mathrm{MC}(Q) \equiv b + \beta Q$, where Q denotes quantity and the parameters a, α, b and β are each non-negative. A comparison is made between the benefits accruing to monopoly and a market in which a single firm sets price equal to marginal cost. Crucial in later developments is the fact that, because the competitive equilibrium is synthesized through the behavior of a single firm, firm and industry costs are identical. The focus of attention is an innovation that causes a vertical, downwards translation of marginal costs that is, a shift $\Delta b < 0$. Since the two equilibria are linear, an explicit expression for dead-weight loss is available, namely (Sexton and Sexton, 1996, p. 202):

$$\mathrm{DWL} \equiv \frac{1}{2}\frac{\alpha^2(a-b)^2}{(2\alpha+\beta)^2(\alpha+\beta)} \qquad (1)$$

From inspection, this expression is declining with respect to parameter b. Therefore, reductions in its value cause dead-weight losses to increase, leading to the conclusion (and the correction of an error in Voon (1994)) that the benefits from research that lowers the value of b are greater under perfect competition than under monopoly. This result is important, and is, indeed, correct, under the assumptions employed. Little more can be said.

There is, however, another cost parameter upon which dead-weight loss depends and it seems natural, moreover thorough, to investigate this effect, even though it is ignored by Voon (1994, 1996) and Sexton and Sexton (1996). Specifically, interest may center on the effects of changes in the slope of marginal costs ($\Delta\beta < 0$). This effect is natural to consider because it simulates a similar innovation in the supply sector, but one in which the marginal-costs reduction increases in respect of scale. From the formula above, the effect on dead-weight loss of a reduction in β (like the reduction in b) is positive, implying that the benefits of innovations causing pivotal shifts are greater under competition than they are under monopoly. This conclusion is wrong.

3. Free-entry cournot equilibrium and pivotal shifts in marginal costs

Extending the analysis to Cournot equilibrium, we continue to employ $\mathrm{p}(Q) \equiv a - \alpha Q$ as the demand schedule and assume that per-firm, variable costs are $C(q) \equiv bq + (1/2)\beta q^2$, so that per-firm marginal costs are the same as in Voon (1994) and Sexton and Sexton (1996). Relegating details to an appendix, the dead-weight loss at arbitrary N is

$$\ell(N) \equiv \frac{(a-b)^2}{2\alpha}\frac{\alpha^2+\alpha(N+2)\beta+\beta^2}{(\alpha(N+1)+\beta)^2} \qquad (2)$$

Expressions (1) and (2) are the same at $B = 0$, $N = 1$, but they differ at other arbitrary values of B

[2] By rearranging terms in the definition of $\ell(N)$, we obtain $\Delta\Psi(N) = \Delta\Psi(N^*) - \Delta\ell(\mathrm{N})$, thereby articulating, mathematically, the claim in Sexton and Sexton, 1996, Footnote 2, p. 203), which is incorrectly attributed to a finding in a previous work, that "the benefits from research in the presence of a distortion are equal to the benefits in the absence of the distortion minus the increase in costs of the distortion due to the supply curve shift."

and N. This difference is important in research cost-benefit evaluation because it gives rise to an effect that reverses the sign of a comparative-static response. The difference between the two formulae stems from the fact that, whereas Voon (1994) and Sexton and Sexton (1996) model competition through the actions of a single firm, the present setting models competition as the limit of the sequence of Cournot equilibria. In the limit of this sequence, as N approaches infinity, each firm produces infinitesimal output and, therefore, industry marginal costs are constant. Put another way, in the competitive equilibrium parameter β has no impact on price, quantity or welfare. (This fact is readily observed from taking limits in the right sides of Appendix Eqs. (A.4)–(A.6) and (A.8) as N goes to infinity). Only in the imperfect market does β impact the loss. In the situation considered by Voon (1994) and by Sexton and Sexton (1996), marginal-cost pricing by the single competitor leads to a price that is higher than the limit of Cournot equilibria, to lower output, and to a different measure for dead-weight loss. This difference is important in light of the result that in order for monopoly to generate greater benefits the deadweight loss must decline.

Taking derivatives in Eq. (2) we obtain

$$\ell_b(N) \equiv \frac{-(a-b)}{\alpha} \frac{\alpha^2 + \alpha(N+2)\beta + \beta^2}{(\alpha(N+1)+\beta)^2} < 0 \quad (3)$$

and

$$\ell_\beta(N) \equiv \frac{-(a-b)}{2\alpha} \frac{N\alpha(\alpha(N+3)+\beta)}{(\alpha(N+1)+\beta)^3} > 0 \quad (4)$$

As before, vertical reductions in marginal costs cause dead-weight costs to rise, thereby generating greater benefits the more competitive the market. But now, pivotal reductions in marginal costs cause dead-weight losses to fall; the loss measure in Eq. (1) predicts that they will rise. The rationale for this difference is simple. It is presented in Fig. 1.

For simplicity, but without loss of generality, the figure compares the cases of pure monopoly and perfect competition. In addition, in order to avoid clutter, it is assumed that the innovation to marginal costs causes β to vanish. Demand is line(AE) and marginal revenue is line(AD). Prior to the innovation, marginal cost is line(BF) and after the innovation it is line(BE). In the pre-innovation situation, the monopolistic equilibrium is point(G) and in the post innovation situation it is point(F). Line segments (GE) and (FE) depict continuums of Cournot equilibria as firm numbers are increased, respectively, in the pre- and post-innovation settings. Both, however, have the same limit, which is point(E), and it is this fact, and this fact alone, that gives rise to the difference between the loss formulae. Thus, with reference to point(E), the dead-weight cost of monopoly prior to innovation is area(H + I + J + K), whereas, after the innovation it is area(K) a clear and unambiguous reduction in the amount area(H + I + J). This is the geometric interpretation of the result, in Eq. (4), that dead-weight costs fall when marginal costs pivot downwards.

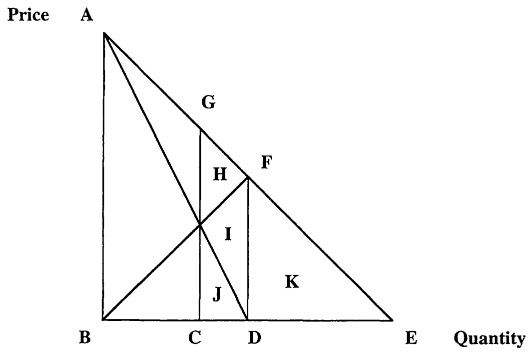

Fig. 1. Loss calculations for pivotal shifts in marginal costs.

In Voon (1994) and Sexton and Sexton (1996), single-firm, competitive-pricing predicts an initial equilibrium, point(F), that shifts to point (E) as a result of the innovation. Monopoly losses before the innovation are area(H). After the innovation they are area(K). Visually, area(K) exceeds area(H), but this will always be the case because the vertical height and horizontal base of the post-innovation triangle must always exceed those of the pre-innovation triangle. Accordingly, in the single-firm competitive-pricing model the effect on loss of pivotal reductions in marginal costs will always be positive, as predicted by Eq. (1). This difference between the two loss measures is further highlighted by the statement (Sexton and Sexton, 1996, p. 201).

> The marginal cost curve for producing the input is also linear... and can be interpreted alternatively as a monopolist's marginal cost curve or the aggregate marginal cost curve (i.e. supply) curve for a group of competitive producers.

This interpretation leads to false predictions about the benefits of research in non-competitive markets.

4. Conclusions

When competing projects target different markets, and the markets differ in structure, a question arises about the relationship between efficient allocations and the levels of the relevant distortions. This note has considered this issue against the backdrop of a recent debate, and a result relating the efficient-funds objective to the impact of research on dead-weight loss. The finding was formalized and used as a basis for an extension to Cournot equilibria. In this context, this *Comment* makes two points. The first is that a pivotal shift in marginal costs generates greater benefits under monopoly than it does under perfect competition. The second is that biases in benefit calculations arise from single-firm models.

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Appendix

Given their costs, firms $\{i_{i=1,2,\ldots,N}\}$ solve:

$$\max_{q_i} \pi(q_i) \equiv \left(a - \alpha\left(q_i + \sum_{j\neq i} q_j\right)\right) q_i - bq_i - (\tfrac{1}{2})\beta q_i^2 \tag{A.1}$$

taking as given the outputs of the $N-1$ rivals. The necessary condition,

$$\pi_{q_i}(q_i) \equiv a - \alpha\left(2q_i + \sum_{j\neq i} q_j\right) - b - \beta q_i = 0, \tag{A.2}$$

is also sufficient since the second-order partial derivative of $\pi(q_i)$, namely

$$\pi_{q_i q_i}(q_i) \equiv -(2\alpha + \beta) \tag{A.3}$$

is negative for positive α and β. At the symmetric point $q_1 = \cdots = q_N \equiv q$ and, thus, $Q = Nq$, a continuum of Cournot equilibria are defined by the solutions

$$q(N) = \frac{a-b}{\alpha(N+1)+\beta} \tag{A.4}$$

$$Q(N) = \frac{N(a-b)}{\alpha(N+1)+\beta} \tag{A.5}$$

$$p(N) = \frac{N\alpha b + a(\alpha+\beta)}{\alpha(N+1)+\beta} \tag{A.6}$$

Welfare, $\Psi(N)$, is the sum of consumer surplus plus profits of the N incumbents,

$$\Psi(N) \equiv \int_0^{Q(N)} D(s)\mathrm{d}s - NC(q(N)) \tag{A.7}$$

where $D(s) \equiv a - \alpha s$. Integrating and using (A.4), welfare at arbitrary N is

$$\Psi(N) \equiv \frac{(a-b)^2}{2} \frac{N(\alpha(N+2)+\beta)}{(\alpha(N+1)+\beta)^2} \tag{A.8}$$

whereupon, differentiation with respect to N yields

$$\Psi_N(N) \equiv (a-b)^2 \frac{2\alpha^2 + \alpha(N+3)\beta + \beta^2}{(\alpha(N+1)+\beta)^3} \tag{A.9}$$

so that welfare is monotonically increasing in N. Therefore, in order to define the loss we take the limit of the right side of Eq. (A.8) as N approaches infinity. Applying l'Hôpital's rule and subtracting the right-side of Eq. (A.8) from its value as N approaches infinity leads to text Eq. (2).

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