DOES MONOPOLY PROMOTE INNOVATION? A THEORETICAL VINDICATION OF THE SCHUMPETERIAN HYPOTHESIS

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DOES MONOPOLY PROMOTE INNOVATION? A THEORETICAL VINDICATION OF THE SCHUMPETERIAN HYPOTHESIS

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Abstract. In this paper we reconsider the well known Schumpeterian hypothesis stating the superiority of monopoly over competition in generating fast technological progress. This hypothesis has been challenged by Arrow (1962) and Dasgupta and Stiglitz (1980), who have shown that a monopolist has lower incentives to innovate. After reassessing Arrow's and Dasgupta and Stiglitz's argument, we show that their conclusion can be reversed and the Schumpeterian conjecture can be confirmed. More precisely, if by "competitive industry" we mean a large Cournot market, then, for small innovations, we show that a monopolist invests in R & D more than such an industry.

Keywords: market structure, innovation

JEL Classification Numbers: L1, O3

1 INTRODUCTION

Few conjectures in economics have attracted more attention than the so-called Shumpeterian hypothesis. Schumpeter (1942) claimed that there exists a positive correlation between innovation and market power [1]. He argued that a monopolist may likely develop and employ a more advanced technology than that used by competitive firms. Hence, a less competitive market structure may lead to a faster pace of innovation, so that society might benefit from sacrificing static efficiency for faster technological progress.

This view has been challenged by Arrow (1962) and Dasgupta and Stiglitz (1980) (henceforth DS), who have shown that the incentives to innovate are stronger in competitive than in monopolised industries. This result seems to imply that, absent technological or financial advantages, monopoly is likely to delay technical progress in addition to involving a static welfare loss.

However, Arrow and DS's result is based on a particular assumption regarding the type of competition prevailing in the post-innovation equilibrium, i.e. Bertrand competition. In this paper we show that, if instead one assumes Cournot competition in the product market, then the Schumpeterian conjecture may be rehabilitated, at least for "small" innovations. That is, even if a monopolist does not enjoy any technical or financial advantage in the innovative activity, it may invest in R & D more than a competitive industry.

[1] An idea of the size of the empirical literature concerning the Schumpeterian hypothesis may be conveyed by the about fourty articles published in the period 1956-85 in four leading journals. For excellent surveys of this literature see Kamien and Schwartz (1982, ch. 2), Baldwin and Scott (1987) and Reinganum (1989).

The paper is organised as follows. In the next section we discuss the assumptions underlying Arrow's result. In section 3 we consider a simple example with a linear demand function, and we show that for "small" innovations the monopolist may have a greater incentive to innovate than a competitive firm (i.e., one that operates in a "large" Cournot market). In section 4 we embedd this insight into a fully fledged model of R & D competition, focusing on the case of a linear R & D technology. Under this assumption, we are able to derive a necessary and sufficient condition for a monopolist to invest in R & D more than a competitive industry. Section 5 concludes the paper.

2 REVISITING ARROW'S MODEL

In a classical piece, Arrow (1962) compared the incentive to undertake a cost-reducing innovation under monopolistic and competitive conditions. Production costs are assumed constant, and the incentive to innovate is defined as the difference between the post-innovation prospective profit and the current (i.e., pre-innovation) profit.

In a monopolistic market (assuming that only the monopolist itself may innovate), such an incentive is represented by the area below the marginal revenue curve, between the old cost level and the new one. In a competitive industry, the pre-innovation profit is zero, and the post-innovation profit (assuming price competition) is equal to the cost improvement times the pre-innovation total output [2]. A simple geometrical argument then shows that the incentive under competition is greater than under monopoly (DS, 1980, p.6).

This conclusion, however, heavily rests on a particular way of modeling competition in the product market. Clearly, there can be no ambiguity as far as monopoly is concerned, but the issue is more delicate when we come to "competition". Actually, the assumption of "competitive industry" cannot be taken literaly in the analysis of the post innovation scenario, as the innovating firm must necessarily enjoy some market power.

Arrow (1962) and DS assume that the winner exploits its market power engaging in limit pricing, so that the new equilibrium price equals the pre-innovation cost and only the winning firm is active. This is tantamount to assuming Bertrand competition in the product market.

However, it is possible to interpret the "competitive equilibrium" in a different way, assuming Cournot competition in the product market and taking the limit for n (the number of firms) approaching infinity [3]. As is well known, if the demand function obeys some regularity conditions, and if all firms share the same constant returns to scale technology, the Cournot equilibrium price smoothly converges to the production cost and individual profits go to zero as n goes to infinity.

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[2] This is true for non drastic innovations, i.e. when the post-innovation monopoly price is greater than the pre-innovation cost. For drastic innovation, the post-innovation profit is identical under monopoly and competition; but, since the pre-innovation profit is higher under monopoly, the incentive to innovate is again greater under competition.

[3] Earlier model of R & D competition between Cournot rivals are Horowitz (1963) and Scherer (1967). A more modern treatment of the same issue can be found in Spence (1984) and Delbono and Denicolò (1991).

As far as the pre-innovation equilibrium is concerned, there is no difference between the outcomes of Bertrand and Cournot competition with n "large". In the post innovation equilibrium, with Cournot competition and n "large", the price equals the pre-innovation cost and losers get nothing, like under Bertrand competition. But, contrary to the Bertrand case, the winner is no longer the only active producer (needless to say, this is true for a non drastic innovation). Indeed, when n tends to infinity, the market share of each individual loser tends to zero, but the aggregate market share of the (n-1) losers may tend to a positive value. As a consequence, the profits of the innovating firm are lower than under Bertrand competition [4].

It seems to us that, a priori, there is no reason to prefer either interpretation of the term "competitive industry" over the other. In this paper we explore the consequences for the Schumpeterian hypothesis of assuming Cournot competition plus n "large".

To begin with, in the next section we show how Arrow's conclusion can be modified when Cournot competition in the product market is assumed. To this end, we consider a simple example.

3 A LINEAR EXAMPLE

For sake of simplicity, hereafter we assume a linear market demand function. There are n firms producing under constant returns to scale, so that marginal and

[4] Obviously, the difference between the profits of the winner under Bertrand and Cournot competition increases as the number of firms decreases, and is highest in duopoly: see Delbono and Denicolò (1990).

average production costs are constant. In the product market, both before and after the innovation, each firm produces a homogenous good whose market demand function is $p = a - Q$, where p is price and Q is total output. Before the innovation, all firms produce at cost c, $0 < c < a$. We assume that the innovation gives the winner the exclusive right to produce at cost $c^* < c$ forever. We assume that the innovation is non drastic [5]. In the linear case this means that $c^* > 2c - a$, or:

(1) $$s > d$$

where $d = (c - c^*)$ denotes the cost improvement and $s = (a\text{-}c)$ is a measure of the size of the market. 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.

Cournot competition

Before the innovation, in the unique symmetric Cournot equilibrium, the price is:

(2) $$p = \frac{nc + a}{n + 1}$$

[5] By drastic innovation we mean a cost reduction which allows the winner to set a monopoly price lower than the pre-innovation cost. If the innovation is drastic, Bertrand competition and Cournot competition yield the same outcome (independently of n). Then, Arrow's result still applies. See footnote 2 above.

and each firm earns profits per unit of time given by:

(3)
$$\pi = \frac{s^2}{(n+1)^2}$$

Obviously, for $n \to \infty, p \to c$ and $\pi \to 0$.

In the post-innovation Cournot equilibrium, on the other hand, we have:

(4)
$$q_W = \frac{s+nd}{n+1}$$

(5)
$$q_L = \frac{s-d}{n+1}$$

where W denotes the innovating firm and L denotes any one of its (n-1) rivals [6]. Equilibrium price and profits are:

(6)
$$p = \frac{a+nc-d}{n+1}$$

[6] Notice that the market share of the winning firm is $(s+nd)/(ns+d)$. When n goes to infinity, this expression tends to $d/s < 1$.

(7) $$\pi_W = \frac{(s+nd)^2}{(n+1)^2}$$

(8) $$\pi_L = \frac{(s-d)^2}{(n+1)^2}$$

It can be easily checked that, when n goes to infinity, the post-innovation equilibrium price tends to the pre-innovation cost c, and π_L tends to zero. On the other hand, π_W tends to d^2.

Bertrand competition

Under Bertrand competition, the post-innovation equilibrium price equals the pre-innovation cost c, and the profits of the non-innovating firms vanish. The profit of the innovating firm is sd, which is greater than d^2 in the case of non drastic innovations (i.e. when $s > d$).

The reason why the innovating firm's profit is higher under Bertrand competition is that, while the price-cost margin is the same as under Cournot, the market share of the winning firm is equal to 1 in the former case, whereas it is d/s in the latter. Notice that in both cases "the winner takes all", in the sense that only the innovating firm makes positive profits; however, the prize is greater under Bertrand.

What does this imply as for the Schumpeterian hypothesis?

Under monopoly, the incentive to innovate is given by the increase in the monopolistic profits, i.e. $(d^2+2sd)/4$. In a competitive industry, on the other hand, pre-innovations profits are zero and therefore the incentive to innovate is given by the post-innovation profit of the winner. It follows that under Bertrand competition, since $(d^2+2sd)/4 < sd$, the incentive to innovate is greater in a competitive industry than under monopoly (recall that $s > d$). Under Cournot competition, on the contrary, the incentive to innovate will be greater under monopoly than under competition if:

(9) $$\frac{d^2+2sd}{4} > d^2$$

that is, if:

(10) $$\frac{d}{s} < \frac{2}{3}$$

Thus, if the innovation is sufficiently "small" relative to the market size, a monopolistic firm will have a greater incentive to engage in R & D investment than a firm operating in a competitive industry, where by "competitive industry" we here mean a "large" (i.e., $n \rightarrow \infty$) market where firms compete in output levels.

Arrow's conclusion may therefore be reversed. The intuition behind this result may be got noticing that d/s is the market share of the innovating firm in a large Cournot market. Thus, if this ratio is close to one, the outcome of Cournot competition is close to the Bertrand one (recall that the price-cost margin is identical in the two regimes) and is therefore larger than under monopoly. If, on the other hand, under Cournot competition the market share of the winner is lower than 2/3, the incentive to innovate falls below that of a monopolist.

However, the above setting is oversimplified and in particular it does not take into account the strategic interaction of firms in the R & D race. In a competitive setting, a firm may be induced to increase its R & D effort by the fear of being outperformed by one of its competitors. Moreover, even if any single firm under competition may undertake a lower R & D investment than the monopolist, it might so happen that the *aggregate* R & D effort be greater. To analyse these issues, one needs to model explicitly the R & D game.

Since our aim is to compare the effect on R & D investment of different market structures, a delicate issue arises. That is, to avoid spurious comparisons, our assumptions must be carefully chosen so as to make technological possibilities independent of the market structure. A very simple way to do this is to assume that constant returns to scale prevail in the R & D technology. To this case we now turn.

4 THE COMPLETE MODEL

In this section we model a fully-fledged two stage non cooperative game. There are n identical firms. Firms compete in the product market, and also compete for a cost reducing innovation. We shall analyse the subgame perfect equilibrium of the two-stage game, where firms compete in R & D in the first stage, and in output levels in the second stage.

Beyond modelling the strategic interaction between players, we enrich Arrow's model assuming exponential uncertainty. More precisely, the instantaneous probability of innovation (given no success to date) is taken to be an increasing function of the R & D effort. At the starting date ($t = 0$), firm i commits itself on an irreversible [7] investment in R & D x_i. Assuming a Poisson discovery process, the probability of being successful at or prior to date t is $1-\exp(-\mu x_i t)$. Thus, the conditional probability that firm i be first to innovate at time t, given no success to date, is μx_i. The hazard function is assumed to be linear because we wish to focus on the case of constant returns in the R & D technology, for reasons explained at the end of section 3. μ is a positive parameter measuring the productivity of R & D expenditure.

We assume that only one innovation is in prospect, which gives the winner the exclusive right to use forever a more productive technology. R & D investment affects the expected date of innovation, but does not affect its nature, nor downstream profits.

In the second stage of the game, firms compete in the product market. We model the product market just like in section 3: we assume a linear market demand function and constant marginal and average production costs. Then, under Bertrand competition, the innovation will be valued sd/r, where r is the (constant) discount rate; under Cournot competition and n large, it will be valued d^2/r.

[7] We follow Loury (1979) and DS (1980) formulation with "contractual" R & D costs. The more common formulation with "non contractual" costs (see Lee and Wilde (1980)) runs into problems in the case of constant returns to scale in the R & D technology, because then the firms' maximization problem does not yield an interior solution.

More generally, we shall solve the R & D game for any given number of firm n and then we focus on the two extreme cases $n = 1$ and $n = \infty$. When n is greater than 1 but finite, one has to take into account the current profits and the post-innovation profits for the losers as well. The payoff function of firm i is the present value of expected profits, net of R & D costs:

(11)
$$V_i = \int_0^\infty \exp\left[-\left(\sum_{j=1}^{n} \mu x_j + r\right)t\right]\left(\mu x_i \frac{\pi_W}{r} + a\frac{\pi_L}{r} + \pi_i\right) dt \quad - x_i \quad = \quad \frac{\mu x_i \pi_W / r + a\pi_L / r + \pi_i}{a + \mu x_i + r} - x_i$$

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 each loser, and π_i is i's current profit in the pre-innovation equilibrium. Moreover, $a = \mu \sum_{j \neq i} x_j$ is the instantaneous probability that one of the (n-1) rivals of firm i innovates.

Using the first order condition for a maximum for firm i [8] we get:

(12)
$$\mu(\pi_W - \pi) + a\frac{\mu}{r}(\pi_W - \pi_L) = (r + a + \mu x_i)^2$$

Focussing on the symmetric Nash equilibrium of the first stage of the game, one

[8] Notice that the second order condition is always satisfied. However, corner solutions may arise because of non-negativity constraints. We take care of this possibility when solving for the equilibrium values.

derives the following equilibrium condition:

(13)
$$\mu(\pi_W - \pi) + (n-1)\frac{\mu^2}{r}(\pi_W - \pi_L)x = (r + n\mu x)^2$$

Monopoly

Under monopoly, the second term on the l.h.s. of (13) vanishes. Moreover, we have $\pi_W = (s+d)^2/4$ and $\pi = s^2/4$, so that the above condition reduces to:

(14)
$$\mu\frac{2sd + d^2}{4} = (r + \mu x)^2$$

The equilibrium R & D effort of a monopolist firm is therefore:

(15)
$$x_M = \max\left\{0, \sqrt{\frac{2sd + d^2}{4\mu}} - \frac{r}{\mu}\right\}$$

Bertrand competition

Consider now the case of Bertrand competition in the product market. Here we have $\pi_L = \pi = 0$ and $\pi_W = sd$, independently of the number of firms (as long as $n \geq 2$). Equation (13) now becomes:

(16)
$$\mu sd + (n-1)\frac{\mu^2}{r}sdx = (r + \mu nx)^2$$

Let $y_B = nx_B$ denote the aggregate[9] R & D effort under Bertrand competition. Then, a simple inspection of expressions (14) and (16) shows that:

i) for $n=1$ [10], $y_B > x_M$;

ii) y_B is a strictly increasing function of n.

It follows that, under Bertrand competition, a competitive industry will unambiguously invest in R & D more than a monopoly. This confirms and strengthens Arrow's result. Not only every single firm under competition has a greater incentive to innovate but competition among laboratories further stimulates R & D investment.

Cournot competition

Let us now turn to the case of Cournot competition in the product market. In section 3 we have derived pre and post-innovation profits (see equations (3), (7) and (8)). Substituting these expressions into (13) we get:

(17)
$$\mu\frac{2nsd+n^2d^2}{(n+1)^2}+(n-1)\frac{\mu^2}{r}\frac{(n-1)d^2+2sd}{(n+1)}x=(r+n\mu x)^2$$

[9] Obviously, the expected time of innovation, which in this model is given by $1/n\mu x$, depends only on the aggregate investment.

[10] Clearly, in the case $n = 1$ one cannot speak of Bertrand competition and therefore equation (16) has no clear economic meaning. However, y_B is still well defined mathematically and this is what matters for our argument.

Equation (17) determines x as a function of n,s,d and θ, where $\theta = r/\sqrt{\mu}$. Let $x^*(n)$ be the strictly positive solution of (17) for a given n [11]. We can then easily derive the effects on the equilibrium R & D effort $x^*(n)$ of a change in the other parameters. For any n:

a) an increase in the cost improvement d will increase the equilibrium R & D effort;

b) an increase in the size of the market s will increase the equilibrium R & D effort [12].

When $n = 1$, i.e. under monopoly, we re-obtain equation (14) above.

In a perfectly competitive industry (i.e. when n approaches ∞), on the other hand, the individual R & D effort x goes to zero [13]. However, the aggregate R & D effort $y_C = nx_C$ tends to a finite limit implicitly given by:

(18)

$$\mu d^2 + \frac{\mu^2 d^2}{r} y_C = (r + \mu y_C)^2$$

Then, the aggregate equilibrium R & D effort of a competitive industry under Cournot

[11] Equation (17) always admits a negative root, which is economically meaningless. The other root may be positive or negative. When both roots are negative, the unique symmetric Nash equilibrium of the game involves zero R & D investment. It can be shown that the unique positive root, if it exists, corresponds to a stable equilibrium.

[12] These results parallel those holding in a similar model with non contractual R & D costs *à la* Lee and Wilde (1980) and a concave hazard function: see Delbono and Denicolò (1991).

[13] Intuitively, the reason is that the incentives to innovate tend to vanish.

competition is:

(19)
$$y_C = \max\left\{0, \frac{d^2}{r} - \frac{r}{\mu}\right\}$$

Comparing (15) and (19) it turns out that, when both y_C and x_M are strictly positive, y_C is greater than x_M if and only if

(20)
$$\frac{2d^2}{\sqrt{2sd + d^2}} > \theta$$

Notice also that y_C is strictly positive if and only if $d > \theta$, whereas x_M is strictly positive if and only if $\sqrt{2sd + d^2} > 2\theta$. Thus, for the equilibrium values y_C and x_M to be positive, θ must not be too large. On the other hand, inequality (20) can be reversed only if θ is large enough. So, what can be said about condition (20)? To answer this crucial question, we distinguish two cases: "small" and "large" innovations.

Case I (large innovations): $d > \frac{2}{3}s$.

In this case,

(21)
$$2d > \sqrt{2sd + d^2}$$

(recall that $s > d$) and therefore

$$\frac{2d^2}{\sqrt{2sd+d^2}} > d$$

(see figure 1). It follows that:

i) for $\theta < (1/2)\sqrt{2sd+d^2}$, $y_C > x_M > 0$;

ii) for $(1/2)\sqrt{2sd+d^2} \leq \theta < d$, $y_C > x_M = 0$;

iii) for $\theta \geq d$, $y_C = x_M = 0$.

Large Innovations: $d > \frac{2}{3}s$

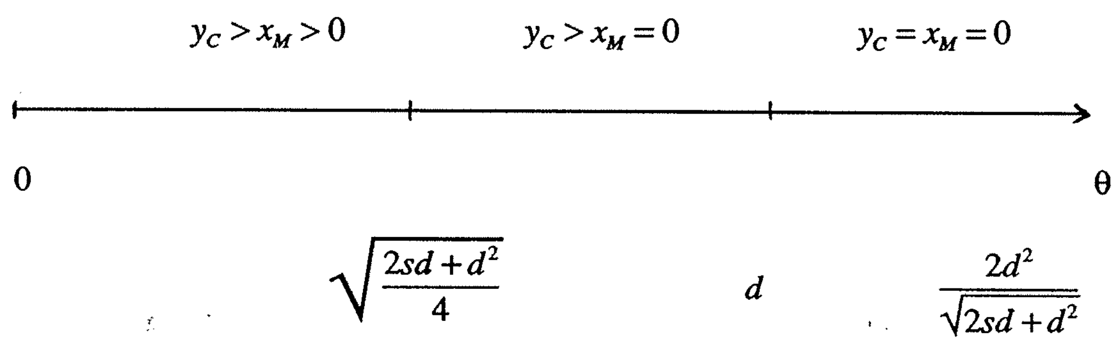

figure 1

The above results imply that, when the cost reduction is large with respect to the market size, condition (20) always holds, except when the discount rate is so high (or the productivity of R & D investment is so low) that no firm invests. This means that the aggregate R & D effort of a competitive industry is larger than a monopolist's one. The reason is that the individual incentive to innovate is greater under competition; moreover, competition in the R & D race stimulates investment. Hence, in this case Arrow's result is confirmed.

Case II (small innovations [14]*):* $d < \frac{2}{3}s$.

In this case,

(22)
$$2d < \sqrt{2sd + d^2}$$

and therefore

$$\frac{2d^2}{\sqrt{2sd + d^2}} < d$$

(see figure 2). It follows that:

[14] In the intermediate case (i.e, $d = \frac{2}{3}s$), it turns out that $y_C = x_M$ for any θ.

i) for

$$\theta \leq \frac{2d^2}{\sqrt{2sd + d^2}}$$

we have $y_C \geq x_M > 0$;

ii) for

$$\frac{2d^2}{\sqrt{2sd + d^2}} < \theta < d$$

we have $x_M > y_C > 0$;

iii) for

$$d \leq \theta < \sqrt{\frac{2sd + d^2}{4}}$$

we have $x_M > y_C = 0$;

iv) for

$$\theta \geq \sqrt{\frac{2sd + d^2}{4}}$$

we have $x_M = y_C = 0$.

Small Innovations: $d < \frac{2}{3}s$

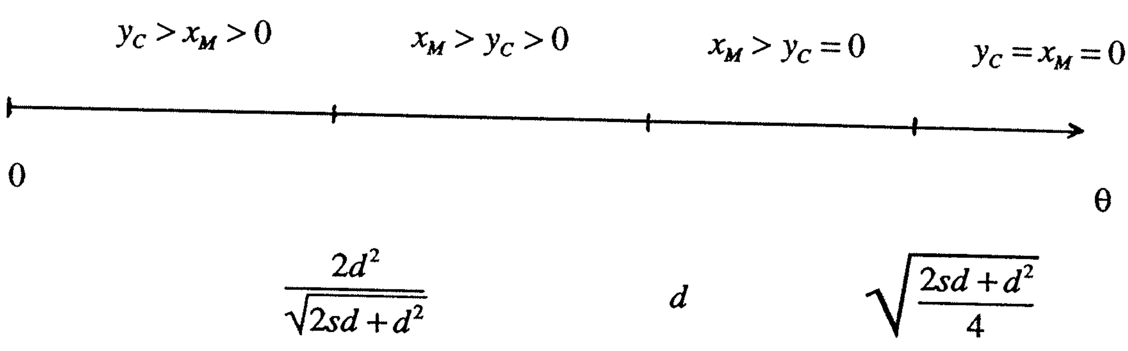

figure 2

The above results imply that, when the cost reduction is small with respect to the market size and the ratio between the discount rate and the square root of the productivity of R & D investment is sufficiently high (but not so high that no firm invests), the aggregate R & D effort of a monopolist may be larger than that of a competitive industry. Hence, in this case Arrow's result is disconfirmed and the Schumpeterian hypothesis is vindicated.

Thus, we have shown that Schumpeter's conjecture holds true under two conditions: first, the market share of the innovating firm must be lower than 2/3 (that is, the cost reduction must not be too large); second, θ must be sufficiently large. The first condition ensures that the individual incentive to innovate is larger under monopoly (see section 3).

As for the second condition, notice first of all that $\theta = r/\sqrt{\mu}$ can be interpreted as an "adjusted" discount rate, i.e. a discount rate corrected for the productivity of R & D investment. Clearly, low values of θ stimulate R & D investment.

However, a decrease in θ increases R & D investment under competition more than under monopoly. The reason is that in the R & D race there are "strategic complementarities" which make each firm's effort an increasing function of its rivals' effort [15]. Thus, there is a multiplicative effect due to the strategic interaction among firms (which is responsible for the well known "duplication of effort"). If θ is sufficiently low, this multiplicative effect (which operates only under competition) outweigths the difference in the individual incentives to do R & D. Thus, for low θ aggregate R & D investment is larger under competition, even if the individual incentive to innovate is lower than under monopoly.

But for larger values of θ the multiplicative effect induced by competition is dominated by the monopolist's larger incentive. In this case, the Schumpeterian conjecture is confirmed.

5 CONCLUDING REMARKS

In this paper we have investigated the relationship between R & D investment and market structure. Most of the large literature on this subject has been inspired by the celebrated Schumpeterian hypothesis, and has aimed at detecting, theoretically or empirically, whether Schumpeter (1942) was right in asserting the superiority of

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[15] This can be seen from equation (12), which shows that x_i is an increasing function of a (i.e., the aggregate investment of firm i's rivals).

monopolistic industries over competitive ones. Within this literature, the elegant and influential papers of Arrow (1962), Loury (1979) and Dasgupta and Stiglitz (1980) have provided interesting arguments to reject the Schumpeterian claim.

However, these arguments are based on the hypothesis that price competition prevails in the product market. This assumption, with or without technological uncertainty, seems to drive the conclusion that "competition" yields a greater incentive to innovate than a monopoly. If Cournot competition is the type of rivalry governing firms' interaction in the product market, however, the incentive can be greater under monopoly. In such a case, in fact, not only the individual incentive to innovate, but also the aggregate R & D investment can be greater under monopoly. This vindication of the Schumpeterian hypothesis turns out to hold for "small" cost reducing innovations. For large innovations, Arrow's result still holds.

Needless to say, there might be other reasons for a monopolistic industry to be more conducive to innovations than a competitive one. First, there may be increasing returns in the R & D technology. Second, the monopolist can enjoy financial advantages which enables it to bear the cost of larger R & D projects. Third, spillovers in the R & D activity or easy imitation can turn the R & D race into a waiting game, thus reducing the incentive to innovate of competitive firms. Though our model sidesteps these issues, we believe they are top-ranked in the agenda for future research.

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