R & D INVESTMENT IN OLIGOPOLY: BERTRAND VS COURNOT

Flavio Delbono
Vincenzo Denicolò

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Abstract

Since the work of Schumpeter, it has been argued that there may exist a trade-off between static and dynamic efficiency. As a contribution to this debate, in this paper we compare the R & D performance of Cournot and Bertrand oligopolists. We model a one-shot noncooperative game in which firms invest in R & D, with the aim of being first in a competition for a patentable cost-reducing innovation. The incentives to innovate are expected market profits and not exogenously given prizes as in most of the earlier literature. We show that firms invest less in R & D in a Cournot market than in a Bertrand market. Thus, technological progress seems to be faster under Bertrand competition. However, when the number of firms is sufficiently high and the productivity of R & D expenditure is sufficiently low, Cournot competition in the product market yields a higher social welfare than Bertrand competition.

1. INTRODUCTION

In this paper we compare the Research and Development (R & D) investment under two alternative types of competition in the product market, Bertrand and Cournot. As is well known, the market equilibrium which results when firms compete in prices is, from a static viewpoint, more efficient than the Cournot equilibrium associated with quantity competition. However, it is an open question whether the same conclusion generalizes to a dynamic setting, for instance when technological improvements are in prospect, and the expected date of innovation depends on the R & D effort of the competing firms.

Since the work of Schumpeter [1943], it has been argued that society might benefit from sacrificing static efficiency for dynamic efficiency [1]. Contrasting a perfectly competitive market and a monopolised one, Schumpeter claimed that in the long run a monopolist may develop and employ a more advanced technology than that used by competitive firms [2]. This claim has attracted a great deal of attention. In a justly celebrated contribution, Arrow [1962] argued that the incentives to innovate are stronger for competitive than for monopolised industries, so that monopoly is likely to delay technical progress in addition to involving a static welfare loss. More recently, in two seminal papers Dasgupta and Stiglitz [1980 a, b] have ranked the equilibrium investment in R & D under three alternative market organizations, namely monopoly, perfect competition and a socially managed industry. They have shown that a monopolistic industry is less innovative than a perfectly competitive one, which in turn delays the expected date of innovation with respect to the social optimum [3].

These comparisons are obviously far from exhaustive. As a matter of fact, most R & D expenditure is made by oligopolistic firms [4]. However, it is not immediately evident how the intensity of rivalry could be measured in oligopoly. Loury [1979] and Lee and Wilde [1980] analyse an oligopolistic market with n firms. Regarding n as a proxy of the degree of rivalry, they study how an increase in n affect firms' investment in R & D. It turns out that the answer depends on the timing of R & D costs. Assuming that the R & D cost is a lump sum payed at the outset (contractual R & D costs), Loury shows that an increase in the number of firms reduces the equilibrium individual R & D effort. Lee and Wilde [1980] reformulate Loury's model assuming that the R & D expenditure is a flow cost that each firm pays until some player succeeds (non contractual R & D costs), and prove that an increase in the number of firms increases the equilibrium individual R & D effort [5].

However, neither Loury [1979] nor Lee and Wilde [1980] explicitely consider the product market. They model technological competition as a race where the prize accruing to the winner is exogenously given and is independent of the number of firms, and the losers get nothing. Furthermore, they do not take account of the possibility that before the innovation firms make positive profits.

This very particular specification of incentives and payoffs is appropriate if symmetric firms compete in prices in a homogenous product market, so that a Bertrand equilibrium results, under constant average and marginal production costs. Then, before the innovation -- when they share the same technology -- all firms make zero profits, and after the innovation the winner, which has reduced his own cost, will be the only active firm. However, such a symmetric Bertrand equilibrium in the product market is independent of the number of firms (as long as $n \geq 2$), so that n cannot be taken as a measure of the intensity of competition. Loury's and Lee and Wilde's comparative statics results are not therefore directly pertaining to the static vs dynamic efficiency controversy.

On the other hand, it is well known that, under some regularity conditions, the number of firms is a proper measure of the intensity of competition in the product market if firms are quantity-setting Cournot players. But in this case firms make positive profits in the pre-innovation symmetric market equilibrium with blockaded entry and, if the innovation is non drastic, in the post-innovation Cournot equilibrium they will still have positive (although different) market shares. Then, the Lee and Wilde results no longer apply and it can be shown that, even with non contractual R & D costs, the equilibrium R & D investment may be positively related to the number of firms (cf. Delbono and Denicolo' 1988). Thus, in a Cournot oligopoly there seems to be no definite relationship between the intensity of competition in a static sense and the speed of technological progress.

For any given finite number of firms, it is unambiguously true that price competition leads to a lower equilibrium price than quantity competition. Another way to contrast static and dynamic efficiency is therefore to ask whether the equilibrium R & D investment is greater under Bertrand or Cournot competition in the product market. In this paper we tackle this problem, and we show that Bertrand competition is not only statically more efficient, but is also more conducive to rapid technological progress than Cournot competition.

However, a more rapid technological progress does not need to be socially desirable. As a matter of fact, if there is Bertrand competition in the product market, then, as we shall show in Section 4, firms overinvest in R & D. This is the result of a 'duplication of effort' effect, which operates because only the firm innovating first benefits from the discovery. In a Cournot oligopoly, on the other hand, there may be both over and under investment with respect to the socially optimal level (cf. Delbono and Denicolò, 1988). It follows that there might be a conflict between static and dynamic efficiency, but this conflict arises for the opposite reason than that envisaged by Schumpeter: that is, because a more competitive market structure may waste more resources in the race for technological improvements.

Specifically, we shall show that social welfare, that is the discounted flow of consumers and producers' surpluses, net of R & D expenses, may be greater under Cournot competition than under Bertrand competition. This is more likely, the greater the number of firms and the lower the productivity of R & D expenditure.

The rest of the paper is organized as follows. In section 2 we present a general framework which allows us to derive an useful relationship between incentives and R & D investment. An immediate corollary of this result is that if the innovation is drastic the equilibrium level of R & D expenditure is greater under Bertrand competition than under Cournot competition. Within a simple linear model, the same conclusion is shown to hold when the innovation is non drastic (section 3). In section 4 a welfare analysis is performed, which shows that social welfare may be greater when firms compete in quantities in the product market. Finally, section 5 contains some concluding remarks.

2. A GENERAL FRAMEWORK

We consider a non cooperative R & D game played by n firms. Firms are competing in the product market, and are also competing for a cost reducing innovation. As far as the technological competition is concerned, we model a one-shot game, i.e. only one innovation is in prospect and it gives the winner the exclusive right to use forever a more productive technology. We assume that all firms have the same constant marginal and average cost before the innovation and the pre-innovation equilibrium in the product market is symmetric. The payoff of firm i (i=1,2,...,n) in the R & D game is given by the present value of expected future profits, net of R & D costs:

$$V_i = \int_0^{\infty} \exp[(-\Sigma_j h(x_j) - r)t][h(x_i)\pi_W^*/r + a\pi_L^*/r + \pi_i - x_i]dt - F$$

$$= \frac{h(x_i)\pi_W^*/r + a\ \pi_L^*/r + \pi_i - x_i}{r + a + h(x_i)}, \qquad (1)$$

where π_W^* is the flow of profits accruing forever to the firm which innovates first, i.e. the winner of the R & D race, π_L^* is the flow of profits accruing forever to the losers, π_i is the current profit of firm i, x_i is i's R & D expenditure, $h(x_i)$ is i's instantaneous probability of innovating, $a = \Sigma_{j\neq i} h(x_j)$ is the instantaneous probability that one of the (n - 1) rivals of firm i innovates, and r is the discount rate. For sake of simplicity, the hazard function $h(x_i)$ is assumed to be strictly concave and to satisfy the following conditions

$$h(0) = 0$$

$$\lim_{x_i \to \infty} h'(x_i) = 0$$

$$\lim_{x_i \to 0} h'(x_i) = \infty$$

These conditions guarantee that the maximisation problem will always yield an interior solution, and that the second order conditions are satisfied.

The first order condition for a maximum for firm i (i=1,2,....,n) is

$$[r + a][h'(x_i)\pi_W*/r - 1] - h'(x_i)a\pi_L*/r - h'(x_i)\pi_i +$$

$$- h(x_i) + x_i h'(x_i) = 0, \qquad (2)$$

which in a symmetric equilibrium, where a = (n-1)h(x), reduces (dropping the subscript i) to:

$$(n-1)(1/r)h(x)h'(x)(\pi_W* - \pi_L*) + h'(x)(\pi_W* - \pi) +$$

$$- [r + nh(x) - xh'(x)] = 0. \qquad (3)$$

Equation (3) determines the equilibrium value of the R & D expenditure x^. A "stability condition" of the model is that in equilibrium a marginal increase in R & D investment by any single firm causes the investment of each other firm to fall by a smaller amount. It can be shown [6] that this condition is equivalent to $\delta f/\delta x < 0$, where f denotes the L.H.S. of equation (3).

The first two terms which appear on the L.H.S. of equation (3) capture the incentives to innovate. One may distinguish two notions of incentives: the first one is the difference between the flow of profits accruing forever to the winner and those accruing to the losers; the second one is the difference between the prospective profits to the winner and his current profit. The former (i.e., $\pi_W* - \pi_L*$) reflects the presence of rivalry in the technological competition: each firm anticipates that, should it fail to innovate, other firms would succeed and gain a technological lead. Thus, this effects characterises situations of strategic interaction. The difference $(\pi_W* - \pi)$ measures the incentive to invest in R & D irrespective of the presence of rivals. This kind of incentive is the only one which appears in the decision theoretic approach to R & D [7].

As a preliminary result, we show that the R & D equilibrium investment is positively related to both incentives:

Lemma 1. The equilibrium R & D investment x^ is an increasing function of $(\pi_W* - \pi_L*)$ and $(\pi_W* - \pi)$.

Proof. Implicitly differentiating the equilibrium condition (3) one gets:

$$\frac{\delta \hat{x}}{\delta(\pi_W* - \pi_L*)} = - \frac{(n-1)\, h(x)\, h'(x)}{r(\delta f/\delta x)} > 0 ,$$

and

$$\frac{\delta x^{\wedge}}{\delta(\pi_W{*} - \pi)} = - \frac{h'(x)}{\delta f/\delta x} > 0 .$$

where we have used the stability condition $\delta f/\delta x < 0$. ▪

This result implies that in order to compare the effects on R & D investment of alternative market structures one can simply focus on the comparison between the incentives $(\pi_W{*} - \pi_L{*})$ and $(\pi_W{*} - \pi)$. Notice that under Bertrand competition $\pi_L{*} = \pi = 0$, so that the equilibrium condition (3) can be further simplified to

$$[(n-1)(1/r)h(x) + 1]\, h'(x)\, \pi_W{*} - [r + nh(x) - xh'(x)] = 0. \tag{4}$$

An immediate consequence of Lemma 1 is that if the innovation is drastic, which means that the post-innovation monopoly price is lower than the pre-innovation production cost, the equilibrium R & D investment is greater under Bertrand competition.

Proposition 1. If the innovation is drastic, the equilibrium R & D investment $x^{\wedge}$ is greater under Bertrand competition than under Cournot competition.

Proof. It suffices to note that, when the innovation is drastic, $\pi_W{*}$ is equal to the monopoly profit, and hence is independent of the type of competition in the product market, whereas $\pi_L{*} = 0$. Then $(\pi_W{*} - \pi_L{*})$ is independent of the market structure, and $(\pi_W{*} - \pi)$ is greater under Bertrand competition. Hence, the Proposition follows from Lemma 1. ▪

The intuition behind this result is fairly simple: under Bertrand competition the pre-innovation profit is zero, so that there is no 'replacement effect'. As is well known (cf. Fudenberg and Tirole, 1986, p.32), the replacement effect is due to the presence of positive current profits (as in the Cournot equilibrium) which induces firms to delay the expected date of innovation.

In the next section, we shall show that this result holds also for non drastic innovations. This will be done in the context of a simple model with a linear demand function.

3. BERTRAND VS COURNOT

In this section we compare the equilibrium of the R & D game resulting from price and quantity competition in a linear product market. Building on the results of section 2, we confine our attention to a comparison of the two incentives mentioned above in the two alternative market regimes.

We consider a market with a fixed number of firms, each producing a homogeneous good whose market demand function is

$$p = a - Q, \qquad (5)$$

where p denotes the price and Q is total output. Before the innovation, all firms produce at constant marginal and average cost c, $0 < c < a$. When firms compete in output levels in the product market a Cournot equilibrium is established. Then:

$$q_i = \frac{s}{n+1}, \qquad i=1,2,\ldots,n \qquad (6)$$

$$Q = \frac{ns}{n+1}, \qquad (7)$$

$$p = \frac{nc + a}{n+1}, \qquad (8)$$

where q_i is the output of firm i, and $s = (a - c)$ can be interpreted as a measure of the size of the market. In the symmetric Cournot equilibrium each firm earns profits per unit of time π given by

$$\pi = \frac{s^2}{(n+1)^2}. \qquad (9)$$

On the other hand, in a symmetric Bertrand equilibrium the price equals the marginal cost c and there are no profits.

Firms compete for an innovation which gives the winner the exclusive right to produce at cost $c^* < c$ forever. Since the case of a drastic innovation is already covered by Proposition 1, we consider a non drastic innovation, so that the winner does not get monopoly power; in other words, the post-innovation monopoly price is greater than the pre-innovation production cost. In our model this means that $c^* > 2c - a$, or

$$s > d, \qquad (10)$$

where $d = (c - c^*)$ denotes the cost improvement. This assumption implies that the losers of the R & D race, while continuing to produce at cost c, will remain active in the post-innovation Cournot equilibrium, though their market shares will shrink. More precisely, in the post-innovation Cournot equilibrium we have

$$q_W^* = \frac{s + nd}{n + 1}, \qquad (11)$$

$$q_L^* = \frac{s - d}{n + 1}, \qquad (12)$$

where W denotes the winner of the R & D game, L denotes the losers, and a star denotes post-innovation variables. From (11) and (12) it follows that

$$Q^* = \frac{ns + d}{n + 1}, \qquad (13)$$

$$p^* = \frac{a + nc - d}{n + 1}, \qquad (14)$$

$$\pi_W^* = \frac{(s + nd)^2}{(n + 1)^2}, \qquad (15)$$

$$\pi_L^* = \frac{(s-d)^2}{(n + 1)^2}. \qquad (16)$$

In the post-innovation Bertrand equilibrium, on the other hand, the price equals c and only the winner makes positive profits, given by

$\pi_W* = sd.$ (17)

We are now ready to prove the main result of this section.

Proposition 2. With a linear demand function, the equilibrium R & D investment $x^\wedge$ is greater under Bertrand competition than under Cournot competition.

Proof. In view of Lemma 1, we need only to compare the incentives to innovate under the two alternative market regimes. Under Cournot competition, from (15) and (16)

$$\pi_W* - \pi_L* = \frac{(s + nd)^2 - (s - d)^2}{(n + 1)^2},$$

and

$$\pi_W* - \pi = \frac{(s + nd)^2 - s^2}{(n + 1)^2},$$

whereas under Bertrand competition $\pi_W* - \pi_L* = \pi_W* - \pi = sd$, because $\pi_L* = \pi = 0$. Some algebra suffices to show that both incentives are greater under Bertrand competition. ∎

Notice that this result relies upon a comparison between symmetric Bertrand and Cournot oligopolies when only one innovation is in prospect. If there is a sequence of innovations, even if the market is symmetric at the outset, after the first innovation the symmetry will be broken, and the analysis will become much more complex. In a truly dynamic setting our result may therefore be reversed.

In an important work, Vickers [1986] models a finite sequence of deterministic technological races for non drastic innovations, and proves that Bertrand competition in the product market implies that an initial technological lead increases over time (Increasing Dominance). On the other hand, Cournot competition in the product market may give the higher cost firm a greater incentive to innovate, so that alternate winning (Action-Reaction) results [9]. It should be noticed, however, that in Vickers' model the timing of innovations is fixed and exogenously given, so that his framework is not suitable to analyse the effect of market structure on the pace of technological progress. To this end, Vickers' model should be reformulated so as to make the date of innovations dependent on the level of R & D expenditure.

4. WELFARE IMPLICATIONS

From Propositions 1 and 2 one may be tempted to conclude that Bertrand competition in the product market is both statically and dynamically superior to Cournot competition. This conclusion, however, does not necessarily follow, because a more rapid technological progress is not necessarily socially desirable: too many resources may be employed to be first in the R & D race.

Indeed, it can be shown that Bertrand competition always leads to overinvestment in R & D. This result is related to, but does not follow from, a similar result by Loury [1979] and Lee and Wilde [1980]. In their welfare analyses, both Loury and Lee and Wilde assume that the social benefit from the innovation equals the prize obtained by the winning firm. Then, the social planner maximises the difference between the discounted value of the social benefit flow and the total R & D cost. However, the equality of private and social benefits is broken in an oligopolistic market, where the private benefit from the innovation is given by expected profits, while the social benefit also includes consumers' surplus. Nonetheless, even if the socially optimal level of R & D expenditure is defined taking account of the true social benefit from the innovation, it turns out that Bertrand competition implies overinvestment with respect to the social optimum.

In determining the socially optimal level of R & D, we assume that the social planner can control the R & D effort of the n firms, but cannot directly affect the outcome of the competition in the product market. Also, there is perfect patent protection. Thus, the objective function of the social planner is given by the expected value U of the discounted flow of consumers and producers' surpluses over an infinite time horizon:

$$U = \int_0^{\infty} \exp[- H(x)t - rt] \, [H(x)W^*/r + W - nx] \, dt$$

$$= \frac{H(x)W^*/r + W - nx}{r + H(x)}, \qquad (18)$$

where $H(x) = n \; h(x)$ is the aggregate hazard function, the social discount rate equals the market interest rate r, W is social welfare (i.e., the sum of consumers and producers' surpluses) in the pre-innovation equilibrium, and $W*$ is the post-innovation social welfare.

In a Bertrand equilibrium with constant average and marginal production costs:

$$W = S, \qquad (19)$$

where S denotes consumers' surplus before the innovation, and

$$W* = \pi_w* + S, \qquad (20)$$

because the post-innovation Bertrand equilibrium price equals the higher (i.e., pre-innovation) cost.

Incidentally, notice that, given that there are decreasing returns in the R & D technology and firms are identical, it is socially efficient to spread total R & D effort uniformly across firms. The socially optimal level of R & D effort, denoted by x_s, is then the solution of the following first order condition

$$h'(x)\pi_w* - [r + nh(x) - nxh'(x)] = 0 \qquad (21)$$

Comparing (21) with (4), we can prove the following result.

Proposition 3. In a Bertrand **equilibrium**, the R & D investment of each firm is greater than the socially optimal level.

Proof. When $n = 1$, from (21) and (4) it follows that $x^\wedge = x_s$. Moreover,

$$\frac{\delta \hat{x}}{\delta n} = - \frac{[h'(x)\pi_S^*/r - 1]h(x)}{\delta f/\delta x} > 0 ,$$

by the "stability" condition $\delta f/\delta x < 0$, while

$$\frac{\delta x_S}{\delta n} = - \frac{xh'(x) - h(x)}{h''(x)\ (\pi_S^* + nx)} < 0$$

by the concavity of $h(x)$. This implies that $\hat{x} > x_S$ for $n \geq 2$. ■

Proposition 3 shows that under Bertrand competition in the product market there is an excess of R & D expenditure in equilibrium, which is not compensated (from the social welfare point of view) by the earlier expected date of innovation. On the other hand, under Cournot competition both over and under investment in R & D may occur (cf. Delbono and Denicolò, 1988, Proposition 8). Can the dynamic inefficiency associated with Bertrand competition offset the static gain from more intensive competition?

To answer this question, one has to compare the levels of net social welfare attained under Bertrand and Cournot competition, that is

$$U_B = \frac{H(x_B)W_E^*/r + W_B - nx_B}{r + H(x_B)} , \qquad (22)$$

and

$$U_C = \frac{H(x_C)W_C^*/r + W_C - nx_C}{r + H(x_C)} . \qquad (23)$$

Generally speaking, the comparison of U_B and U_C is very cumbersome. However, the economic intuition suggests that the greater the number of firms n, the more likely is that $U_C > U_B$. For, as n approaches infinite, the static welfare loss associated with Cournot competition becomes negligible, while the dynamic inefficiency associated with Bertrand competition increases, as the proof of Proposition 3 makes clear. Then, for n large enough, Cournot competition in the product market may yield a greater social welfare than Bertrand competition.

To provide an example, we specialize the model assuming a linear demand function as in section 3, and we further postulate the following well-behaved hazard function

$$h(x) = 2\,\mu\,\sqrt{x} , \qquad (24)$$

where μ is a positive parameter measuring the productivity of R & D expenditure. Then, we have

Proposition 4. With a linear demand function and the hazard function (24), if the number of firms is sufficiently large and $\mu < \sqrt{2}$, then social welfare is greater under Cournot than under Bertrand competition.

Proof. Letting n approach infinite, U_B and U_C tend to

$$U_B = \frac{sd + \frac{1}{2}s^2}{r} - \frac{x_B}{h(x_B)}$$

and

$$U_C = \frac{d^2 + \frac{1}{2}s^2}{r} - \frac{x_C}{h(x_C)},$$

respectively, where x_B is the solution of (4) in the linear case, and x_C is the solution of (3) in the linear Cournot case. As n approaches infinite, the solution of the equilibrium condition (3) tends to the value implicitly determined by the condition

$$\frac{1}{r} h(x)\ h'(x)\ (\pi_W* - \pi_L*) - h(x) = 0.$$

Thus, as n approaches infinite, x_B and x_C tend to the values determined implicitly by

$$h'(x_B) = \frac{r}{sd}$$

and

$$h'(x_C) = \frac{r}{d^2},$$

respectively, which, in view of (24), yield:

$$\sqrt{x_B} = \frac{sd}{\mu r}$$

and

$$\sqrt{x_C} = \frac{d^2}{\mu r} .$$

Hence,

$$U_C - U_B = \frac{d}{r} (s - d) \left(\frac{1}{2\mu^2} - 1 \right).$$

Clearly, then, $U_C - U_B > 0$ for $\mu < \sqrt{2}$. •

5. CONCLUDING REMARKS

In this paper we have set forth a simple model which allows us to tackle one of the most debated issues of the Schumpeterian legacy, that is, the trade-off between static and dynamic efficiency. We have considered an oligopolistic industry, contrasting two alternative market structures: the first one (Bertrand competition) is statically more efficient than the second one (Cournot competition). Then, we have shown the relationship between incentives to innovate and R & D investment (Lemma 1), and we have proved that price-setting firms invest more than quantity-setting firms when drastic as well as non drastic innovations are in prospect (Propositions 1 and 2).

This, however, does not imply that Bertrand competition is socially superior to Cournot competition. Actually, the welfare analysis carried out in section 4 shows that there may be a conflict between static (i.e., pertaining to the product market) and dynamic (i.e., pertaining to the technological competition) efficiency. However, the nature of this conflict is different from the one stressed by Schumpeter [1943]. According to Schumpeter, a less intensive competition in the product market will be associated to a faster pace of innovation, which he judged to be always socially desirable. In our model, on the contrary, since price-setting firms always overinvest with respect to the socially optimal level (Proposition 3), it could be the case that social welfare net of R & D expenditures is greater under Cournot than under Bertrand competition. This is more likely to occur, the greater the number of firms and the lower the productivity of R & D expenditure (Proposition 4). In other words, under Bertrand competition firms waste resources in an attempt to win the innovating race, and the resulting duplication is detrimental to social welfare.

Among the possible extensions and generalizations of our model, two seem worth mentioning. First, the analysis of the free-entry equilibrium where n is endogenously determined by the zero-profit condition, along the lines of Dasgupta and Stiglitz [1980 a, b] and Loury [1979]. Second, it would be interesting to compare the R & D performance of alternative market structures within a model in which a sequence of uncertain technological innovations are in prospect, as we mentioned in section 3. These kinds of long run analysis seem more appropriate to address issues of static vs dynamic efficiency in a Schumpeterian tradition.

FOOTNOTES

(1) "A system ... that at <u>every</u> point in time fully utilizes its possibilities to its best advantage may yet in the long run be inferior to a system that does so at <u>no</u> given point in time, because the latter's failure to do so may be a condition for the level or speed of long run performance" (Schumpeter 1943, p. 83).

(2) "The Schumpeterian hypothesis ... is that the presence of some monopoly power and the opportunity to realise some monopoly profits contribute to technical advance, whereas perfect competition now and in the future retards it ... . Thus technical advance appears to require the sacrifice of some allocative efficiency at each moment in time for the purposes of greater efficiency in the long run" (Kamien and Schwartz 1982, p. 216-7).

(3) See also Lee [1983], where it is shown that a monopolist underinvests in R & D with respect to a social surplus maximiser who controls both the production and the R & D decisions.

(4) See Dasgupta [1988, p. 71] for convincing arguments as to why "the economics of scientific and technological change perforce is concerned with oligopolistic industrial structure".

(5) See Reingamun [1984, p. 62] for an account of the intuition behind these conclusions.

(6) Cf. Delbono and Denicolò [1988, fn. 3].

(7) For an excellent survey of the decision theoretic approach see Kamien and Schwartz [1982, ch. 4].

(8) An implication of Vickers' result is that social welfare over a multi-period time horizon may be greater under Cournot competition (and Action-Reaction) than under Bertrand competition (and Increasing Dominance): cf. Delbono [1988].

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