Delegation vs Cost-Reducing R&D in a Cournot Duopoly[1]

Luca Lambertini[#] - Gabriele Primavera[x]

Dipartimento di Scienze Economiche

Università degli Studi di Bologna

Strada Maggiore 45, I-40125 Bologna, Italy

fax +39-051-2092664

e-mail lamberti@spbo.unibo.it

§ e-mail gprimavera@hotmail.com

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Abstract

We describe a duopoly model where stockholders assess the relative profitability of delegation versus process innovation. Delegation may not be a dominant strategy. When it is, the game is not necessarily a prisoners' dilemma. Our model yields several equilibria where at least one firm remains entrepreneurial and finds it preferable to undertake cost-reducing R&D activities. Then, we introduce the possibility of using delegation and cost-reducing R&D jointly. The use of R&D investment by entrepreneurial firms is a dominated strategy, so that firms always separate ownership from control, while they don't necessarily combine delegation with process innovation.

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1 Introduction

Recent literature on oligopolistic interaction has treated separately two relevant issues, namely, (i) the incentive to separate ownership and control through delegation of the output or price decision to managers; and (ii) the incentive for pro…t-seeking …rms to activate R&D investments aimed at process or product innovation under either Bertrand or Cournot behaviour. Both approaches can be thought of as modelling cost-reducing activities, which respectively translate into an e¤ective reduction of marginal cost in the case of R&D, or into a perceived reduction in the case of delegation. Our aim is to model the stockholders' choice between R&D and delegation in a Cournot model.

As to the interplay between market competition and the internal organization of the …rm, several contributions show that, in order to acquire the Stackelberg leader's position in the product market, …rms' stockholders delegate the control over the marketing behaviour of …rms to managers[1] interested in maximizing an objective function consisting in a weighted sum of pro…ts and sales (Fershtman, 1985; Vickers, 1985; Fershtman and Judd, 1987; Sklivas, 1987; Fershtman et al., 1991; Polo and Tedeschi, 1992; Barcena-Ruiz and Paz Espinoza, 1996; 1999; Lambertini, 2000a,b). In the Cournot equilibrium, all …rms delegate control to managers in order to try and achieve a dominant position.[2] Each …rm would prefer the rivals not to delegate, the equilibrium being a¤ected by a prisoner's dilemma (Vickers, 1985). Basu (1995) extends the basic model to describe the owner's decision to hire a manager in a Cournot duopoly. He shows that a Stackelberg equilibrium may arise, with just one …rm delegating, even though the cost of hiring an agent is the same across owners.

[1] An alternative justi…cation for the use of delegation is given by Zábojník (1998). Shareholders may …nd it optimal to provide managers with incentives to maximise sales in addition to pro…ts if a double agency problem exists. In this case, the compensation contract not only affects executive's market decisions, but also provides a remedy to the underinvestment in human capital by workers.

[2] The incentive to hire managers not aligned with the owners' objectives may also derive from the owners' attempt at stabilising collusion (Lambertini and Trombetta, 2000).

As to the R&D behaviour of profit-seeking agents, Brander and Spencer (1983) and Dixon (1985) investigate the Cournot setting and Bertrand setting, respectively, finding that firms overinvest (respectively, underinvest) in cost-reducing R&D as compared to cost minimization if downstream competition takes place in quantities (prices).

We merge these two streams of literature in a single model where stockholders are assumed to evaluate the relative profitability of delegation versus process innovation. First, we investigate a game where delegation and R&D activity are alternative (i.e., mutually exclusive) strategies. This simple perspective enables us to produce equilibria where delegation is no longer a dominant strategy, and, whenever it is a dominant strategy, the associated equilibrium is not necessarily the outcome of a prisoners' dilemma. That is, our model yields several equilibria where at least one firm remains entrepreneurial and finds it preferable to undertake cost-reducing R&D activities. Hence, in general, we may expect that the strategic advantage generated by separation between ownership and control may be more than offset by other strategies leading to output expansion or equivalently to an increase in the market share of the firm adopting such alternative strategies.

Then, we consider a more realistic game where R&D and delegation can be combined so as to activate cost-reducing investments in a managerial firm. The main findings are that, in such a game, (i) the investment in cost-reducing R&D by entrepreneurial firms is a strictly dominated strategy; accordingly, it is never observed in equilibrium; (ii) firms always delegate control to managers, although they may not always undertake R&D investments, i.e., (iii) the joint use of delegation an R&D for process innovation is not necessarily an equilibrium strategy, due to the fact that the R&D investment may be too expensive.

The remainder of the paper is organized as follows. Section 2 introduces the basic setting. Section 3 deals with market subgames, given the stockholders' decision at the first stage. Section 4 illustrates the equilibrium analysis of the stockholders' game where either (i) delegation and R&D are mutually exclusive, or (ii) stockholders can combine delegation and cost-reducing investments. Section 6 contains concluding remarks.

2 The model

We adopt the same setup as in Vickers (1985). Two symmetric firms compete on a market for homogeneous products, supplying one good each. The inverse demand function is

$$p = A - Q \; ; \; Q = q_1 + q_2 \qquad (1)$$

In the remainder, we model the following story. Competition takes place in two stages. In the first, stockholders decide whether to delegated control to managers or to invest in cost-reducing R&D, or combine the two strategies. In the second stage, firms optimise simultaneously w.r.t. output levels, given the choices taken at the previous stage. This means that stockholders directly control output decisions if they have not delegated control to managers, while managers control the marketing behaviour in the opposite case where stockholders have delegated control to them (and may or may not have decided to invest in cost-reducing R&D).

We assume firms initially operate with the same technology, characterized by a constant marginal production cost c, which a firm may reduce to $\hat{c} \in [0; c)$ by investing in R&D an amount of resources equal to k: Firm i's profits are:

$$\pi_i = \begin{cases} (p - c)\, q_i & \text{if the firm does not invest} \\ (p - \hat{c})\, q_i - k & \text{if the firm does invest} \end{cases} \qquad (2)$$

In the remainder, we assume that the development cost k is sufficiently low to ensure positive profits to the firm undertaking the R&D activity, irrespective of whether the rival firm adopts the same strategy or instead separates ownership from control or adopts both strategies jointly.

Alternative or in addition to the R&D activity, firms' stockholders may decide to delegate control to managers who are not interested in profit maximization as such, as they own no share, but rather in sales, so that in case of managerialization firm i's maximand at the market stage modifies as follows:[3]

$$M_i = \pi_i + \theta_i q_i; \tag{3}$$

where parameter θ_i identifies the weight attached to the volume of sales, and is optimally set by the stockholder in the employment contract, in order to maximize profits (Vickers, 1985). Parameter θ_i is assumed to be observable.[4] Managerial remuneration is a two-part wage, where a component is exogenously fixed and the other is increasing in output (see Fershtman and Judd, 1987; and Basu, 1995).

In order to characterise the subgame perfect equilibrium of the two-stage game, we proceed by backward induction, solving first the market subgames given the decision taken by stockholders at the first stage. This is done in the following section.

3 Stage II: Market subgames

The symmetric subgames where both firms are either entrepreneurial (i.e., pure profit-seeking units) or managerial, can be quickly dealt with.

Consider first the setting where Cournot competition takes place between profit maximizers operating at marginal cost $\hat{c}$: In this case, profits amount to:

$$\pi^N(k; k) = \frac{(A - \hat{c})^2}{9} - k \tag{4}$$

for both firms. Superscript N stands for Nash equilibrium.

Now examine the setting where both firms keep the initial (symmetric) technology unaltered, and delegate control to managers operating the output decision with a marginal cost equal to c: In such a case, symmetric equilibrium profits are:

$$\pi^N(\theta; \theta) = \frac{2(A - c)^2}{25}; \tag{5}$$

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[3] Considering a linear contract only is restrictive, but this assumption is adopted for the sake of comparability with most of the existing literature.

[4] As shown by Katz (1991), if contracts were unobservable then delegation would have no effect on the equilibrium of the game, i.e., it would be the same as in the game without agents. See, in particular, Corollary 1 (Katz, 1991, p. 315). See also Barcena-Ruiz and Paz Espinoza (1996, p. 348). For a general approach to the issue of delegation, see Polo and Tedeschi (2000), where several results are shown to be robust to secret side-contracts.

the optimal extent of delegation being $\theta^N = (A - c)/5$ (see Vickers, 1985).

Now we are in a position to investigate the asymmetric case where firm i chooses to delegate while firm j remains entrepreneurial and invests the amount k in R&D.

At the second stage, the manager of firm i maximises $M_i(\theta; k) = \pi_i + \theta_i q_i$ w.r.t. q_i; while the owners of firm j maximises $\pi_j(k; \theta) = (p - \mathbf{b})\, q_j$. Notice that investment k is obviously irrelevant at this stage, as it does not enter firms' first order conditions, which are:

$$\frac{\partial M_i}{\partial q_i} = A - 2q_i - q_j - c + \theta_i = 0\,; \tag{6}$$

$$\frac{\partial \pi_j}{\partial q_j} = A - 2q_j - q_i - \mathbf{b} = 0\,. \tag{7}$$

Solving the system (6-7) yields optimal output levels:

$$q_i^N(\theta; k) = \frac{A - 2(c - \theta_i) + \mathbf{b}}{3}\,;\; q_j^N(k; \theta) = \frac{A - 2\mathbf{b} + c - \theta_i}{3} \tag{8}$$

generating the following profits:[5]

$$\pi_i^N(\theta; k) = \frac{(A - 2c + \mathbf{b})^2}{8}\,;\; \pi_j^N(k; \theta) = \frac{(A + 2c - 3\mathbf{b})^2}{16} - k\,. \tag{9}$$

Finally, we describe the case where firm i's stockholders both activate a cost-reducing investment and delegate control to a manager. Firm j can, alternatively, (i) remain entrepreneurial and reduce marginal cost to $\mathbf{b}$ by investing k; (ii) become managerial without investing in cost-reducing R&D; or (iii) replicate firm i's behaviour.[6]

In case (i), we have:

$$\pi_i^N(k\theta; k) = \frac{(A - \mathbf{b})^2}{8} - k\,;\; \pi_j^N(k; k\theta) = \frac{(A - \mathbf{b})^2}{16} - k\,; \tag{10}$$

[5] The optimal extent of delegation for firm i at the first stage is:

$$\theta_i^* = \frac{A - 2c + \mathbf{b}}{4}$$

[6] We omit the detailed illustration of calculations for the sake of brevity.

where $(k\mu; k)$ indicates that …rm i is managerial and invests in R&D, while …rm j is entrepreneurial and invests in R&D.

The relevant pro…ts in case (ii) are:

$$\pi_i^N(k\mu;\mu) = \frac{2(A+2c-3\mathbf{b})^2}{25} - k\ ;\ \pi_j^N(\mu;k\mu) = \frac{2(A+2\mathbf{b}-3c)^2}{25}: \qquad (11)$$

Equilibrium pro…ts in case (iii) are obviously as follows:

$$\pi^N(k\mu;k\mu) = \frac{2(A-\mathbf{b})^2}{25} - k: \qquad (12)$$

This concludes the description of market subgames. In the following section, we deal with stockholders' decisions at the …rst stage of the game.

4 Stage I: The stockholders' problem

Here we proceed in two steps. First, as an illustration, we consider the game where cost-reducing R&D and delegation are mutually exclusive strategies (possibly due to …nancial constraints). Then, we extend the analysis to allow for the possibility of using both strategies jointly. We label the two cases as game I and game II, respectively.

4.1 Game I

Using pro…ts (4), (5), and (9), we build matrix 1, yielding a reduced-form description of the …rst stage, where stockholders decide whether (i) to invest in cost-reducing R&D while keeping with them the control of the …rm's marketing decision, or (ii) to delegate control to a manager while keeping unchanged the …rm's technology represented by marginal cost c.

		2	
		k	µ
1	k	$\frac{(A-\mathbf{b})^2}{9} - k\ ;\ \frac{(A-\mathbf{b})^2}{9} - k$	$\frac{(A+2c-3\mathbf{b})^2}{16} - k\ ;\ \frac{(A-2c+\mathbf{b})^2}{8}$
	µ	$\frac{(A-2c+\mathbf{b})^2}{8}\ ;\ \frac{(A+2c-3\mathbf{b})^2}{16} - k$	$\frac{2(A-c)^2}{25}\ ;\ \frac{2(A-c)^2}{25}$

Matrix 1

The equilibrium outcome of the first stage of the game depends upon the sign of:

$$\pi^N(\theta;\theta) - \pi^N(k;\theta) = \frac{2(A-c)^2}{25} - \frac{(A+2c-3\beta)^2}{16} + k \tag{13}$$

and

$$\pi^N(\theta;k) - \pi^N(k;k) = \frac{(A-2c+\beta)^2}{8} - \frac{(A-\beta)^2}{9} + k\,: \tag{14}$$

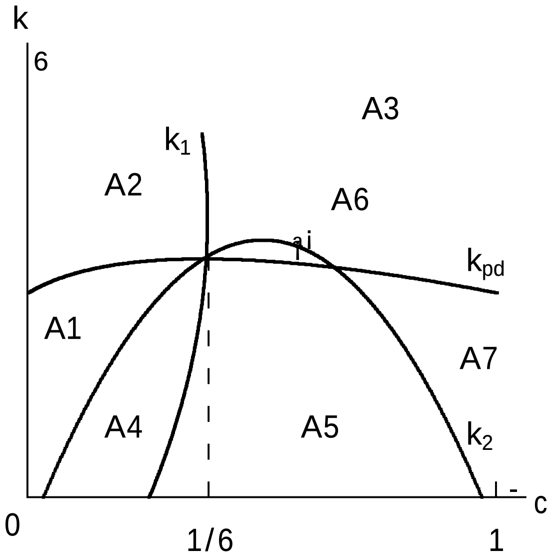
Moreover, the additional information concerning the sign of

$$\pi^N(\theta;\theta) - \pi^N(k;k) = \frac{2(A-c)^2}{25} - \frac{(A-\beta)^2}{9} + k \tag{15}$$

is relevant in order to establish whether the game is a prisoners' dilemma, in case the equilibrium outcome is symmetric and unique.

The solution of the game involves the evaluation of (13), (14) and (15) over the parameter space $\{A; c; \beta; k\}$: To obtain explicit solutions, we set $A = 1$; and $\beta = 0$; which involves no further loss of generality. This normalisation allows us to plot conditions (13), (14) and (15) in the space $\{c; k\}$; producing Figure 1.

Figure 1 : Equilibrium analysis. First stage, game I



Notice that, for $A = 1$; and $\beta = 0$; we have:

$$\pi^N(\theta;\theta) - \pi^N(k;\theta) > 0 \text{ if } k > \frac{4c(17c+41)-7}{400} \equiv k_1 \tag{16}$$

$$\pi^N(\theta;k) - \pi^N(k;k) > 0 \text{ if } k > \frac{36c(1-c)-1}{72} \equiv k_2 \tag{17}$$

$$\pi^N(\theta;\theta) - \pi^N(k;k) > 0 \text{ if } k > \frac{18c(2-c)+7}{225} \equiv k_{pd} \tag{18}$$

where subscript pd in (18) stands for prisoners' dilemma. Whenever a symmetric equilibrium arises, condition (18) determines whether the game is a prisoners' dilemma or not.

Without further discussion, we are now in a position to formulate the main results of our analysis:

Proposition 1 The Nash equilibrium at the first stage can be characterised as follows:

- In the parameter region A1, we have a prisoners' dilemma with both stockholders playing their dominant strategy θ:
- In the parameter region A2, the unique Nash equilibrium is $\{\theta;\theta\}$; and is also Pareto-efficient.
- In the parameter region A3, we have a chicken game with two Nash equilibria, $\{\theta;k\}$ and $\{k;\theta\}$:
- In the parameter region A4, we have a coordination game, with $\{k;k\} \succ \{\theta;\theta\}$:
- In the parameter region A5, the unique Nash equilibrium is $\{k;k\}$; and is also Pareto-efficient.
- In the parameter region A6, we have a prisoners' dilemma with both stockholders playing their dominant strategy k:
- In the parameter region A7, again we have a chicken game with two Nash equilibria, $\{\theta;k\}$ and $\{k;\theta\}$:

A few comments are now in order. First, the size of regions where at least one …rm chooses to conduct R&D in equilibrium is increasing in the e¤ectiveness of such activity, and decreasing in its cost, i.e., it is decreasing in both $\mathbf{b}$ and k. Second, when the stockholders' menu includes two strategies leading to output expansion (either due to a cost reduction through or to a perceived cost reduction through delegation), then, in contrast with Vickers's (1985) …ndings, delegation is not necessarily a dominant strategy any more. Finally, even when delegation is a dominant strategy, the associated equilibrium is not necessarily a prisoners' dilemma. Indeed, in region A2, bilateral delegation is observed in a subgame perfect equilibrium outcome which is also Pareto-optimal.

4.2 Game II

Now we extend the stockholders' perspective, to account for the possibility of activating R&D investments for process innovation and separating ownership from control. The issue at stake is whether the joint use of delegation and cost-reducing investments is necessarily going to be observed at equilibrium. The reduced form of the game is represented by matrix 2.

		2		
		k	µ	kµ
1	k	$\frac{(A-\mathbf{b})^2}{9}-k;\ \frac{(A-\mathbf{b})^2}{9}-k$	$\frac{(A+2c-3\mathbf{b})^2}{16}-k;\ \frac{(A-2c+\mathbf{b})^2}{8}$	$\frac{(A-\mathbf{b})^2}{16}-k;\ \frac{(A-\mathbf{b})^2}{8}-k$
	µ	$\frac{(A-2c+\mathbf{b})^2}{8};\ \frac{(A+2c-3\mathbf{b})^2}{16}-k$	$\frac{2(A-c)^2}{25};\ \frac{2(A-c)^2}{25}$	$\frac{2(A+2\mathbf{b}-3c)^2}{25};\ \frac{2(A+2c-3\mathbf{b})^2}{25}-k$
	kµ	$\frac{(A-\mathbf{b})^2}{8}-k;\ \frac{(A-\mathbf{b})^2}{16}-k$	$\frac{2(A+2c-3\mathbf{b})^2}{25}-k;\ \frac{2(A+2\mathbf{b}-3c)^2}{25}$	$\frac{2(A-\mathbf{b})^2}{25}-k;\ \frac{2(A-\mathbf{b})^2}{25}-k$

Matrix 2

First, notice that strategy kµ strictly dominates strategy k for all $\mathbf{b} \in [0; c)$: The intuition behind this result is the following. Since in these two cases …rms operate cost-reducing investments independently of whether they are managerial or entrepreneurial, the choice between these strategies depends upon the profitability of delegation in a game with symmetric marginal costs. Hence, exactly as in Vickers (1985), there emerges that delegation is a dominant strategy, all else equal.

Therefore, the game reduces to a 2×2 matrix defined by strategies θ and $k\theta$: The equilibrium behaviour of firms depends upon the following conditions:

$$\pi^N(\theta;\theta) - \pi^N(k\theta;\theta) > 0 \text{ if } k > \frac{6(2A + c - 3\beta)(c - \beta)}{25} \equiv k_3 \quad (19)$$

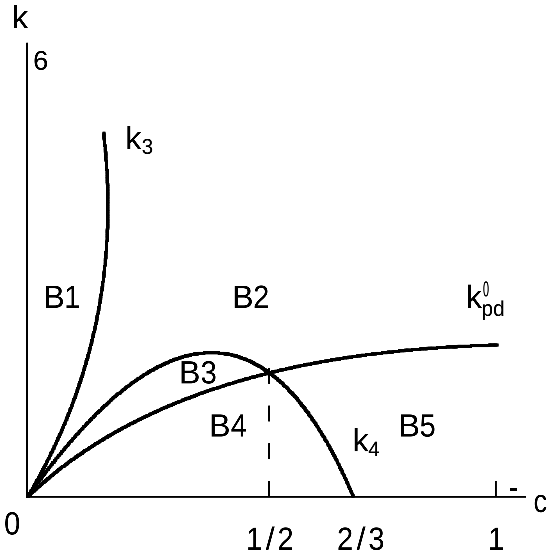
$$\pi^N(\theta;k\theta) - \pi^N(k\theta;k\theta) > 0 \text{ if } k > \frac{6(2A - 3c + \beta)(c - \beta)}{25} \equiv k_4 \quad (20)$$

The prisoners' dilemma condition writes as follows:

$$\pi^N(\theta;\theta) - \pi^N(k\theta;k\theta) > 0 \text{ if } k > \frac{2(2A - c - \beta)(c - \beta)}{25} \equiv k^0_{pd} \quad (21)$$

Once again, w.l.o.g. we set $A = 1$; and $\beta = 0$; which involves no further loss of generality. This allows us to plot conditions (19), (20) and (21) in the space $\{c; k\}$; yielding Figure 2.

Figure 2 : Equilibrium analysis. First stage, game II



The inspection of Figure 2 produces the following:

Proposition 2 The Nash equilibrium at the first stage can be characterised as follows:

- In the parameter region B1, the unique Nash equilibrium is $\{\mu, \mu\}$; and is also Pareto-efficient.
- In the parameter region B2, we have a chicken game with two Nash equilibria, $\{k\mu, \mu\}$ and $\{\mu, k\mu\}$.
- In the parameter region B3, we have a prisoners' dilemma with both stockholders playing their dominant strategy $k\mu$.
- In the parameter region B4, the unique Nash equilibrium is $\{k\mu, k\mu\}$; and is also Pareto-efficient.
- In the parameter region B5, we have a chicken game with two Nash equilibria, $\{k\mu, \mu\}$ and $\{\mu, k\mu\}$.

Hence, game II always entails managerialization, while allowing for asymmetric behaviour concerning R&D activity. Under this respect, it is worth noting that parameter regions B2 and B5 yield equilibria where firms' perceived technologies are asymmetric both because of asymmetric delegation contracts and because of unilateral R&D investments. This is an example of a situation where ex ante symmetric firms (i.e., both managerial) have asymmetric incentives towards process innovation.[7] Finally, there exists a parameter region (B1) where neither firm conducts R&D in equilibrium, as the investment is too costly. In this case, unlike game I, the equilibrium outcome $\{\mu, \mu\}$ is Pareto-efficient.

5 Concluding remarks

The acquired wisdom on strategic delegation maintains that separating ownership from control is a dominant strategy (Fershtman, 1985; Vickers, 1985; Fershtman

[7] Asymmetric R&D races have received relatively little attention in the existing literature. A relevant exception is Delbono and Denicolò (1991).

and Judd, 1987, inter alia). However, this literature has not assessed the interplay among delegation and other strategies that a firm might adopt to achieve a dominant market position.

Process innovation through R&D is one such activity. In a simple Cournot duopoly with homogeneous goods, we have investigated the relative profitability of delegation versus cost-reducing R&D investment, finding that delegation does not always emerge as the equilibrium strategy. Then, we have extended the analysis to allow for the possibility of using delegation and cost-reducing R&D jointly. In this case, there emerges that the use of R&D investment by entrepreneurial firms is a dominated strategy, so that firms always separate ownership from control, while they don't necessarily combine delegation with process innovation.

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