Cooperative Managerial Delegation, R&D, and Collusion

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Key words: Incentive scheme, managerial delegation, semi-collusion, R&D

JEL Classifications: L10, L13

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Abstract

Existing literature on managerial delegation indicates that collusive outcomes can be obtained in an oligopoly game through cooperative managerial delegation. In contrast, this paper shows that, if managers are delegated to choose R&D, in addition to choosing production levels, full-collusive outcomes *cannot* be achieved through cooperative delegation. Moreover, (a) under cooperative delegation, semi-collusion *always* yields lower profit, higher R&D, higher price, and lower social welfare than that in case of competition, and (b) cooperative delegation leads to higher profit, lower R&D, higher price, and lower social welfare than no delegation case, irrespective of product market conducts.

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1 Introduction

Strategic managerial delegation is a very common phenomenon in firms that faces oligopolistic market structure. Starting with Vickers (1985), Fershtman and Judd (1987), and Sklivas (1987), the literature on strategic delegation has been enriched by many studies, which examines implications of strategic delegation to various issues [1]. It is argued that, in case of Cournot type quantity competition, owners realize strategic advantage by inducing managers to be more aggressive in the product market. Moreover, in equilibrium, each firm offers a sales oriented incentive scheme and earns lower profit compared to that under standard Cournot competition. In other words, owners face a Prisoners' Dilemma type of situation while deciding incentive schemes, sales oriented vis-à-vis based on profit only, for managers and end up with Pareto inferior outcome. The fundamental assumption is that owners cannot coordinate with each other before designing managerial delegation contracts. On the other hand, it is easy to observe that owners can actually ensure collusive level of profits, if they can design delegation contracts cooperatively. In case of cooperative managerial delegation, the optimum incentive scheme will penalize sales maximization and over compensate managers at the margin of profit, which will induce managers to choose collusive level of quantity. This argument is valid in case of Bertrand like price competition too. However, this set of analysis considers only one strategic variable: price or quantity. Whereas, it is widely observed and also well documented in the literature that, other than production levels and prices, firms choose other strategic variables, such as R&D, advertising, capacity, quality, etc.. Therefore, the question is, can cooperative delegation lead to collusive level of profits, when firms compete in more than one dimension, e.g., investment in R&D and production level?

[1] For example, sequential entry (Church and Ware, 1996), mixed oligopoly (White, 2001), equivalence of price and quantity competition (Miller and Pazgal, 2001), mergers (Gonzalez-Maestre and Lopez-Cunat, 2001; Ziss, 2001), cartel stability (Lambertini and Trombetta, 2002), choice of incentive scheme (Jansen et al., 2007), wage bargaining (Szymanski, 1994), delegation to bureaucrats (Basu et al., 1997), trade policy (Das, 1997), environmental damage control (Barcena-Ruiz and Garzon, 2002), to name a few.

A sizeable literature has been emerged recently that analyses collusive behaviours of firms in all or some aspects of interactions in oligopolistic market structure. Contrary to conventional wisdom, it is argued that collusive behaviour may not lead to higher profits compared to competition. For example, Fershtman and Gandal (1994) shows that, if the cost of investment in R&D is lower than a critical level, collusion only in the product market will lead to lower profits than that under competition. Brod and Shivakumar (1999) have extended the analysis to a differentiated-products oligopoly model with the possibility of spillover effect of R&D, and find the same result, if the degree of product differentiation and spillover effect are not very high. The intuition behind this apparently surprising result is, when firms choose both R&D and production levels as strategic variables, collusion in the product market alone leads to fierce competition in investing in cost reducing R&D, which strengthens firms to protect or enhance their share in the product market. As a result, if the cost of R&D is relatively low, firms end up investing in R&D excessively, which is wasteful and leads to lower overall profits. Although this strand of literature examines firms strategic behaviours in a more general setup, it sidesteps the issue of managerial delegation in firms.

Recently, Zhang and Zhang (1997) examine the effects of strategic delegation on equilibrium outcomes, where firms choose both R&D and level of production non-cooperatively. They argue that low spillover of R&D induces managers to invest more in R&D to gain competitive advantage in the product market, and that inducement is further aggravated by sales-oriented incentive contract for managers. As a result, managerial delegation will lead to higher R&D investment, higher output, and lower profits in equilibrium compared to no delegation case, if spillover effect of R&D is small. We note that Kopel and Riegler (2006) show that results of Zhang and Zhang (1997) may not hold true always. Nonetheless, Zhang and Zhang (1997) provide the basic framework to analyse the issue and have opened up an interesting avenue of research. Following Zhang and Zhang (1997), Lambertini and Primavera (2001) examines relative profitability of delegation versus process innovation, and Krakel (2004) examines the role of strategic delegation and R&D in case of oligopolistic contests. However, to the best of our knowledge, the issue of semi-collusion under managerial delegation have not received much attention in the literature so far.

In this paper, we first attempt to analyse whether cooperative managerial delegation can ensure collusive level of profits in a setup where managers are delegated to choose both the level of R&D and production in an oligopolistic environment. The sequence of events that we consider is as follows. In the beginning of the game, owners of firms cooperatively decide the incentive scheme, a linear combination of profits and sales, for risk-neutral managers and delegate the choice of R&D investment and level of output. Managers decide the level of investment in R&D non-cooperatively before they engage in Cournot type quantity competition in the product market.

Next, we turn to the issue of profitability under semi-collusion. In order to do so, we deviate from the initial setup by allowing managers to collude in the product market. We also examine individual effects of cooperative delegation and semi-collusion on profit, R&D, output, and social welfare, by comparing equilibrium outcomes in alternative scenarios.

We find that, if there is an additional strategic variable, R&D, other than output, owners cannot ensure full-collusive level (collusion at both R&D and output decision stages) of profit through cooperative managerial delegation. This result is in sharp contrast to that in case of single strategic variable (output or price). The reason is, when there are more than one aspect of interaction, optimum strategies of different stages of interactions affect each other, and managers' decisions at both stages get affected by the incentive scheme. To illustrate it further, note that investment in R&D in one firm will have positive impact on its own output, and negative impact on rivals' output. Therefore, if the incentive scheme induces managers to choose a particular level of output, that will also distort the choice of R&D investment that may not be desired to ensure full-collusive level of profit. Upon inspection, we find that the investment in R&D is higher, and both output and profit are lower under cooperative delegation compared to that under full-collusion case. Moreover, both the choice of R&D and output under delegation move in the same direction due to a change in the incentive parameter. As a result, owners cannot induce managers to choose both R&D and output at the full-collusive level.

We also show that cooperative delegation leads to higher profit, less investment in

R&D, less output, and lower social welfare, irrespective of whether managers collude in the product market or not, compared to no delegation case. These are opposite to the corresponding equilibrium outcomes under non-cooperative managerial delegation as in Zhang and Zhang (1997). The intuition behind this finding is, through cooperative delegation contract, owners try to induce managers to act less aggressively in the product market and that also acts as a disincentive for managers to invest more in R&D.

Comparing equilibrium outcomes, in case of cooperative managerial delegation, under semi-collusion vis-à-vis competition, we find that semi-collusion is detrimental for firms, even if the cost of investment in R&D is high. Possible reason behind it is, when owners design delegation contracts cooperatively, semi-collusion leads to sufficiently large investment in R&D that more than offsets the gain from collusion in the product market, irrespective of the cost of investment in R&D. This result is in contrast to that of Fershtman and Gandal (1994), which argues that semi-collusion is detrimental only if the cost of investment in R&D is lower than a critical level. We also find that, in case of cooperative managerial delegation, semi-collusion leads to lower output and lower social welfare compared to that under competition.

The rest of the paper proceeds as follows. The next section briefly analyses the role of cooperative managerial delegation on equilibrium outcomes when firms do not undertake R&D activity. Section 3 presents the basic model and compares equilibrium outcomes under cooperative delegation with that of full-collusion case. Section 4 examines the effects of semi-collusion under cooperative delegation. Comparison of equilibrium outcomes under cooperative delegation vis-à-vis no-delegation is presented in Section 5. Section 6 concludes.

2 Collusive profit through cooperative delegation

In this section we analyse the role of cooperative delegation in a setup similar to Fershtman and Judd (1987). We consider an industry where two firms, firm 1 and firm 2, produce homogeneous products and compete in terms of quantity in the product market. We assume that the demand function is given by, $p = 1 - q_1 - q_2$, where p is the price of output, and

q_1 and q_2 are outputs of firm 1 and firm 2 respectively. Production technologies of both the firms are assumed to be identical, and the marginal cost of production is constant c $(0 < c < 1)$. Firms do not undertake any R&D activity.

Owners of both firms hire managers and delegate them to take decisions concerning output. Owners know that managers are risk-neutral and they will engage in Cournot type quantity competition in the product market. Thus, given the incentive structure, which is a linear combination of profits and sales, managers will maximize $O_i = \alpha_i \pi_i + (1 - \alpha_i) p q_i$, $i = 1, 2$, where π_i is the profit of firm i and α_i is the incentive parameter set by firm i.

Unlike Fershtman and Judd (1987), we assume that owners can communicate with each other before deciding incentive schemes for managers. Therefore, the stages of the game are as following. In stage 1, owners cooperatively decide the incentive parameter so that profit is maximized. In stage 2, each manager chooses quantity, simultaneously and independently, to maximize the incentive scheme, given the incentive parameter. We solve this game by backward induction method.

It is straight forward to see that, in stage 2, the reactions functions of managers of firm 1 & 2 are, $q_1 = \frac{1-q_2-c\alpha_1}{2}$ and $q_2 = \frac{1-q_1-c\alpha_2}{2}$, respectively, which are similar to equation (3) of Fershtman and Judd (1987). Solving these two equations we get, $q_1 = \frac{1-2c\alpha_1+c\alpha_2}{3}$ and $q_2 = \frac{1-2c\alpha_2+c\alpha_1}{3}$.

Now, in stage 1, owners choose incentive parameter(s) by maximizing the joint profit $(\pi_1 + \pi_2)$, given the optimum strategies of managers in stage 2. Solving owners problem, we get $\alpha_1 = \alpha_2 = \frac{3c+1}{4c} = \alpha$, say, since firms are symmetric. As $\alpha > 1$, in equilibrium, owners penalize sales maximization and overcompensate managers at the margin of profit, which is exactly opposite to that under non-cooperative managerial delegation. The equilibrium incentive scheme induces managers to be less aggressive in the product market and ensures that managers find it optimum to choose collusive level of outputs, $q_1 = q_2 = \frac{1-c}{4}$. Hence, in equilibrium, firms earn collusive level of profits, $\pi_1 = \pi_2 = \frac{(1-c)^2}{8}$.

Proposition 1: Owners of firms can ensure collusive level of profits, in equilibrium, by designing the incentive scheme for managers cooperatively. The optimum incentive scheme penalizes managers for sales maximization and over compensates at the margin of profit.

3 R&D and output: delegation versus full-collusion

We consider a duopolistic industry in which firms produce homogeneous products and engage in Cournot type quantity competition. The market demand is given by $p = 1 - q_1 - q_2$; where p is the price of output, and q_1 and q_2 are outputs of firm 1 and 2, respectively. Firms also invest in cost reducing R&D before engaging in production activity. Each firm has a cost of production $C_i(q_i, x_i) = (c - x_i)q_i$, $i = 1, 2$, $0 < c < 1$; where $x_i \leq c$ is the amount of investment in R&D, and q_i is the output produced by firm i. The cost of investing x_i is given by $\frac{1}{2}rx_i^2$. For the sake of simplicity, we assume that $\frac{1}{3} < c < 1$ and $r > 1$.[2]

Owners of each firm delegates the decisions concerning R&D and output to managers. Managers are risk-neutral and are offered the incentive scheme, a linear combination of own profit and sales revenue, $O_i = \alpha_i \pi_i + (1 - \alpha_i)pq_i$. We assume that owners design the managerial delegation contract cooperatively, i.e., they cooperatively decide incentive parameters α_i, $i = 1, 2$, so that profit is maximized. Clearly, given the incentive parameter, manager of firm i will try to maximize O_i. We also assume that managers compete both in R&D and in output stages. We will refer this case as 'cooperative delegation and no collusion' (DNC in short) The stages of the game are as follows.

Stage 1: Owners design the managerial delegation contract cooperatively.

Stage 2: Managers of each firm decide the level of investment in R&D, simultaneously and independently.

Stage 3: Managers are engaged in Cournot type quantity competition in the product market.

We calculate the subgame perfect Nash equilibrium (SPNE) using standard backward

[2]These parametric restrictions ensure that equilibrium outcomes are positive in all cases that we have analysed in this paper.

induction method. Given, α_1, α_2, x_1, and x_2, the Cournot Nash equilibrium in Stage 3 is given by,

$$q_{i,DNC}(x_i, x_j, \alpha_i, \alpha_j) = \frac{1}{3}\{1 - 2(c - x_i)\alpha_i + (c - x_j)\alpha_j\}, \;\; i, j = 1, 2, \;\; j \neq i, \tag{1}$$

the subscript DNC denotes cooperative delegation and no-collusion, i.e., competition in both Stage 2 and Stage 3.

Given the Stage 3 strategies $q_{i,DNC}(x_i, x_j, \alpha_i, \alpha_j)$, managers compete in terms of investment in R&D in Stage 2. The equilibrium investment in R&D in Stage 2 is given by,

$$x_{i,DNC}(\alpha_i, \alpha_j) = \frac{4[3r + (3cr - 4)\alpha_j + \alpha_i(4c\alpha_j - 6cr)]}{3r(9r - 8\alpha_j) - 8\alpha_i(3r - 2\alpha_j)}, \;\; i, j = 1, 2, \;\; j \neq i \tag{2}$$

Given (1) and (2), owners choose α_1 and α_2 cooperatively. That is, in Stage 1, owners choose incentive parameter(s) such that the joint profit, $\pi_1(\alpha_1, \alpha_2) + \pi_2(\alpha_1, \alpha_2)$, is maximized. Since firms are symmetric, in equilibrium, owners will choose the same incentive parameter (α), which implies that $x_{i,DNC}(\alpha) = \frac{4(1-c\alpha)}{9r-4\alpha}$ and $q_{i,DNC}(\alpha) = \frac{3r(1-c\alpha)}{9r-4\alpha}$. So, the equilibrium outcome in Stage 1 is given by,

$$\alpha_{1,DNC} = \alpha_{2,DNC} = \frac{9(1 + 3c)r - 8}{4(9cr + c - 3)} = \alpha_{DNC} \tag{3}$$

Now, from (1), (2), and (3) we derive the SPNE outcomes of the game as given in Lemma 1. [3]

Lemma 1: Under cooperative managerial delegation, when managers compete in both aspects, choice of the level of investment in R&D and the choice of the level of production, the equilibrium incentive parameter, investment in R&D in each firm, output of each firm, price, profit of each firm, and social welfare (sum of consumer surplus and profits) are are as following: $\alpha_{DNC} = \frac{9(1+3c)r-8}{4(9cr+c-3)}$, $x_{DNC} = \frac{3(1-c)}{9r-2}$, $q_{DNC} = \frac{9(1-c)r}{36r-8}$, $p_{DNC} = \frac{9(1+c)r-4}{18r-4}$, $\pi_{DNC} = \frac{9(1-c)^2 r}{8(9r-2)}$, and $SW_{DNC} = \frac{9(1-c)^2(27r-4)r}{8(2-9r)^2}$.

[3]Second-order condition, in Stage 2, requires $0 < \alpha_{DNC} < \frac{9r}{8}$. It is easy to check that, if $r > 1$ and $\frac{1}{3} < c < 1$, equilibrium outcomes are positive, and also $x_{DNC} < c$ holds true. $18cr > 5(1+c)+\sqrt{25c^2 - 14c + 25}$ ensures second-order condition in Stage 2.

It is easy to check that $\alpha_{DNC} > 1$. Therefore, in equilibrium, owners induce managers to be less aggressive in the product market, by penalizing managers for sales maximization through the optimum incentive scheme. As a result, equilibrium outcomes under cooperative managerial delegation move, from that in case of no delegation, in the opposite direction to that under non-cooperative delegation as in Zhang and Zhang (1997).

Now, we characterize the equilibrium outcomes under full-collusion (FC), i.e., collusion in both in both stages: R&D stage and output stage. Since, in this case, there is no scope of strategic interaction, managers will be asked to maximize profits only. In other words, owners will set the incentive parameter (α) equal to one, which is, in some sense, synonymous to no managerial delegation. The equilibrium outcomes under full-collision are given in Lemma 2.

Lemma 2: In case of full-collusion, the optimum R&D in each firm, output of each firm, price, profit of each firm, and social welfare are, respectively, $x_{FC} = \frac{1-c}{4r-1}$, $q_{FC} = \frac{r(1-c)}{4r-1}$, $p_{FC} = \frac{2r(1+c)-1}{4r-1}$, $\pi_{FC} = \frac{r(1-c)^2}{2(4r-1)}$, and $SW_{FC} = \frac{r(1-c)^2(6r-1)}{(1-4r)^2}$. The subscript FC denotes full-collusion.

Comparing Lemma 1 and Lemma 2 yields the following proposition.

Proposition 2: In case of cooperative delegation and no-collusion, firms invest more in R&D, produce less output, earns lower profit, and leads to lower social welfare compared to full-collusion case, i.e. $x_{DNC} > x_{FC}$, $q_{DNC} < q_{FC}$, $\pi_{DNC} < \pi_{FC}$, and $SW_{DNC} < SW_{FC}$.

Note that $Sign\ [\frac{\partial}{\partial\alpha}\{x_{i,DNC}(\alpha)\}] = Sign\ [\frac{\partial}{\partial\alpha}\{q_{i,DNC}(\alpha)\}]$. Therefore, if there is any change in the incentive parameter (α) from the equilibrium value (α_{DNC}), choice of both R&D and output will be distorted and the interaction effect between the managers' optimum responses in R&D and output choice is such that both R&D and output choice will be distorted in the same direction from respective equilibrium values. Clearly, it is not possible for owners to induce managers to choose full-collusive level of R&D and output. If owners compel managers, through the incentive scheme, to choose full-collusive level of R&D, it is optimum for managers to choose a lower level of output compared to unrestricted case (q_{DNC}), since the effective marginal cost of of production, $\alpha(c - x_{DNC}(\alpha))$, increases due to the distortion in optimum incentive parameter that reduces investment in R&D from x_{DNC} to x_{FC}. On the other hand, if owners compel managers to choose full-collusive level of output (q_{FC}), which is higher than q_{DNC}, managers will invest more in R&D, since that reduces effective marginal cost of production. Moreover, there doesn't exist any feasible combination of R&D and output, which leads to full-collusive level of profits, that owners can compel managers to choose. Therefore, due to interdependence of managers' optimum strategies in different aspects of competition, R&D and output, owners can never ensure collusive level of profit even if they design managerial delegation contract cooperatively. This is in sharp contrast to Proposition 1.

Proposition 3: Owners cannot ensure full-collusive level of profits through cooperative delegation, if managers compete in both R&D and output stages.

Proof: Since firms are symmetric, in case of cooperative delegation and no collusion (DNC), owners will choose the same incentive parameter (α, say). Therefore, the the profit expression of each firm in Stage 3 can be written as $\pi_{DNC}(\alpha) = \frac{r(1-c\alpha)[4+(9-27c)r+2\alpha\{c(4+9r)-6\}]}{(9r-4\alpha)^2}$. On the other hand, optimum profit of each firm in case of full-collusion is $\pi_{FC} = \frac{2r(1+c)-1}{4r-1}$. So, to ensure full-collusive level of profit in case of DNC, owners need to set the incentive parameter, α, such that $\pi_{DNC}(\alpha) = \pi_{FC}$ holds true. Solving this quadratic equation in α, we get, $\alpha = \frac{12-12r+c[-4+r\{-65+9c+36r(1+3c)\}]\pm(1-c)(4-9cr)\sqrt{-(4r-1)}}{16+4c[-2+r\{-24+c(7+36r)\}]}$, which are imaginary, since $(4r-1)$ is positive. Therefore, it is not possible for owners to ensure full-collusive level of profit through cooperative delegation.

To illustrate it further, note that $x_{DNC} > x_{FC}$ and $q_{DNC} < q_{FC}$. Now, in case of DNC, if owners choose α, such that $x_{DNC}(\alpha) = x_{FC}$, the incentive parameter will be given by, $\frac{4(1-c\alpha)}{9r-4\alpha} = \frac{1-c}{4r-1}$; which implies $\alpha = \frac{(7+9c)r-4}{16cr-4} = \alpha_R$, say. It is easy to check, $q_{DNC}(\alpha_R) = \frac{3r(1-c)}{16r-4} < q_{DNC}$ and $\pi_{DNC}(\alpha_R) < \pi_{DNC} \Rightarrow \pi_{DNC}(\alpha_R) < \pi_{FC}$.

Alternatively, in case of DNC, if owners choose α such that $q_{DNC}(\alpha) = q_{FC}$, we have $(c - x_{DNC}(\alpha))\alpha = (c - x_{FC}) \Rightarrow \alpha = \frac{-4-16r+23cr+36cr^2\pm\sqrt{144cr(4r-1)(1-4cr)+[-4+r(-16+c(23+36r))]^2}}{8c(4r-1)}$ $\Rightarrow x_{DNC}(\alpha) > x_{FC} \Rightarrow \pi_{DNC}(\alpha) < \pi_{FC}$. Q. E. D.

4 Semi-collusion: collusion in the product market

We now consider a scenario in which managers compete in terms of investment in R&D, but collude in the product market. In other words, managers compete in Stage 2, but collude in Stage 3 of the game. We will refer this case as 'cooperative delegation in case of semi-collusion' (DC, in short). Following Fershtman and Gandal (1994), we assume that firms sign a binding agreement and we adopt the market division collusive technology, where each consumer, actual or potential, is assigned to a single firm. Now, lets denote the contingent market share (as defined by Shubik (1959)) of firm i by s_i, $i = 1, 2$; $s_1 + s_2 = 1$. Therefore, the demand of firm i is $q_i = s_i d(p_i) = s_i(1 - p_i)$. Given α_i and s_i, in Stage 3, manager of firm i maximizes $O_i = \alpha_i\{(1 - \frac{q_i}{s_i} - c + x_i)q_i - \frac{r}{2}x_i^2\} + (1 - \alpha_i)((1 - \frac{q_i}{s_i})q_i)$ by producing $q_i = \frac{s_i(x_1,x_2)}{2}\{1 - (c - x_i)\alpha_i\}$, $i = 1, 2$. Therefore, in Stage 3, the value of the incentive package of firm i's manager, net of investment, is $R_{i,DC} = \frac{s_i}{4}\{1 - (c - x_i))^2\}$.

We assume that managers choose the division (s_1, s_2) such that managers receive equal percentage gains, by colluding, over the incentive package that would be earned in case of no collusion. This market division rule is same as that considered by Fershtman and Gandal (1994); the only difference is, here firms' profits has been replaced by managers incentive packages. Therefore, given x_1 and x_2 in Stage 2, $s_i(x_1, x_2)$ is determined by the following equation.

$$\frac{R_{1,DC}}{R_{2,DC}} = \frac{R_{1,DNC}}{R_{2,DNC}}, \tag{4}$$

where $R_{i,DNC} = \frac{1}{9}\{1 - 2(c - x_i)\alpha_i + (c - x_2)\alpha_j\}^2$, $i, j = 1, 2$; $j \neq i$.

In Stage 2, manager of firm i choose x_i to maximizes $O_i(x_1, x_2; \alpha_1, \alpha_2)$, after substituting the optimum output choice of Stage 3 and the expression of $s_i(x_1, x_2)$ in O_i. Finally, in Stage 1, owners' problem is to decide incentive parameter(s) so that the joint profit, $\pi_1(\alpha_1, \alpha_2) + \pi_2(\alpha_1, \alpha_2)$, is maximized. Now, exploiting the symmetry of firms, we get the SPNE of the game as given in Lemma 3.

Lemma 3: In case of semi-collusion, under cooperative managerial delegation, the equilibrium incentive parameter, share of each firm, the optimum R&D in each firm, output of each firm, price, profit of each firm, and social welfare are, respectively, $\alpha_{DC} = \frac{2cr}{c(1+2r)-1}$, $s_{DC} = \frac{1}{2}$, $x_{DC} = \frac{1-c}{2r}$, $q_{DC} = \frac{1-c}{4}$, $p_{DC} = \frac{1+c}{2}$, $\pi_{DC} = \frac{(1-c)^2}{8}$, and $SW_{DC} = \frac{3(1-c)^2}{8}$.

Clearly, in equilibrium, owners set the incentive parameter larger than 1, i.e. managers are penalized for sales maximization and over compensated at the margin of profit, as in case of DNC.[4] Now, comparing Lemma 1 and Lemma 3, we get the following.

Proposition 4: Under cooperative managerial delegation, in equilibrium, semi-collusion results in lower profits, higher investments in R&D, lower outputs, higher price, and lower social welfare than under non-cooperative interaction by managers.

In contrast to Fershtman and Gandal (1994), the above proposition demonstrates that, under cooperative managerial delegation, semi-collusive interaction by managers is detrimental for firms, irrespective of the cost of investment in R&D. That is, in case of cooperative managerial delegation, the loss due to over investment in R&D always offsets the gain from collusion in the product market.

It is interesting to note that, even in case of semi-collusion by managers, owners cannot ensure full-collusive level of profit through managerial delegation. Comparing Lemma 2 and Lemma 3, we get $\pi_{DC} < \pi_{FC}$. In case of semi-collusion also, we have $x_{DC} > x_{FC}$ and $q_{DC} < q_{FC}$, and $q_{DC} = \frac{r}{2} x_{DC}(\alpha) = \frac{r(1-c\alpha)}{2(2r-\alpha)}$, i.e. both $x_{DC}(\alpha)$ and $q_{DC}(\alpha)$ will move in the same direction due to a change in α. Therefore, it is not possible for owners to induce managers, through the incentive scheme, to choose full-collusive level of R&D and output, even if managers collude at the output stage.

5 Cooperative delegation versus no-delegation

We now attempt to delineate the effects of cooperative managerial delegation under two alternative scenarios: semi-collusion vis-à-vis Cournot type competition in the product

[4]For $(c - x_{DC})$ to be positive, we must have $c(1 + 2r) > 1$, which is also the required condition for $\alpha_{DC} > 1$. Also, note that the condition $c(1 + 2r) > 1$ is always satisfied, if $r > 1$ and $\frac{1}{3} < c < 1$, which we have assumed.

market. In order to do so, we first characterize the equilibrium outcomes of the following two cases: (a) No-delegation in Stage 1, and competition in both Stage 2 and Stage 3 (NDNC), and (b) No-delegation in Stage 1, competition in Stage 2, but collusion in Stage 3 (NDC). In some sense, no-delegation in firms is synonymous to entrepreneurial, i.e. owner managed, firms. Fershtman and Gandal (1994) have analysed both NDNC and NDC scenarios. Therefore, we leave out the details and summarize the equilibrium outcomes in case of NDNC and NDC in Lemma 4 and Lemma 5, respectively.

Lemma 4: When there is no managerial delegation and firms compete in both R&D and output, in equilibrium, investment in R&D in each firm, output of each firm, price, profit of each firm, and social welfare are as following: $x_{NDNC} = \frac{4(1-c)}{9r-4}$, $q_{NDNC} = \frac{3(1-c)r}{9r-4}$, $p_{NDNC} = \frac{3(1+2c)r-4}{9r-4}$, $\pi_{NDNC} = \frac{r(1-c)^2(9r-8)}{(9r-4)^2}$, and $SW_{NDNC} = \frac{4r(1-c)^2}{9r-4}$.

Lemma 5: If there is no managerial delegation and firms collude in the product market, but compete in R&D, in equilibrium, investment in R&D in each firm, output of each firm, price, profit of each firm, and social welfare are as following: $x_{NDC} = \frac{1-c}{2r-1}$, $q_{NDC} = \frac{r(1-c)}{2(2r-1)}$, $p_{NDC} = \frac{r(1+c)-1}{2r-1}$, $\pi_{NDC} = \frac{r(r-1)(1-c)^2}{2(2r-1)^2}$, and $SW_{NDC} = \frac{r(3r-2)(1-c)^2}{2(1-2r)^2}$.

The equilibrium outcomes under DNC and DC are presented in Lemma 1 and Lemma 3, respectively.

Now, comparing Lemma 3 and Lemma 5, we find that cooperative delegation results in higher profit, lower R&D, lower output, and lower social welfare than no-delegation case, if there is collusion in the product market. This result also holds, if there is competition in both R&D and output stages (compare Lemma 1 and Lemma 4).

Proposition 5: In equilibrium, cooperative delegation leads to higher profit, lower R&D, higher price, and lower social welfare compared to no delegation case, irrespective of product market conducts.

6 Conclusion:

This paper examines the effects of cooperative managerial delegation on optimum strategies of managers. It shows that, when managers interact in more than one aspects, for example R&D and output, cooperative delegation contract cannot lead to full-collusive level of profits. This result contradicts with the implications of existing literature on managerial delegation: owners can ensure collusive level of profit, if coordination among owners is made possible at the incentive designing stage. It also shows that, under cooperative managerial delegation, semi-collusion leads to lower equilibrium profits than competition, even if the cost of investment in R&D is high.

Semi-collusion, under cooperative managerial delegation, results in lower investment in R&D, lower output, and lower social welfare than that in case of competition. Moreover, it shows that cooperative managerial delegation leads to higher profits and lower social welfare than no-delegation case, irrespective of product market conducts.

Therefore, it suggests that, regulators need to consider the internal organization and incentive designing process of firms, other than examining firms' conduct in other dimension(s), in order to design effective antitrust laws. It also demonstrates that antitrust laws should not unfetter semi-collusion from its parasol. Because, although semi-collusion is detrimental for firms, it results in lower social welfare.

It might be interesting to extend the present analysis by considering spillover effects of R&D. However, it is easy to observe that as long as spillover effects are not very high, qualitative results of this paper will remain valid. The underlying reason is, unless spillover effects are very high, associated free rider problem, which act as disincentive to spend in R&D, may not be dominating. Nonetheless, it might be interesting to examine the role of spillover effects explicitly. This is a limitation of this paper. It might also be interesting to examine the consequences of semi-collusion under non-cooperative managerial delegation.

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