COST REDUCING INPUTS, UNDERPRODUCTION AND ECONOMIC WELFARE

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Abstract

The object of this paper is to investigate social and strategic overinvestment in cost reducing inputs, when such investment enters directly in the other firms' objective function (public inputs). When externalities are introduced we isolate the trade-off between the degree of publicness of the input and the number of firms that determine its social excessiveness. In this respect it is shown that, for quite general demand structures and in Cournot competition, social overinvestment is ruled out for very low levels of the externalities, even if the number of firms is high. In Bertrand competition social overinvestment does not occur even when there are no spill-overs from the production of the public input.

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1 Introduction

In many models of oligopolistic competition the possibility of overinvestment with respect to different bench-marks has been noticed. The simplest example of this tendency is given by models where first period investment decisions of a firm affect the second stage behaviour of its competitors. For instance in homogeneous Cournot oligopoly there is a strategic incentive to overinvest with respect to the cooperative solution. The opposite holds when a Bertrand game is examined in which the reaction functions are upward sloping[1]. This overinvestment result does not allow one to draw unambiguous inferences on its impact in terms of welfare. In fact, if it is true that a positive strategic investment generally causes an increase in the consumer surplus, it also reduces the rival firm profits. The sign of the two combined effects on the total surplus cannot be determined in general.

Another area in which overinvestment has been often pointed out is the literature on Research and Development. Here R&D spending is often shown to be excessive with respect to the cooperative solution with too many firms competing, each investing too much. As Reinganum (1989), shows here the overinvestment thesis is explained by two factors. On one hand the firms do not take into account the reduction imposed in the rivals' expected value from R&D investment. Moreover, new entrants in the R&D competition do not consider the intertemporal efficiencies realizable investing at a lower rate over a longer planning horizon[2].

This notion of strategic overinvestment is however not only not completely satisfactory from a welfare point of view, but it also suffers from the limitation of an exogenously given number of firms. Recently, however, some contributions (Mankiw and Whinston (1986) and Suzumura and Kiyono (1987)), have drawn attention to the possibility that socially excessive levels of investment may arise in models that allow for free entry. In particular the first authors analyze a two stage game like the one described above for homogeneous oligopolies. They consider the second best problem faced by a public agency who can control the number of firms that enter the industry, but not their oligopolistic behaviour after entry. In such framework they show that the free entry assumption leads to excessive entry with respect to a social standard if the output price exceeds marginal costs and the outputs are strategic substitutes[3]. In other words, given those assumptions, when n is endogenously determined, the conditions that in the example above lead to strategic overinvestment in the Mankiw and Whinston model generate social overinvestment. Intuitively, the new firm's incentives to enter are higher than its marginal contribution to the total surplus. This is because the entrant does not take into account the reductions in output of the incumbent firms that accommodate the new entry. Those reductions decrease the overall efficiency of the industry when sunk costs are present and therefore negatively affect the total surplus.

The main object of this paper is to see if the overinvestment thesis has to be qualified when the first stage variable enters directly in the other firms' objective function (public inputs). It is reasonable, in fact that if the investment goods give rise to positive externalities, their welfare evaluation has to be reconsidered. In particular it can be expected that for some levels of such externalities and of the number of the firms in the industry under and not over-production arises from a welfare standpoint. Here the characteristics of the public input and of the oligopolistic competition that indeed cause such underproduction results will be depicted extending a recent work of Okuno-Fujiwara and Suzumura (1988). These authors, for purely private investment goods, have derived a method to determine the number of firms necessary to obtain overproduction for different demand curves and structures of the second period game. Such welfare criterion is set up in a second best world since the public agency is unable to force a competitive pricing in the second stage.

Allowing for the presence of externalities we isolate the trade-off existing between the degree of publicness of the input and the number of firms in determining the social excessiveness of its production. In this respect it is shown that in Cournot competition and with strategic substitutes, when the level of externalities increases, the number of firms that generate social overproduction rises more than proportionally. Secondly, under the same conditions, we find that strategic overinvestment is a necessary condition for social overinvestment to arise. Thirdly it is shown that in Cournot competition social overinvestment is ruled out for very low levels of the externalities. Finally, in Bertrand competition with strategic complements, social overproduction does not occur even when there are no spill-overs from the production of the public input.

In section 2 the homogeneous Cournot model is illustrated with an arbitrary number of firms and the criterion of social over or under production at the margin is introduced. In section 3 the production of the public input under monopoly, oligopoly and welfare maximizing agency are derived in order to isolate the notions of strategic and social over-production. A useful diagram is introduced in order to clarify the relation between the two concepts and the role of the externalities and of the number of firms in generating such over-production. In section 4 a different type of externalities generated by the public input is introduced in order to better understand the welfare properties of such input. In section 5 the Bertrand case is examined. Section 6 concludes with some comparisons with the existing literature.

2 The marginal criterion

In the second stage each firm produces the output q^i at the variable cost $C^i = c^i(G^i)q^i$. The cost of producing a unit of g^i is assumed to be one. The latter enters the cost functions according to the following expression:

$$G^i = g^i + \theta \sum_{i \neq j} g^j \qquad i = 1, .., n$$

where $0 \leq \theta \leq 1$ is, as before, the parameter that denotes the external effect of g on the rival firms' cost structure. It is further assumed that:

$$c^i_G < 0 \qquad \text{and} \qquad c^i_{GG} > 0. \qquad i = 1, .., n$$

The revenue function of the firm i is $r^i = q^i f(Q)$ where $Q = \sum_{i=1}^{n} q^i$ and its profits π^i are:

$$\pi^i = r^i(Q, G^i) - c^i(G^i)q^i - g^i \qquad i = 1, .., n$$

We assume that the outputs of the two firms are strategic substitutes. In other words an increase in the output of one firm reduces the marginal revenue of the other. The Nash equilibrium in the second stage is characterised by the following first order conditions:

$$\pi^i_i = r^i_i(Q, G^i*) - c^i(G^i) = 0 \qquad i = 1, .., n \qquad (1)$$

and second order conditions:

$$\pi^i_{ii} = r^i_{ii} < 0 \qquad i = 1, .., n$$

To ensure stability it is also assumed that there is a constant $\delta_0 > -\infty$ such that[4]:

$$\delta(Q) = \frac{Qf''(Q)}{f'(Q)} \geq \delta_0 \qquad \forall Q \qquad with \qquad f(Q) > 0 \qquad (2)$$

Throughout this paper we assume that the second stage equilibrium q^* are symmetric ($q^{i*}(G^i) = q^{j*}(G^j)$) for all i and j if the production of the public input is symmetric so that $G^i = G^j$ for all i and j. The first stage equilibrium g^* is also assumed to be symmetric ($g^{i*} = g^{j*}$) for all i and j, so that the subgame perfect equilibrium is symmetric. Totally differentiating (1) with respect to g^i, in view of our assumptions of symmetry, we obtain:

$$r_{ii}\frac{\partial q^i}{\partial g^i} + (n-1) r_{ij}\frac{\partial q^j}{\partial g^i} - c_G = 0$$

and $\qquad i \neq j = 1, .. n$

$$r_{ii}\frac{\partial q^j}{\partial g^i} + (n-2) r_{ij}\frac{\partial q^j}{\partial g^i} + r_{ij}\frac{\partial q^i}{\partial g^i} - c_G\theta = 0$$

where the subscripts indicate differentiation. From the expressions above it is easy to derive:

$$\frac{\partial q^i}{\partial g^i} = \frac{c_G(r_{ii} + r_{ij}(n-2) - r_{ij}\theta(n-1))}{S} \tag{3}$$

$$\frac{\partial q^j}{\partial g^i} = \frac{c_G(\theta r_{ii} - r_{ij})}{S} \tag{4}$$

where $$S = r_{ii}[(n-2)r_{ij} + r_{ii}] - r_{ij}[(n-1)r_{ij}] > 0$$

From (3) it follows that the Cournot-Nash equilibrium level of output is strictly increasing in g, recalling that $\theta \leq 1$. On the other hand the sign of (4) depends on the value taken by θ that is on the degree of "publicness" of the public input, according to the expression:

$$\frac{\partial q^j}{\partial g^i} \geq 0 \quad \Leftrightarrow \quad \theta \geq \frac{r_{ij}}{r_{ii}} \tag{5}$$

We also define $\frac{r_{ij}}{r_{ii}}$ as the degree of strategic susceptibility[5]. It measures how much change in the rival firms' output is induced by a unit of change in own output. As it becomes larger, a change in a firm's behaviour induces greater responses from the other firms and the amount of profit shifting becomes larger. If θ is higher than the degree of strategic susceptibility, an increase in the production of g^i shifts outwardly the reaction function of the other firms to such an extent as to increase their equilibrium outputs. If we indicate with k^i the profits of the firm i in the first stage, which embody the optimal choice of q in the following stage, we can write the objective function for the firm i as:

$$\max_{g^i} \quad k^i = r^i(Q^*(G)) - c^i(G^i)q^i - g^i \qquad i = 1, \ldots, n$$

where $G = \sum_i G^i$. The Cournot-Nash equilibrium in public input levels is characterized by the first order conditions:

$$k_i^i = r_j^i \frac{\partial q^j}{\partial g^i}(n-1) - c_G^i q^i - 1 = 0 \qquad i \neq j = 1, \ldots, n \tag{6}$$

It is assumed that the conditions - shown in Dixit (1986) - for an interior profit maximum hold.

The welfare criterion that will be used in the following section is the net surplus function evaluated at the second stage Nash equilibrium, which is defined as:

$$W(G) = \int_0^{Q^*(G)} f(Q)dQ - \sum_{i=1}^{n} [c^i(G^i)q^i + g^i] \tag{7}$$

Following Okuno-Fujiwara and Suzumura (1988), when $(\partial W / \partial G^i > 0)$, a marginal increase in the public input production at the subgame perfect equilibrium increases welfare so that such production is socially insufficient at the margin[6]. To have a better understanding of the economic variables influencing the sign of the derivative of the expression it is useful to decompose it into two terms that can be defined respectively as the distortionary and the strategic effects. Differentiating the second term of (7) with respect to g^i and using (1) and (6), the strategic effect can eventually be written as:

$$[(p - c^i)q_i^j(n-1)](1 + (n-1)\theta) \qquad i = 1, \ldots, n$$

where $q_i^j = \frac{\partial q^j}{\partial g^i}$. It indicates the amount of profit shifting caused by a marginal increase in the firm's i production of the public input. Its sign depends on the value taken by q_i^j that on its turn depend on the degree of "publicness" of the public input. If $\theta = 0$ the cross effect of a marginal increase in g^i on the rival firms' output is negative and so the strategic effect becomes negative too. Moreover, as we recall, the sign of q_i^j depends also on the degree of strategic susceptibility. As the latter becomes larger, a change in a firm's production of the public input induces greater responses from the other firms and the sign of the strategic effect is more likely to become negative.

Differentiating the first term in (7) it is possible to derive the distortionary effect as:

$$(1+(n-1)\theta)\sum_{j}(p-c^{j})\frac{\partial q^{j}}{\partial g^{i}}$$

that represents the consumer surplus' variations due to a marginal increase in the production of g^i. Its sign depends again on that of q_i^j, but also on that of q_i^i.

The sum of the strategic and distortionary effects can be expressed as:

$$\frac{\partial W}{\partial g^{i}}=(p-c^{i})[q_{i}^{i}+2(n-1)q_{i}^{j}](1+(n-1)\theta) \qquad i=1,..,n \tag{8}$$

From (8) it follows that social overproduction may occur only when increasing the production of g a firm shifts profits reducing the quantity of output produced by the rivals. However this is not a sufficient condition because the sign of (8) depends also on the number of the firms. It is also to be noticed that, given the expressions for q_i^i and q_i^j, the welfare criterion is well-behaving.

3 Social and strategic underproduction

In order to better understand the circumstances under which social overproduction may occur we will characterize the equilibrium production of g in a monopoly. This in order to specify the nature of the strategic overproduction and to highlight its role in explaining the occurring of the social overproduction. Assuming the same demand and cost structure that has been used for the oligopoly case, under monopoly the derivative of the profit function with respect to g is:

$$\frac{\partial \pi}{\partial g} = -c_g q^* - 1 \qquad (9)$$

where q^* is the output equilibrium level. The derivative of the welfare function with respect to g becomes:

$$[f(q^*(g)) - c]q_i^i - c_G q^* \qquad (10)$$

In the oligopoly case the marginal effects of g^i on the objective function are:

$$\frac{\partial k^i}{\partial g^i} = r_j^i q_i^j - c_g^i q^i - 1 \qquad (11)$$

that differ from condition (9) for the term $r_j^i q_i^j$. If $q_i^j < 0$ then there is overproduction with respect to the monopolistic case. This is due to the existence of profit shifting and therefore has been defined in the introduction as strategic overproduction. The amount of the latter is directly related with the term $r_j^i q_i^j$. Accordingly, if $q_i^j > 0$, a negative term is added to the equilibrium production of g under monopoly, and so strategic underproduction takes place. As we shown in expression (8), the existence of social over or underproduction of g depends on the sign of the following:

$$(f(Q^*(G)) - c)[q_i^i + q_i^j(n-1)] - c_G q^*$$

that differs from (10) for the term $(f(Q^*(G)) - c)[(n-1)q_i^j]$. A main conclusion can be drawn from these comparisons. The occurrence of strategic underproduction is a sufficient condition for social underproduction, whereas strategic overproduction is only a necessary condition for social overproduction. We are now ready to investigate more closely which are the values of θ and of the degree of susceptibility that determine the existence of strategic and social under or overproduction.

In the case of homogeneous output oligopoly, the following holds:

$$r_{ii} = 2f'(Q(G)) + f''(Q(G))q^i(G^i)$$

and (12)

$$r_{ij} = f'(Q(G)) + f''(Q(G))q^i(G^i)$$

.

From (2) and (12), (5) can be rewritten as:

$$q_i^j \geq 0 \quad \Leftrightarrow \quad n(2\theta - 1) - \delta(1 - \theta) \geq 0 \qquad (13)$$

Expression (13) shows that strategic overproduction is ruled out for any $\theta > 1/2$. Using an isoelastic demand function it is easy to derive that $-\delta = (\epsilon + 1)$. In (13) the number of firms above which strategic overproduction takes place depends ultimately on the elasticity of the demand curve and on the degree of publicness of the intermediate good.

Substituting (3) and (4) in (7) we end up with the following inequalities:

$$\frac{\partial W}{\partial g^i} \geq 0 \quad \Leftrightarrow \quad (2r_{ii}\theta - r_{ij}(1 + \theta))n + r_{ii}(1 - 2\theta) + r_{ij}\theta \geq 0 \qquad (14)$$

Using (2) and (12), we can rewrite (14) as:

$$\frac{\partial W}{\partial g^i} \geq 0 \quad \Leftrightarrow \quad n^2(3\theta - 1) + (2 - \delta + \theta(\delta - 3))n + (1 - \theta)\delta \leq 0$$

from which it is easily realized that when $\theta > 1/3$, $\partial W/\partial g^i > 0$ so that social overproduction is ruled out. When $\theta < 1/3$ it is possible to solve the expression above explicitly for n as:

$$n = \frac{(2-3\theta+\delta(\theta-1)) \pm \sqrt{9\theta^2+4+\delta^2(1-\theta)^2-12\theta+6\delta\theta(1-\theta)-4\delta(1-\theta)(1-(1-3\theta))}}{2(1-3\theta)} \tag{15}$$

The greater of the two solutions obtained in (15) gives the number of firms above which social overproduction arises for different values of the elasticity of demand. It is now possible to derive a first conclusion from the analysis pursued so far. Whatever functional form the demand curve takes, there are two different upper limits to the existence of strategic and social overproduction. More specifically the value of θ above which no social overproduction can take place (1/3) is smaller than the one that rules out the strategic overproduction (1/2).

The only way to derive the thresholds between over and under production in both the strategic and the social cases for different values of θ and ϵ is to solve (13) and (15) for different values of the two variables. The main results of this exercise are shown in table 1. In the latter the critical values of n above which overproduction occurs are shown for some significant values of θ and ϵ. In figure 1 these values are mapped in a (n,θ) space that allows for a more immediate understanding of the relations existing in general - but always with an isoelastic demand function - between the value taken by the parameter θ and the presence of overproduction.

There are five main features in the relation described in figure 1. First, the number of firms necessary to create both strategic and social overproduction is a monotonic and direct function of the degree of publicness of the intermediate good for any level of demand elasticity. Second, the social overproduction forms a subset of the strategic overproduction in the space (n, θ). Third, - coeteris paribus - the strategic and the social overproduction sets shrink when the elasticity of demand increases. In fact, when this happens the degree of susceptibility decreases and the incentive to produce g in order to shift profits from the rival firms becomes smaller. Fourth, for reasonably low values of θ and ϵ, the number of firms necessary to create social overproduction is considerably high. Finally, as noticed before, social overproduction is ruled out for values of $\theta > 1/3$ irrespective of the values taken by n and ϵ

4 The spill-over effect

Some of these results can now be compared with those obtained by Okuno-Fujiwara and Suzumura. In their paper they derive the position of the point A along the vertical axis, because they are interested in intermediate goods that have no spill-overs on the rival firms' cost structure. In the present model, it is possible to map the overproduction sets in the two-dimensional space (n, θ). This allows us to reconsider the general overproduction results, sketched in the introduction, when public intermediate goods are taken into account. However to make such comparison more meaningful we have to isolate the two effects that are at work when welfare comparisons are made on the equilibrium production of a public input. As shown in the previous section, in fact, both a strategic and a spill-over effects are present. The former can lead to either social over or underproduction depending on the value of θ. The latter always gives rise to social underproduction. In this section the strategic effect is isolated normalizing the spill-overs with respect to the number of firms, so that an increase in the latter does not raise the spill-overs. Accordingly the public input enters the cost function of the rival firms in the following way:

$$G^i = g^i + \theta \sum_j \frac{g^j}{(n-1)}$$

Following the same steps as in the previous section we have:

$$q_i^i = \frac{c_G(r_{ii} + (n-2)r_{ij} - \theta r_{ij})}{S'} \tag{3'}$$

$$q_i^j = \frac{c_G(r_{ii}\theta - (n-1)r_{ij})}{S'(n-1)} \tag{4'}$$

$$S' = [r_{ii}^2 + (n-2)r_{ii}r_{ij} - (n-1)r_{ij}^2]$$

and from the welfare criterion:

$$\frac{\partial W}{\partial g^i} = (p^i - c^i)[q_i^i + 2(n-1)q_i^j](1+\theta) \tag{8'}$$

We are now able to derive the conditions respectively for strategic and social overproduction:

$$n = \frac{1 - \delta + 2\theta + \sqrt{4\theta + 4\theta^2 + 1 + \delta^2 + 2\delta}}{2} \tag{13'}$$

and

$$n = \frac{2 + 3\theta - \delta + \sqrt{4 + 9\theta^2 + \delta^2 + 12\theta - 2\delta\theta}}{2} \tag{15'}$$

In table 2 are listed some values of n that generate overproduction when this version of the model is considered. As can be seen (see also figure 2), now only the first three features of the relation between n and θ pointed out in the last section hold. It is no longer true that for $\theta < 1/2$ and $\theta < 1/3$ respectively strategic and social overproduction are ruled out. Furthermore now the number of firms necessary to create social overproduction may be relatively small.

The introduction of externalities, whose spill-overs are limited as shown above, does not change significantly the results obtained in the private input case. There is indeed a direct relation between the number of firms that induces social overproduction and the degree of publicness, but even for $\theta = 1$ such number is relatively low, for any value of the elasticity of demand. Therefore it is the spill-over effect that is responsible for the impossibility of overproduction shown in the previous section.

5 Bertrand oligopoly

The Bertrand competition can be characterized in the second stage by output functions such as: $q^i = d^i(p(G^i))$ where $d^i_i < 0$, $d^i_j > 0$, $d^i_{ii} < 0$ and $d^i_{ij} > 0$ because they are assumed to be strategic complements. We keep the same assumptions on the cost reducing effects of g and on its own costs of production. The firm i maximizes its profits k^i:

$$\max_{p^i} k^i = p^i d^i(p(G^i)) - c^i(G^i)d^i(p(G^i)) - g^i \qquad i = 1,..,n$$

The Bertrand-Nash equilibrium is then defined by the following first order conditions:

$$\pi^i = d^i + (p - c^i)d^i_i = 0 \qquad i = 1,2 \tag{16}$$

Totally differentiating the former with respect to g^i and all g^j with $i \neq j$ we end up with the following expressions:

$$\frac{\partial p^i}{\partial g^i}=\frac{c_G^i((n-1)(2d_i^i-\theta d_j^i)+(p^i-c^i)[d_{ii}^i(n-1)-d_{ij}^i((n-2)-(n-1)\theta)])}{S}$$

$$\frac{\partial p^j}{\partial g^i}=\frac{c_g^j[(2\theta d_i^i(n-1)-d_j^i)+(p^j-c^j)(\theta d_{ii}^i(n-1)-d_{ij}^i)]}{S}$$

where (17)

$$S=[(2d_i^i+(p-c)d_{ii})(2d_i^i+(p-c)d_{ii})-(d_j^i+(p-c)d_{ij})(d_j^i+(p-c)d_{ij})]$$

That are both negative given our assumptions on d^i.

If we indicate with k^i the profits of the firm i in the first stage, its objective function becomes:

$$\operatorname*{Max}_{g^i} k^i=p(G^i)d^i(p(G^i))-c^i(G^i)d^i(p(G^i))-g^i \qquad i=1,..,n$$

and the Bertrand-Nash equilibrium in public input levels is characterized by the following first order conditions:

$$p_i^i[d^i+(p^i-c^i)d_i^i]+(p^i-c^i)d_j^i p_i^j-c_G^i d^i-1=0 \qquad i\neq j=1,..,n$$

As before we can write the total surplus function as:

$$W(G)=\int_0^{d(p^*)} p\,d(d(p^*))-\sum_j[c^j(G^j(g^i))q^j(g^j(g^i))-g^j] \qquad (18)$$

that derived with respect to g^i gives:

$$\frac{\partial W}{\partial g^i}=[(p-c)(d_i^i p_i^i+(n-1)d_j^i p_i^j)-c_G^i d^i](1+(n-1)\theta) \qquad (19)$$

where $p_i^i=\partial p^i/\partial g^i$ and $p_i^j=\partial p^j/\partial g^i$. Using (16), (19) can be rewritten as:

$$\frac{\partial W}{\partial g^i}=(p-c)d_i^i(1+(n-1)\theta)$$

that is always positive. Expression (19) is in fact the sum of the term expressing strategic underproduction plus a positive term that indicates the distortionary effect. It follows that under Bertrand competition overproduction can never occur under our assumptions on d^i, irrespective of the values taken by θ and ϵ

6 Conclusions

In this paper a criterion to verify the social insufficiency or excessiveness of the production of the public input is examined. In this respect the most relevant results are the following.

In a Cournot environment the presence of strategic overproduction is a necessary but not sufficient condition for social overproduction to occur. When complete spill-overs are assumed, no strategic overproduction takes place for $(\theta > 1/2)$. In the same conditions, only when $\theta < 1/3$ social overproduction may take place. Moreover, the number of firms necessary to have both strategic and social overproduction is - coeteris paribus - a direct function of the degree of publicness of the intermediate good and of the elasticity of the demand curve. In the Bertrand case no social overproduction at the margin can take place because both the distortionary and the strategic effects on the welfare function of a marginal increase in the production of g are positive. That is in line with the results of the previous chapter that show how the incentives for the private production of a public input are lower in Bertrand competition. As a whole the possibility of underproduction of the public input has been confirmed in the case in which more than two firms are present. Furthermore, an extension of the literature on the overproduction of cost reducing intermediate goods has been provided.

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Table 1		$\epsilon = 0.1$	$\epsilon = 1$	$\epsilon = 5$
$\theta = 0$	W_i	2.7	3.4	7.2
	$q^j{}_i$	1.1	2.0	6.0
$\theta = 0.1$	W_i	3.4	5.0	9.0
	$q^j{}_i$	1.4	2.3	6.8
$\theta = 0.25$	W_i	5.9	10.5	20.8
	$q^j{}_i$	1.8	3.0	9.0
$\theta = 0.33$	W_i	∞	∞	∞
	$q^j{}_i$	2.2	4.1	12.0

Table 2		$\epsilon = 0.1$	$\epsilon = 1$	$\epsilon = 5$
$\theta = 0$	w_i	2.69	3.41	7.16
	q^j_i	0.0	0.0	0.0
$\theta = 0.5$	w_i	4.35	5.01	8.50
	q^j_i	2.50	2.73	5.60
$\theta = 1$	w_i	5.76	6.37	9.78
	q^j_i	3.81	4.56	8.27

Endnotes

1. For an introduction to this literature see the survey of Shapiro (1989).

2. A serious limitation of the welfare implication drawn from most of the R&D models is that comparison with surplus maximizing standard in the rate of investment is often ambiguous. This is due to the fact that the overall quantity of R&D expenditure is reduced by the impossibility for the innovator to appropriate the full surplus. See Hirshleifer and Riley (1979).

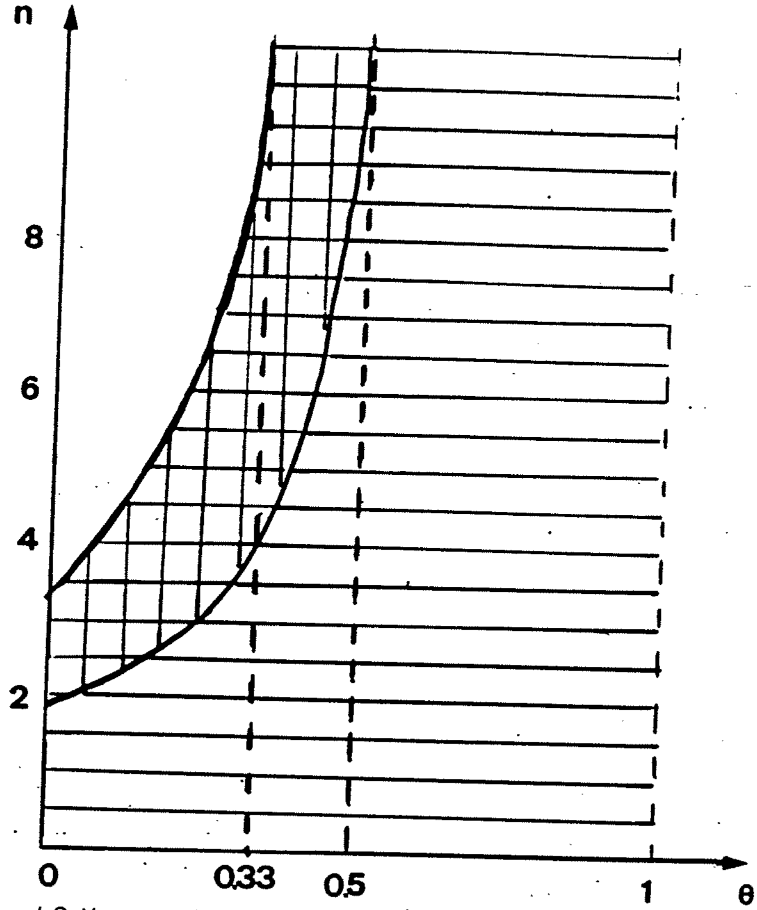
3. Suzumura and Kiyono (1987) have a somewhat different approach since they assume the existence of a first best social planner that can enforce the equality between price and marginal costs in the output market as well as determine the optimal entry. They show that the optimal number of firms in such first best world is smaller than the one when free entry is assumed.

4. Such condition is always satisfied by concave inverse demand functions. Concavity is often assumed in this literature to prove the existence and the stability of the Cournot-Nash equilibrium. See Dixit (1986).

5. As defined by Okuno-Fujiwara and Suzumura. Note the relation existing between the degree of susceptibility and the notion of substitutibility. In fact, the more the outputs are substitutable, the higher is the degree of susceptibility.

6. Problems may arise if the net surplus function is not concave. In that case the marginally welfare-improving adjustment would be a "wrong" adjustment from the viewpoint of global optimization of social welfare.

Fig. 1



- In both figures 1 and 2 the area below the upper curve indicates social underproduction and the area below the lower curve indicates strategic underproduction for Cournot equilibria with ε =1.Fig.1 is drawn for complete spillovers (sec.3.3) and fig.2 for weighted ones (sec.3.4).

Fig. 2