# Ambiguity between Pirate Incentive and Collective Desirability within Semi-delegation Pattern*

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**Abstract**

In this paper, we extend the literature on strategic delegation to a model with a semi-delegation structure. We investigate how the level of spillovers and the degree of product differentiation affect the owner's decision, taking all possible cases (symmetric & asymmetric) into account. It is found that owners face a prisoner's dilemma when the level of spillovers is very small or the products are sufficiently differentiated, and this paper highlights the conflict between individual and collective rationality. Concerning the behavior, managers act less aggressively on the market where there are delegated-firms than on the market where entrepreneurial firm and managerial firm coexist. It is found whether to delegate or not demonstrably depends on the extent of spillovers. The influence of product heterogeneity, compared to spillovers, has not the prominent impact on the firm's decision. Furthermore, we highlight the existence of the ambiguous areas. In these areas, delegations make firms profitable, but they cannot generate desirable welfare. Whether the delegation leads to an individual-collective unanimity or an individual-collective conflict, depends on the two extrinsic factors: the level of spillovers and the degree of product differentiation.

*Keywords:* Incentive Scheme; Product Differentiation; R&D Spillovers; Semi-delegation
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# 1 Introduction

It is well known that most large firms are characterized by a separation of ownership and management. This applies particularly in large publicly-owned companies where there are many shareholders, none of whom has a controlling interest. It cans also apply to family-owned companies in which the business is run by managers. In formulating incentives for managers, it is generally argued that owners should compensate them according to profits instead of sales, output, or other variables. However, such an argument may not hold in a strategic context, and hence the owner-manager relationship can be regarded as a strategic delegation problem rather than a principal-agent problem. The compensation schemes for managers serve as commitment devices used by owners to *pre* commit managers to certain actions in later stage, which in turn alter the actions taken by rival managers. The purposes of this paper are to discover how both the level of spillovers and the degree of product differentiation influence the shareholders' decision(whether to delegate or not), to shed light on how two above-mentioned factors affect the R&D effort, the level of output and the profit *via* the incentive scheme in managerial firm, to dig out under which circumstances managerial firms prevail over entrepreneurial firms in the context of semi-delegation which is not paid much attention.

Earlier work on delegation has shown that firms have a unilateral incentive to delegate tasks to independent agents. Representative papers, where the final stage choices are in quantities, initiated by Vickers (1985), Fershtman and Judd (1987), Sklivas (1987), and Fershtman, Judd, and Kalai (1991). By delegating output choices, firms instruct their managers to choose an equilibrium output that is greater than under the standard Cournot equilibrium. Based on these mentioned pioneer authors, the strategic delegation has been enriched by many studies. For example, sequential entry (Church and Ware, 1996), mixed oligopoly (White, 2001), equivalence of price and quantity competition (Miller and Pazgal, 2001), relative performance measure (Fumas, 1992; Aggarwal and Samwich, 1999; Miller and Pazgal, 2002), mergers (Gonzalez-Maestre and Lopez-Cunat, 2001; Ziss, 2001; Banal-Estanol, 2007), cartel stability (Lambertini and Trombetta, 2002), choice of incentive scheme (Jansen et al., 2007), wage bargaining (Szymanski, 1994; Conlin and Furusawa, 2000), delegation to bureaucrats (Basu et al., 1997), trade policy (Das, 1997), environmental damage control (Barcena-Ruiz and Garzon, 2002), Stackelberg strategic delegation (Kopel and Löffler,2008).

Within this large body of literature, Zhang and Zhang (1997) introduce a model which combines elements from the two distinct streams of literature: strategic delegation and R&D incentive under spillovers[1]. They consider a three-stage game, where the owners of the firms delegate the choices of R&D investment and production quantities to managers. Managerial compensation is based on the performance measures (profits and sales). Each manager can make investments in R&D. These investments reduce their own production costs, but due to spillovers effect, they also lower production costs of the rival firm. The goal of Zhang and Zhang's analysis is to give a comparison of optimal level of R&D expenditures, production quantities, firm profits and welfare. They find that managerial delegation leads to higher R&D investment, higher output, and lower profits in equilibrium compared to "No Delegation" case, when R&D spillover effect is small. Kopel and Riegler (2006) show that the results of Zhang and Zhang (1997) may not always hold true and the key results of their work are incorrect due to an improper handling of the first order conditions at the contracting stage. Nonetheless, Zhang and Zhang provide the basic framework to analyze the issue and have opened up an interesting avenue of research. Following these seminal researches, Lambertini and Primavera (2001) investigate a game in which the relative profitability of delegation and cost-reducing R&D investment are alternative strategies. They show that delegation does not always emerge as the equilibrium strategy; and the owners prefer not to delegate

[1]The seminal works on R&D incentives under spillovers by Spence (1984), d'Aspremont and Jaquemin (1988), Suzumura (1992) Kamien et al. (1992) has lead to a burgeoning literature.

their power when they are allowed to choose delegation and cost-reducing R&D jointly. Kräkel (2004) is based on the Zhang and Zhang setup. Instead of the Cournot game, he considers a contest game to model oligopolistic competition between firms. In this contest, players compete against each other by exerting effort or spending resources to win a certain prize. He finds if an entrepreneurial firm competes against a managerial firm, the latter one will achieve larger or equal profits. Lambertini (2004) studies the asymmetric case where an entrepreneurial firm competes with a managerial firm with homogenous goods in Cournot competition. He finds the managerial firm's R&D effort is larger than the entrepreneurial firm's. At equilibrium, the managerial firm earns higher profit than the rival. To the best of our knowledge, the issue of semi-delegation has not received much attention so far.

This paper focuses on the important and interesting issue "semi-delegation". As in a great number of firms, although owners hire the manager in order to deal with the operative problems, for instance, fixation of product price, product quantity, they still withhold the power which has the enormous effect on firm's development and orientation, such as R&D investment. Both empirical evidence, theoretical finding and various examples can be used to illustrate semi-delegations. Barcena-Ruiz and Casado-Izaga (2005) study the delegation problem in the spatial game, and find that owners have an incentive to keep the most important decisions for themselves and to delegate the operative decisions to their managers. Mitrokostas and Petrakis (2005) investigate different scopes of delegation in a Cournot duopoly model, and find the fact that only short-run decisions are delegated and owners hold the R&D decisions. In the real world, the owners of BMW[2] are very much involved in the management of the firm (in their long-run), at the same time, they delegate short-run decisions such as marketing plans to the managers of subsidiaries. The owners of Benneton are very involved in the long-run decisions. As Jarillo and Martnez (1990, p. 72) explain: Benneton approved location of the shops and Luciano (the owner) personally oversaw the more strategic sites. Additional evidence is given by Microsoft, in this firm Bill Gates, the main owner, plays a dominant role in the strategic decisions of the firm. Thereby, we build a model where semi-delegation is designed, and it is reasonable that we assume the owners take responsibility of R&D decisions, and then decide whether to delegate the short-run decision or not. In our model, the differentiated products competition takes place as part of a delegation game, the elasticity of residual demand that a firm's manager perceives can be manipulated by the firm's owner through the incentive scheme. The question of interest in this paper is under which circumstances have owners a tendency to delegate and how owners manipulate the manager's behaviors to realize more profit.

Several authors have considered the impact of manipulating the managers' behavior in duopoly games to gain a strategic advantage. Heretofore, these authors almost study the strategic delegation in the case of Cournot type quantity competition, because in quantity-setting game owners realize strategic advantage by inducing managers to be more aggressive in the product market. Miller and Pazgal (2001) illustrate in a two-stage delegation game, if the set of incentive parameters available to the owner is great enough, the equilibrium prices and quantities will be the same regardless of whether the firms compete by price-setting or by quantity-setting. However, it is valid when there is no cost-reducing and when firms compete in only one dimension and the relative performance is regarded as incentive scheme. In this paper, we use the price-setting instead of Cournot structure in order to differentiate the analysis in delegation game. The attractive feature of the Bertrand setup, compared with the Cournot market structure, stems from the fact that firms are able to change prices faster and at less cost than to set quantities, because changing quantities will require an adjustment of inventories, which may necessitate a change in firms'capacity to

[2]The case of the BMW (Bavarian Motor Works) company illustrates the Semi-Delegation situation. In this company, in 1984, between 50 and 75% of the property of the firm was in the hands of the Quandt family who also held a very active position in the supervisory board of BMW; the remainder of the firm was owned by a group of European banks and employees of the firm. As Jenster et al. (1990, p. 142) point out: Although the parent company, BMW in Munich, established broad guidelines, the subsidiaries are responsible for developing their own strategic objectives and marketing plans within their regions.

produce, according to Shy (1996). Thus, in the short run, quantity changes may not be feasible, or may be too costly to the seller. Concerning the choice of the type of contract, we adopt the scheme based on sales to relative performance, because the value of optimal contract will be negative in this model if we consider relative performance ($R_i = \pi_i - \theta\pi_j$) as incentive scheme. It signifies even if the manager increases the rival's profit instead of the profit of firm where he is employed, he could also improve his utility. Furthermore, knowing the rival's profit is difficult in practice.

In general, there are two distinct factors that could influence the delegation decisions: intrinsic factor and extrinsic factor. The former is the self-control element, in other words, the owners can be master of it. For example, choice of the different types of contract, namely the contracts rewarding managers on the base of a combination of profits and revenues (Fershtman and Judd 1987 and Sklivas 1987), or combination of profits and quantity (Vickers 1985), or the schemes based on market or relative profits (Jansen et al., 2007). The behavior of owners remaining with intrinsic factor could also affect the delegation decision (Freshtman and Gandal 1994, Brod and Shivakumar 1999, Pal 2010). The latter is the factor out of control, such as the level of spillovers, the degree of product differentiation[3].To the best of our knowledge, the study on delegation issue focussing on these extrinsic factors is rare. Our framework can fill the gap and instruct the owners to make a better and more profitable decision, according to the actual level of extrinsic factors.

In this paper, we extend the literature on strategic delegation to a model with a semi-delegation structure. We investigate how the owner's decisions are influenced by the level of spillovers and the degree of product differentiation, taking all possible cases (symmetric & asymmetric) into account. The sequence of events that we consider is as follow: in the beginning of the game, the owners of each firm decide the level of R&D investment simultaneously and independently; and then, the owners choose whether to employ the manager in charge of the decision on price on owner's behalf; subsequently, only the owner who has adopted a delegation strategy can choose the incentive scheme of his manager; finally, the product prices are taken simultaneously by the decision-makers who could be either manager or owner. According to this timming, we find in the asymmetric case where there are both entrepreneurial firm and managerial firm, the profit of entrepreneurial firm is always greater than the profit of managerial firm, regardless of the product differentiation and the level of spillovers; we have the inverse outcome in the symmetric case where there are exclusively either entrepreneurial firms or managerial firms. It is found that owners face a prisoner's dilemma if the level of spillovers is very small or if the products are sufficiently differentiated, and this paper highlights the conflict between individual and collective rationality. We also illustrate that managers act less aggressively on the market where there are two delegated-firms than on the market where entrepreneurial firm and managerial one coexist. It is found whether to delegate or not demonstrably depends upon the extent of spillovers. The influence of product heterogeneity, compared to spillovers, has not the prominent impact on the firm's decision. Nevertheless, if there is no spillover effect, the impact of product differentiation becomes remarkable, and clearly affect the owner's choice.

The issue of social welfare is also the point we pay attention to. It is argued that the gap of welfare among different cases disappears (or becomes infinitesimal) when the level of spillovers is high. Moreover, when spillovers are sufficiently small, the No Delegation strategy generates higher welfare if the products are comparatively differentiated; whereas, if the goods are fairly similar, the delegation strategy is the best choice in public view. In addition, combining the welfare implication with the outcomes in terms of profit, we find the ambiguous areas in which delegations can make firms profitable, but cannot give rise to desirable welfare. Whether the delegation generates an individual-collective unanimity or leads to an individual-collective conflict depends on the two extrinsic factors highlighted in this paper.

[3]Lambertini (1993), Wang and Stiegert (2007) were interested in the impacts of degree of product differentiation on delegation.

The rest of the paper proceeds as follows. The two following sections describe the model and briefly analyze the benchmark case. Section 4 studies the equilibrium outcomes under semi-delegation ( symmetric case and asymmetric case). In section 5, multiple comparisons of equilibrium are presented. Section 6 provides some concluding remarks.

# 2 The Model

There are two firms indexed by $i$ ($i = 1,2$) competing in a market for a differentiated product. We develop the model of strategic delegation with cost-reducing R&D stemming from the possibility of spillovers across firms in price-setting duopoly.

We assume that owners offer "*take-it-or-leave-it*" linear incentive schemes to their managers. When saying "Owner", we mean an individual or a group whose sole purpose is to maximize the profits of the firm; "Manager" refers to an agent that the owner hires to make real time operating (price) decisions. The manager of firm $i$ receives a payoff $A_i + B_iR_i$, where $A_i$ and $B_i$ are constants, and $R_i$ is a linear combination of profits and sales revenue. The owner selects $A_i$ so that the manager only gets his opportunity cost, which is normalized to zero. Managers are risk neutral and maximize $R_i = \theta_i\pi_i + (1-\theta_i)S_i = S_i - \theta_iC_i$, where $\pi_i$, $S_i$ and $C_i$ are profits, sales revenue and effective production cost respectively. Clearly, maximizing $A_i + B_iR_i$ and maximizing $R_i$ are equivalent. The incentive parameter $\theta_i$ is chosen by the owner of firm $i$. Note that $\theta_i$ just affects the manager's perspective on cost. If $\theta_i < 1$, it signifies that firm $i$'s manager moves away from strict profit maximization toward including consideration of sales, then firm $i$'s reaction function moves out in a parallel fashion since the managers view $\theta_iC_i$ as the marginal cost of production. In this case the owner puts positive weight on the sales component in the performance measure in order to induce the manager to act more aggressively in the market. However, if $\theta_i > 1$, owners penalize sales maximization and overcompensate managers at the margin of profit, this type of incentive scheme induces managers to be less aggressive in the product market, and the manager is supposed to reduce sales in order to keep market price high.

Concerning the function of cost, each firm has the same initial cost indexed by $c_0$. It can be reduced by investing in R&D. Due to spillovers, the R&D investment $x_i$ benefits the investing firm $i$, and also leads to lower unit costs for rival firm $j$. Let $j$ ($j = 1,2$ and $i \neq j$) refer to the respective rival firm, then firm $j$'s effective production unit cost is $C_j = c_0 - x_j - \lambda x_i$ with $\lambda \in [0,1)$ as the measure of the size of the spillovers effect. R&D investment reduces the initial cost $c_0$. In order to guarantee the non-negative value of the effective production cost, we assume that the initial cost is always higher than the cost-saving *via* R&D investment ($c_0 > max(x_i + \lambda x_j, x_j + \lambda x_i)$). Note that investing in R&D is expensive, and the R&D cost function is represented by $\frac{1}{2}x_i^2$.

The demand function is given by $q_i(p_i, p_j) = 1 - p_i + \beta p_j$, where $\beta$ is a product differentiation parameter which inversely indicates the strength of product heterogeneity. Suppose $\beta \in (0,1]$, and the closer is $\beta$ to 1, the closer the two varieties are to being perfect substitutes.

The timing of the game is as follows.

Stage 1: The owners of each firm decide the level of R&D effort simultaneously and independently

Stage 2: The owners choose whether to employ the manager in charge of the decision on price on owner's behalf. *In the absence of manager, the price decision is taken by owners at stage 4.*

Stage 3: The owner who has adopted a delegation strategy can choose the incentive scheme of his manager. *The contracts (incentive schemes) cannot be renegotiated and they become common knowledge once they are signed.*

Stage 4: The decision-makers (either owner or manager) simultaneously take the price decisions.

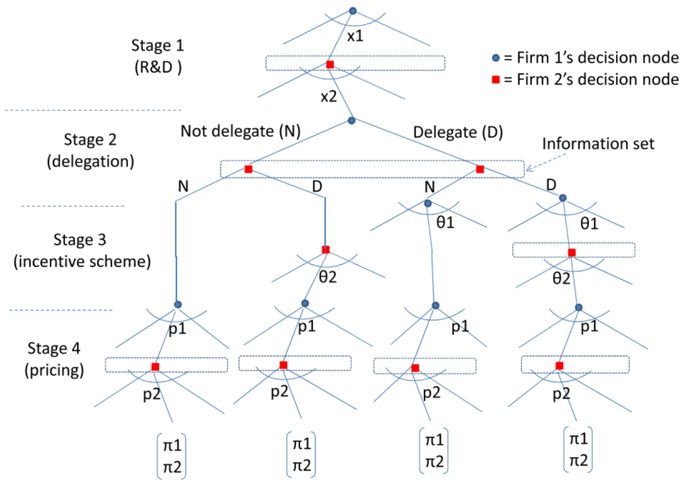


Figure 1: Timing of game

According to this timing, our game obviously has four different cases: the first one is that owners take responsibility for both R&D effort decision and price decision; the second refers to the case in which both owners delegate the price decisions to managers; the third and fourth are those in which one owner delegates the price decision while the other owner takes it himself.

For simplicity, we use the letter **N** representing "No Delegation", the letter **D** standing for "Delegation". Then the first case detailed in the following section can be noted by **NN**, because neither owner hires manager. Since both owners appoint the manager to decide on price, the second one will be transformed into **DD**. The rest can be regarded as **ND**, **DN** respectively.

# 3 Benchmark

Since neither owner delegates the price decision to managers in this case, it reduces to the sequential game consisted of two stages (Stage 1 and 4), which more or less coincides with the case studied by d'Aspremont and Jaquemin (1988) and Brod and Shivakumar (1999). We consider this case as a benchmark.

As is standard, we solve the model backwards beginning with the last stage in which the owners decide the price simultaneously and independently. Each owner $i$ chooses price $p_i$ to maximize profit:

$$\pi_i = p_i q_i - (c_0 - x_i - \lambda x_j) q_i - \frac{1}{2} x_i^2 \tag{1}$$

It is straightforward to show that the product price is given by:

$$p_i^{NN} = \frac{(2+\beta)(1+c_0)-(2+\beta\lambda)x_i^{NN}-(2\lambda+\beta)x_j^{NN}}{4-\beta^2} \quad (2)$$

$$\begin{cases} \frac{\partial p_i^{NN}}{\partial x_i^{NN}} & = \frac{-(2+\lambda\beta)}{4-\beta^2} & <0 \\ \frac{\partial p_i^{NN}}{\partial x_j^{NN}} & = \frac{-(2\lambda+\beta)}{4-\beta^2} & <0 \end{cases}$$

Since the signs of these derivatives are negative, the product price is negatively influenced by an increase of R&D effort. This impact not only stems from the enhancement in R&D exerted by firm $i$, but also stems from the one exerted by his rival firm $j$[4]. Furthermore, the slope of curve $\frac{\partial p_i^{NN}}{\partial x_i^{NN}}$ is obviously more abrupt[5] ($|\frac{\partial p_i^{NN}}{\partial x_i^{NN}}| > |\frac{\partial p_i^{NN}}{\partial x_j^{NN}}|$), it demonstrates that the R&D investment of firm $i$ can reduce the product price more efficiently than the R&D investment[6] exerted by his rival firm.

The owners decide the R&D investment to maximize profits in the first stage. The R&D efforts are shown:

$$x_i^{NN} = x_j^{NN} = \frac{2(2-\lambda\beta-\beta^2)[1-(1-\beta)c_0]}{\Gamma} \quad (3)$$

$$\text{with } \Gamma = 4(1-\lambda)+2\lambda(\lambda+3)\beta-(2\lambda+1)\beta^3-2\lambda^2\beta^2 > 0$$

We derive the optimal price and profit:

$$p_i^{NN} = p_j^{NN} = \frac{(2\lambda+1-c_0)\beta^2+2\lambda(1+\lambda)\beta+4(c_0-\lambda)}{\Gamma} \quad (4)$$

$$\pi_i^{NN} = \pi_j^{NN} = \frac{(8+8\lambda\beta-\beta^4-4\lambda\beta^3-2\lambda^2\beta^2)(\beta c_0-c_0+1)^2}{\Gamma^2} \quad (5)$$

It is straightforward that their R&D effort $x_i^{NN}$, price $p_i^{NN}$ and profit $\pi_i^{NN}$ are always positive for all values of $\beta \in (0,1]$ and $\lambda \in [0,1)$.

# 4 Equilibrium under semi-delegation

## 4.1 Symmetric case: both firms delegate the price decision

In this case, both firms delegate the price decision. We begin with the price chosen by managers who seek for the maximization of $R_i = \theta_i\pi_i + (1-\theta_i)S_i = S_i - \theta_i C_i$.

[4] In contrast, an increase in R&D effort by firm $j$ exerts two conflicting effects in quantity-setting game: On the one hand, by bringing down firm $j$'s costs, the R&D effort induces firm $j$ to expand output at the expense of firm $i$. This effect is greater the more substitutable the products are. On the other hand, because spillovers lower firm $i$'s cost, the R&D effort by firm $j$ tends to increase firm $i$'s output.

[5] As long as the level of spillovers doesn't attain the maximal value.

[6] Notice that in the extreme case where the spillovers achieve the maximal value($\lambda = 1$), the investment proceed by firm $i$ and the one by firm $j$ have the effect of the same extent on price.

Given $x_i^{DD}, x_j^{DD}, \theta_i^{DD}$ and $\theta_j^{DD}$, the firm $i$'s price is shown as follows:

$$p_i^{DD} = \frac{2\theta_i^{DD}(c_0 - x_i - \lambda x_j^{DD}) + 2 + \beta\theta_j^{DD}(c_0 - x_j^{DD} - \lambda x_i^{DD}) + \beta}{4 - \beta^2} \tag{6}$$

At stage 3, owners endogenously design the managerial incentive scheme, given the R&D effort. We can easily rewrite both $\pi_i^{DD}$ and $\pi_j^{DD}$ as a function of $x_i^{DD}$, $x_j^{DD}$. Then, the extent of delegation can be found. Plugging all these expressions into the profit functions would yield the profits of the owners solely as a function of the R&D efforts. *i.e.*$\pi_i^{DD}(x_i^{DD}, x_j^{DD})$ and $\pi_j^{DD}(x_i^{DD}, x_j^{DD})$.

Back to the first stage, the owners choose R&D efforts to maximize profits. The R&D investment, contract, price and profit in equilibrium are derived respectively.

R&D investment:

$$x_i^{DD} = x_j^{DD} = \frac{4(\beta^2-2)(\beta c_0 - c_0 + 1)\left[\beta\lambda(\beta^2-2) - 3\beta^2 + 4\right]}{\Theta_1\lambda^2 + \Theta_2\lambda + \Theta_3} \tag{7}$$

with

$$\Theta_1 = 4\beta(\beta^5 - \beta^4 - 4\beta^3 + 4\beta^2 + 4\beta - 4)$$
$$\Theta_2 = 4\beta(\beta^5 - 4\beta^4 - \beta^3 + 14\beta^2 - 6\beta - 12) + 32$$
$$\Theta_3 = \beta^6 - 10\beta^5 - 4\beta^4 + 16\beta^3 + 24\beta^2 - 32$$

Note that the R&D investment is always positive, and the relationship $x^{DD} > x^{NN}$ holds true all the time. Owners are motivated to invest more in R&D in this symmetric case.

Incentive parameter:

$$\theta_i^{DD} = \theta_j^{DD} = \frac{\Xi_1\lambda^2 + \Xi_2\lambda + \Xi_3}{\Xi_1\lambda^2 + \Xi_2\lambda + \Xi_4} \tag{8}$$

with

$$\Xi_1 = 4\beta^5 - 16\beta^3 + 16\beta$$
$$\Xi_2 = 4\beta^5 - 12\beta^4 - 16\beta^3 + 40\beta^2 + 16\beta - 32$$
$$\Xi_3 = c_0\beta^7 + (1 - 2c_0)\beta^6 - 14c_0\beta^5 + (28c_0 - 24)\beta^4 + 40c_0\beta^3 + (56 - 80c_0)\beta^2 - 32c_0\beta + 64c_0 - 32$$
$$\Xi_4 = -c_0\beta^6 - 2c_0\beta^5 + (16c_0 - 12)\beta^4 + 24c_0\beta^3 + (40 - 64c_0)\beta^2 - 32c_0\beta + 64c_0 - 32$$

By the numerical analyses, it is found the incentive parameters is always higher than 1, the owners overcompensate the managers for profits by penalizing sales. This outcome coincides with the result of Fershman and Judd (1987) who demonstrate $\theta_i > 1$, therefore the incentive equilibrium is such that managers are overcompensated at the margin for profits. Note that their result is valid in the absence of competition on R&D investment.

Price:

$$p_i^{DD} = p_j^{DD} = \frac{-\Xi_1\lambda^2 - \Xi_2\lambda + \Lambda_1}{\Theta_1\lambda^2 + \Theta_2\lambda + \Lambda_2} \tag{9}$$

with

$$\Lambda_1 = c_0\beta^6 + (10 - 14c_0)\beta^4 + (40c_0 - 16)\beta^2 - 32c_0$$
$$\Lambda_2 = \beta^6 - 10\beta^5 - 4\beta^4 + 16\beta^3 + 24\beta^2 - 32$$

Profit:

$$\pi_i^{DD} = \pi_j^{DD} = \frac{(4-2\beta^2)(\beta c_0 - c_0 + 1)^2(\Psi_1\lambda^2 + \Psi_2\lambda + \Psi_3)}{\Theta_1\lambda^2 + \Theta_2\lambda + \Theta_3^2} \tag{10}$$

with

$$\begin{aligned}
\Psi_1 &= 4\beta^8 - 24\beta^6 + 48\beta^4 - 32\beta^2 \\
\Psi_2 &= -24\beta^7 + 128\beta^5 - 224\beta^3 + 128\beta \\
\Psi_3 &= \beta^8 + 12\beta^6 + 8\beta^4 - 128\beta^2 + 128
\end{aligned}$$

It is straightforward to show that the profit in Delegation (DD) is always higher than the profit in No Delegation (NN), regardless of spillovers and product differentiation. In other words, strategic delegation is always beneficial to firms (in the symmetric case).

## 4.2 Asymmetric case: only one firm delegates the price decision

Assume in this asymmetric case, firm $j$ is managerial while firm $i$ is entrepreneurial. The objective functions at the production stage are:

$$\begin{aligned}
\pi_i &= p_i q_i - (c_0 - x_i - \lambda x_j)q_i - \frac{1}{2}x_i^2 \\
R_j &= \theta_j \pi_j + (1-\theta_j)S_j
\end{aligned}$$

Taking the first-order-conditions, we have:

$$p_i^{ND} = \frac{2 + 2c_0 - 2x_i^{ND} - 2\lambda x_j^{ND} + \beta\theta_j^{ND}c_0 - \beta\theta_j^{ND}x_j^{ND} - \beta\theta_j^{ND}\lambda x_i^{ND} + \beta}{4-\beta^2} \tag{11}$$

$$p_j^{ND} = \frac{2\theta_j^{ND}c_0 - 2\theta_j^{ND}x_j^{ND} - 2\theta_j^{ND}\lambda x_i^{ND} + 2 - \beta\lambda x_j^{ND} + \beta + \beta c_0 - \beta x_i^{ND}}{4-\beta^2} \tag{12}$$

Both owners decide upon his own R&D effort to seek for profit-maximization, where the R&D investment are respectively determined as follow.

$$x_i^{ND} = \frac{(\beta c_0 - c_0 + 1)\left[(\beta^3 - 2\beta)\lambda - 3\beta^2 + 4\right]\left[(\beta^2+\beta)\lambda^2 + (\beta^3 - 3\beta - 2)\lambda - \beta^3 - 2\right]}{\Upsilon_1\lambda^4 + \Upsilon_2\lambda^3 + \Upsilon_3\lambda^2 + \Upsilon_4\lambda + \beta^6 + 2\beta^2 - 8} \tag{13}$$

$$x_j^{ND} = \frac{(\beta\lambda - 2 + \beta^2)(\beta c_0 - c_0 + 1)(\Upsilon_5\lambda^2 + \Upsilon_6\lambda + \beta^3 - \beta^2 + 4)}{\Upsilon_1\lambda^4 + \Upsilon_2\lambda^3 + \Upsilon_3\lambda^2 + \Upsilon_4\lambda + \beta^6 + 2\beta^2 - 8}$$

with

$$\begin{aligned}
\Upsilon_1 &= \beta^6 - 3\beta^4 + 2\beta^2 \\
\Upsilon_2 &= \beta^7 - 8\beta^5 + 15\beta^3 - 8\beta \\
\Upsilon_3 &= -3\beta^6 + 10\beta^4 - 12\beta^2 + 8 \\
\Upsilon_4 &= -\beta^7 - 2\beta^5 + 21\beta^3 - 24\beta \\
\Upsilon_5 &= \beta^4 + \beta^3 - 2\beta^2 - 2\beta \\
\Upsilon_6 &= -\beta^4 - 4\beta^3 - \beta^2 + 6\beta + 4
\end{aligned}$$

Note that $x_i^{DN} = x_j^{ND}$ and $x_i^{ND} = x_j^{DN}$, we find

- $x_i^{ND} > x_i^{DN}$, if $\beta < \frac{\sqrt{17}-1}{4}$ and $\forall\, \lambda \in [0,1]$
- $x_i^{ND} < x_i^{DN}$, if $\beta > \frac{\sqrt{17}-1}{4}$ and $0 \leq \lambda < \frac{2\beta^2+\beta-2}{2-\beta^2}$
- $x_i^{ND} > x_i^{DN}$, if $\beta > \frac{\sqrt{17}-1}{4}$ and $1 \geq \lambda > \frac{2\beta^2+\beta-2}{2-\beta^2}$

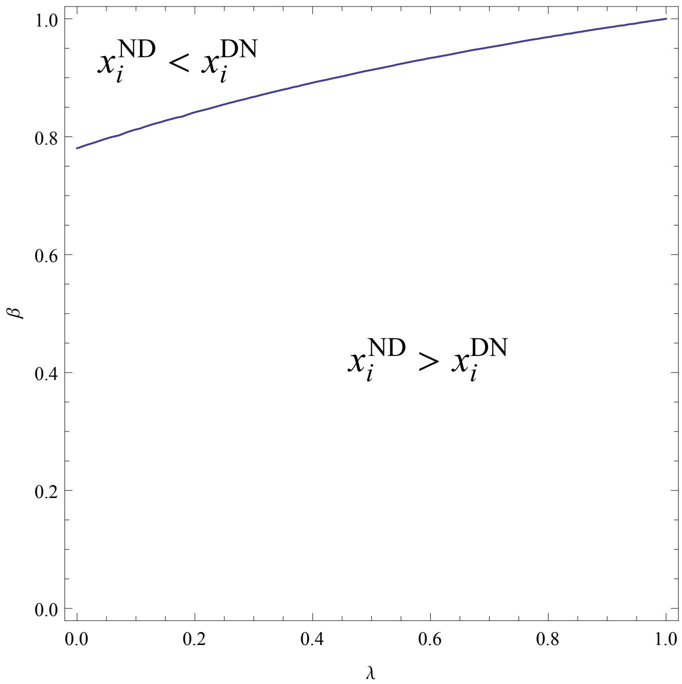


Figure 2: R&D investment level in the asymmetric case

According to Figure 2, the owner of entrepreneurial firm has more interest to invest in R&D, when the goods are sufficiently heterogenous ($\beta < \frac{1}{4}(\sqrt{17}-1)$). By contrary, when the products are similar ($\beta > \frac{1}{4}(\sqrt{17}-1)$) and the spillovers is not large enough ($\lambda < \frac{2\beta^2+\beta-2}{2-\beta^2}$), the owner of managerial firm will spend more on R&D investment. Due to introducing the degree of product differentiation, we illustrate the more complete results compared to the work of Lambertini (2004) which finds the managerial firm exerts more R&D effort than the entrepreneurial firm. In our model, the R&D effort exerted by entrepreneurial firm can be greater than the one by managerial firm if the products are sufficiently differentiated. In the extreme case where the goods are homogenous ($\beta = 1$), we retrieve the outcome which coincides with the main result of Lambertini (2004).

Having characterized the sub-game perfect equilibria, we list the incentive parameter of firm $j$, firms' prices and profits respectively:

Incentive parameter:

$$\theta_j^{ND} = \frac{\Phi_1\lambda^4 + \Phi_2\lambda^3 + \Phi_3\lambda^2 + \Phi_4\lambda + \Phi_5}{\Phi_1\lambda^4 + \Phi_2\lambda^3 + \Phi_6\lambda^2 + \Phi_7\lambda + \Phi_8} \tag{14}$$

with

$$\Phi_1 = \beta^5 + \beta^4 - 2\beta^3 - 2\beta^2$$
$$\Phi_2 = \beta^6 + \beta^5 - 7\beta^4 - 7\beta^3 + 8\beta^2 + 8\beta$$
$$\Phi_3 = c_0\beta^7 + \beta^6 - (2+6c_0)\beta^5 - (8-2c_0)\beta^4 + 4(1+3c_0)\beta^3 + 4(4-c_0)\beta^2 - 8c_0\beta - 8$$
$$\Phi_4 = -c_0\beta^7 - (2+3c_0)\beta^6 + (8c_0-5)\beta^5 + (14c_0+1)\beta^4 + (15-20c_0)\beta^3 + (16-24c_0)\beta^2 + 16c_0\beta + 16c_0 - 16$$
$$\Phi_5 = c_0\beta^6 + (2-4c_0)\beta^5 - 2\beta^4 + (12c_0-2)\beta^3 + (10-12c_0)\beta^2 - 8c_0\beta + 16c_0 - 8$$
$$\Phi_6 = -3(1+c_0)\beta^5 - (6-2c_0)\beta^4 + (6+10c_0)\beta^3 + 4(4-c_0)\beta^2 - 8c_0\beta - 8$$
$$\Phi_7 = -\beta^6 + (5c_0-1)\beta^5 + (7c_0+2)\beta^4 + 9(1-2c_0)\beta^3 + 4(3-5c_0)\beta^2 + 8(2c_0-1)\beta - 16(1-c_0)$$
$$\Phi_8 = (1-2c_0)\beta^5 - (1+c_0)\beta^4 + 2(4c_0-1)\beta^3 + 2(3-4c_0)\beta^2 - 8c_0\beta + 16c_0 - 8$$

By the numerical analyses, it is found that the incentive parameter is always higher than 1. In the following section, the incentive parameter of different cases will be compared.

Price:

$$p_i^{ND} = \frac{\Psi_1\lambda^4 + \Psi_2\lambda^3 + \Psi_3\lambda^2 + \Psi_4\lambda + \Psi_5}{\Psi_6\lambda^4 + \Psi_7\lambda^3 + \Psi_8\lambda^2 + \Psi_9\lambda + \beta^6 + 2\beta^2 - 8} \tag{15}$$

$$p_j^{ND} = \frac{\Psi_1\lambda^4 + \Psi_2\lambda^3 + \Psi_{10}\lambda^2 + \Psi_{11}\lambda + \Psi_{12}}{\Psi_6\lambda^4 + \Psi_7\lambda^3 + \Psi_8\lambda^2 + \Psi_9\lambda + \beta^6 + 2\beta^2 - 8}$$

with

$$\Psi_1 = -\beta^5 - \beta^4 + 2\beta^3 + 2\beta^2$$
$$\Psi_2 = -\beta^6 - \beta^5 + 7\beta^4 + 7\beta^3 - 8\beta^2 - 8\beta$$
$$\Psi_3 = c_0\beta^6 + 4\beta^5 + 4(1-c_0)\beta^4 - 2(5+c_0)\beta^3 - 4(3-c_0)\beta^2 + 4(1+c_0)\beta + 8$$
$$\Psi_4 = (1-c_0)\beta^6 - 3c_0\beta^5 + (2c_0-1)\beta^4 + (12c_0+1)\beta^3 - 4(2-c_0)\beta^2 - 4(1+3c_0)\beta + 8(1-c_0)$$
$$\Psi_5 = -(1-c_0)\beta^5 - 2c_0\beta^3 + 2(2c_0-1)\beta^2 - 8c_0$$
$$\Psi_6 = \beta^6 - 3\beta^4 + 2\beta^2$$
$$\Psi_7 = \beta^7 - 8\beta^5 + 15\beta^3 - 8\beta$$
$$\Psi_8 = -3\beta^6 + 10\beta^4 - 12\beta^2 + 8$$
$$\Psi_9 = -\beta^7 - 2\beta^5 + 21\beta^3 - 24\beta$$
$$\Psi_{10} = (3+c_0)\beta^5 + 2(2-c_0)\beta^4 - 4(2+c_0)\beta^3 - 4(3-c_0)\beta^2 + 4(1+c_0)\beta + 8$$
$$\Psi_{11} = \beta^6 - (3c_0-1)\beta^5 - c_0\beta^4 + (12c_0-1)\beta^3 - 2(5-3c_0)\beta^2 - 4(1+3c_0)\beta + 8(1-c_0)$$
$$\Psi_{12} = (2c_0-1)\beta^5 + (1-c_0)\beta^4 - 4c_0\beta^3 - 2(2-3c_0)\beta^2 - 8c_0$$

By the numerical analyses, we find $p_i^{ND} < p_i^{DN}$ for all $\lambda \in [0,1)$ and $\beta \in (0,1]$. The entrepreneurial firm proposes the price lower than the price proposed by the managerial one.

Profit:

$$\pi_i^{ND} = \frac{\Omega_1\Omega_2^2(\beta c_0 - c_0 + 1)^2}{2\Omega_3^2} \tag{16}$$

$$\pi_j^{ND} = \frac{\Omega_4\Omega_5^2(\beta c_0 - c_0 + 1)^2}{2\Omega_3^2}$$

with

$$
\begin{aligned}
\Omega_1 &= -[(4\beta^2-4\beta^4+\beta^6)\lambda^2-(16\beta-20\beta^3+6\beta^5)\lambda+\beta^4+8\beta^2-16] \\
\Omega_2 &= \beta(\beta+1)\lambda^2+(\beta^3-3\beta-2)\lambda-\beta^3-2 \\
\Omega_3 &= (\beta^6-3\beta^4+2\beta^2)\lambda^4+(\beta^7-8\beta^5+15\beta^3-8\beta)\lambda^3+(-3\beta^6+10\beta^4-12\beta^2+8)\lambda^2 \\
&\quad +(-\beta^7-2\beta^5+21\beta^3-24\beta)\lambda+2\beta^2+\beta^6-8 \\
\Omega_4 &= -[\beta^2\lambda^2+2\beta(\beta^2-2)\lambda+\beta^4-4] \\
\Omega_5 &= (\beta^4+\beta^3-2\beta^2-2\beta)\lambda^2+(-\beta^4-4\beta^3-\beta^2+6\beta+4)\lambda+\beta^3-\beta^2+4
\end{aligned}
$$

It is found that $\pi_i^{ND} > \pi_i^{DN}$, the profit of entrepreneurial firm is always more important than that of managerial one regardless of product differentiation and spillovers. We obtain the inverse outcome in the symmetric case. The primal reason is on account of the high incentive parameter. The contract $\theta$ is always higher than 1, it signifies that the initial marginal cost is distorted and turns into $\theta c_0$. Due to the augmentation of cost, the managerial firm has to raise the price. Consequently, the entrepreneurial firm prevails against[7] the managerial one because of the marginal cost advantage.

As is shown, the delegation is beneficial to owner when there is an unanimity of firm's types (benchmark case and symmetric case); whereas in the asymmetric case where a entrepreneurial firm and a managerial firm coexist, the owner prefers to hold the short-run decision in order to acquire more profit. Hence, this may be an unavoidable outcome ensured by the underlying prisoners' dilemma driving the shareholders' incentives towards managerialization. In what follows, we will verify whether the strategic delegation is a strictly dominant strategy, study the problem of prisoners' dilemma and analyze the results in terms of R&D investment, incentive scheme and social welfare, on taking into account all possible cases.

# 5 Result

In this section, we adopt the multiple-comparison method in order to carry out the in-depth analysis by taking into account four alternative cases.

## 5.1 R&D investment

Although we cannot arrange all $x_\Omega^\Psi$ ($\Psi = NN, DD, ND, DN$ and $\Omega = i, j$), it is possible to find out the most important value.

**Result 1:** In all situations, we have

$$
x_\Omega^{DD} > \begin{cases} x_\Omega^{NN} \\ x_i^{ND} = x_j^{DN} \\ x_i^{DN} = x_j^{ND} \end{cases}
$$

then it is straightforward that $x_\Omega^{DD}$ has the most important value.

[7] Although Lambertini (2004) has analyzed the similar asymmetric case, the results are comparatively different. In a Cournot game and absence of product differentiation, he finds at equilibrium the managerial firm earns higher profit than the rival entrepreneurial firm.

When both owners choose managerial firm strategy, they will spend more on R&D investment compared to the benchmark case and the asymmetric cases.

## 5.2 Incentive scheme

Since the owners always take responsibility of R&D investment decision, there are only two possible types of incentive scheme: the incentive parameter in the case of two managerial firms is noted by $\theta^{DD}$, the other one where the entrepreneurial firm and the managerial firm coexist is noted by $\theta^{ND}$.

**Result 2:** $\theta^{DD} > \theta^{ND} > 1$

This ranking always holds true for $\lambda \in [0,1)$ and $\beta \in (0,1]$. Running counter to the quantity-setting competition[8], the incentive parameter is always higher than 1 in the price-setting game, and managers behave non-aggressively, each owner knows that any credible increase in its own price will be followed by an increase in rival's price. Therefore in equilibrium, owners induce managers to be less aggressive in the product market, by penalizing managers for sales maximization and charge a price above the profit-maximization price. Furthermore, if both firms delegate, owners induce the managers to act less aggressively on the market where there are only delegated-firms than the market where entrepreneurial firm and managerial one coexist.

## 5.3 Profit and prisoner's dilemma

The Prisoner's Dilemma is a well-known metaphor used in economic research to model situations of social conflict between two (or more) interdependent actors. The essence of the dilemma is that each individual actor has an incentive to act according to narrow self-interest (individual profit), even though all actors are collectively better off if they both delegate. As depicted in the figure entitled "Profit Matrix", the strategies for each owner of firm can be summarized as "Delegation" or "No Delegation". Assume firm $i$ is the row player and firm $j$ is the column player. The payoffs appearing in the matrix are the profits accruing to firm at the market price stage, and they are computed in the previous section. We investigate the sub-game perfect equilibria (henceforth SPNE) of the whole game in terms of profit.

**Result 3:**

- when $\lambda \in (0.0709115, 1)$, the SPNE is unique in pure strategies, both firms delegation $(DD, DD)$ will be dominant strategy.
- when $\lambda \in (0.0557069, 0.0709115]$, the game has two Nash equilibria in pure strategies, namely $(DD, DD)$ and $(NN, NN)$.
- when $\lambda \in (0, 0.0557069]$, strategy $(NN, NN)$ is the SPNE, both owners prefer to choose No delegation strategy.
- when $\lambda = 0$, there are three possibilities:
  - if $\beta \in (0.587601, 1]$, strategy $(DD, DD)$ will be SPNE.

[8] In the quantity competition case, $\theta_i < 1$ and owners motivate managers to behave aggressively and propose the low price in order to realize more sales. Each owner acts as a Stackelberg leader with respect to the opposing manager, and recognizes the negative slope of its rival manager's reaction function.

| | | Firm j | |
|---|---|---|---|
| | | Delegation | No Delegation |
| Firm i | Delegation | $\pi^{DD}$, $\pi^{DD}$ | $\pi^{DN}$, $\pi^{ND}$ |
| | No Delegation | $\pi^{ND}$, $\pi^{DN}$ | $\pi^{NN}$, $\pi^{NN}$ |

Figure 3: Profit Matrix

- if $\beta \in (0.510132, 0.587601)$, there are two SPNE, they will be respectively $(DD, DD)$ and $(NN, NN)$ strategy.
- if $\beta \in (0, 0.510132]$, strategy $(NN, NN)$ will be SPNE.

See Figure 4 and Figure 5.

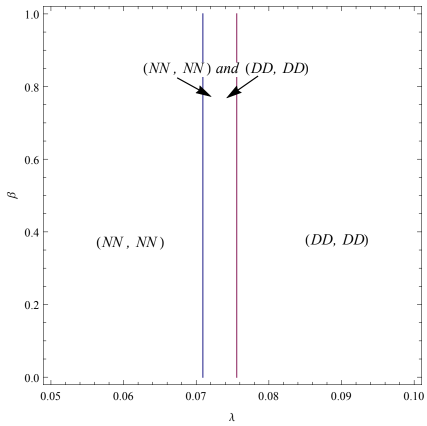


Figure 4: $\lambda \neq 0$

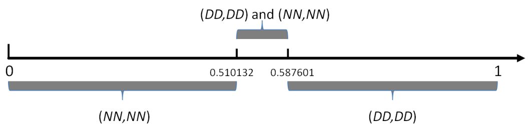


Figure 5: $\lambda = 0$

The profit of the managerial firm is more important than the owner-managed firm's profit. The intuition of this result is the following. In the symmetric (delegation) case, the owner selects a high positive weight on profits and a high negative weight on sales in the manager's contract. This action results in punishing the manager for aggressive behavior on the market and keeps the price higher, which in turn leads to higher profits for the owner if a manager is hired when spillovers is sufficiently great ($\lambda > 0.0709115$). Thereby, in many situations owners prefer delegations to making a price-decision themselves.

Moreover, this result highlights the situation where the spillover is tiny. It is found that the strategic delegation is no more in the dominant position when $\lambda \leq 0.0709115$. For example, it is possible that there are two Nash equilibriums, even both owners choose "No Delegation". Evidently, whether to delegate or not demonstrably depends upon the extent of spillovers. The influence of product heterogeneity, compared to spillovers, has not the prominent impact on the firm's decision. Nevertheless, if there is no spillovers on market, the impact of product differentiation becomes remarkable.

Kräkel (2004) points out when there is the minimal spillover, the delegation is considered as a dominant strategy; and in the case of maximal spillovers, each owner prefers "No Delegation". This outcome is valid just in the quantity-setting game under homogenous goods. In our model, even if the spillovers parameter is maximal, the owners will choose delegation due to higher profit achieved by managers; if there is no spillovers, the delegation is no longer the dominant strategy because of differentiation of products.

Furthermore, if the level of spillovers is low ($\lambda < 0.0557069$) or the products are sufficiently differentiated ($\beta < 0.510132$) with zero spillovers, it is easy to find that

$$\pi^{ND} > \pi^{DD} > \pi^{NN} > \pi^{DN}$$

This condition ensures that the equilibrium outcome is "No Delegation". However, "Delegation" strategy *Pareto* dominates equilibrium play. This payoff structure illustrates the owners'dilemma by highlighting the conflict between individual and collective rationality: while "No Delegation" is the optimal choice for an individual (*i.e.*, owner *i*) who does not know his counterpart's strategy, "Delegation" is collectively optimal for both parties[9]. If that condition does not hold, precisely when spillovers are sufficiently large or the products are less differentiated in the absence of spillovers, the problem of "prisoner's dilemma" disappears, there will be an unanimity between individual and collective incentive, as the owners are collectively better off by delegating the price decision to managers.

## 5.4 Welfare analysis

Assume that the utility function of the consumer is due to Bowley:

$$U = \sum_{i=1}^{n} \alpha q_i - \frac{1}{2}\left(\sum_{i=1}^{n}(q_i)^2 + 2\varphi \sum_{i \neq j}^{n} q_i q_j\right) + I \tag{17}$$

where $q_i$ is the output of firm $i$, $q_j$ stands for the output of firm $j$; $I$ represents the numeraire good, and it is assumed to be zero for simplicity. And the parameters $\alpha$, $\varphi$ are noted as follows:

$$\varphi = \frac{1}{2\beta}\left[(1+4\beta^2)^{\frac{1}{2}} - 1\right] \tag{18}$$

$$\alpha = 1 + \varphi = 1 + \frac{1}{2\beta}\left[(1+4\beta^2)^{\frac{1}{2}} - 1\right] \tag{19}$$

We begin to calculate the producer surplus (denoted by PS) and consumer surplus (denoted by CS).

[9]In addition to the above condition $\pi^{ND} > \pi^{DD} > \pi^{NN} > \pi^{DN}$, if the game is repeatedly played by two players, the condition $\pi^{DD} > \frac{\pi^{ND}+\pi^{DN}}{2}$ should be added. Since the Prisoner's Dilemma usually has multiple stages (i.e., repetitions), owners' decisions during one round affect decisions made during subsequent rounds, which may alter the utility of any particular Delegation or Non delegation decision. Thus, each owner can observe their counterpart's actions, making reciprocity and trust critical components of the Prisoner's Dilemma.

$$PS = \pi_i + \pi_j \quad (20)$$
$$CS = U - (p_i q_i + p_j q_j) \quad (21)$$

The social welfare is the sum of producer surplus and consumer surplus: $W = PS + CS$

Here we can find the expression of social welfare described by two unknown parameters such as $\beta$, $\lambda$, and they are considered as aleatory variables[10]. We plot the following graphic.

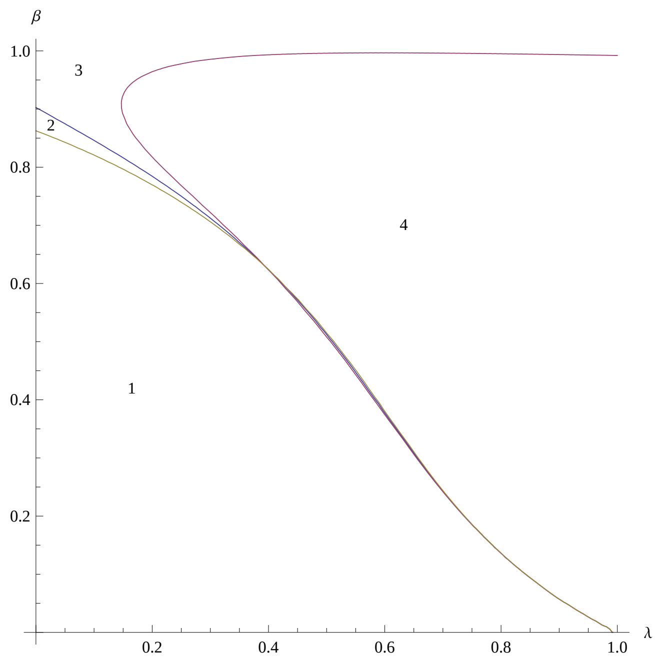


Figure 6: Four regions

According to the figure 6, we have the following result:

**Result 4:**

- Region 1 : $W^{NN} > W^{ND} > W^{DD}$
- Region 2 : $W^{NN} > W^{DD} > W^{ND}$
- Region 3 : $W^{DD} > W^{NN} > W^{ND}$
- Region 4 : $W^{DD} > W^{ND} > W^{NN}$

[10]It is found that there is a multiplier term $\left[1 - c_0(1-\beta)\right]$ which can be reduced in two sides of equation

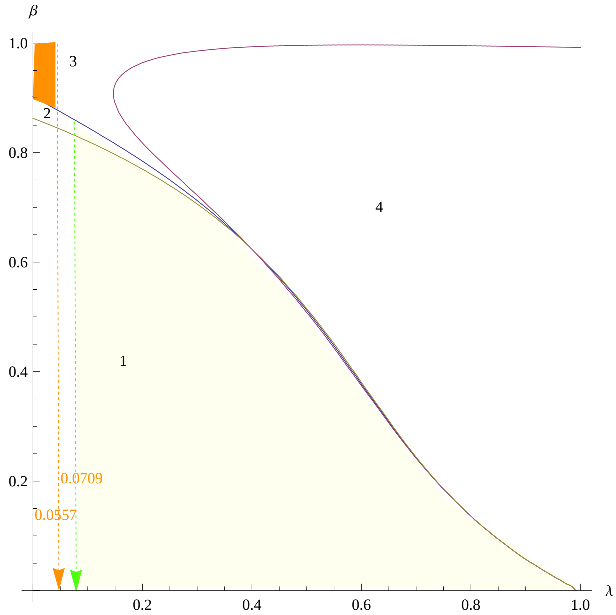


Figure 7: Conflict areas

This outcome shows whether the strategic delegation generates the higher welfare depends not only on the level of spillovers but also on the extent of product heterogeneity. The results that we obtain here are comparatively different from the traditional literature concerning the theory of delegation. For instance, in the context of full delegation in the quantity-setting game (Kopel and Riegler, 2006), the social welfare increases due to delegation when no spillovers exist; the delegation can decrease the welfare if spillovers exist and the basic unit production costs are sufficiently low.

We find when the level of spillovers is probably higher than 0.4, the gap of welfare in the different cases disappears or becomes infinitesimal. Moreover, when the spillover is sufficiently small and the products are comparatively differentiated, the delegation is not the strategy which leads to higher social welfare; whereas the delegation strategy is the best choice in terms of social welfare, when the goods are fairly similar. Intuitively, we know due to delegation the increase in firms' profit might overcompensate a decrease in the consumer rent when the products are similar. Under this circumstance, the semi-delegation could generate welfare-enhancing. Inversely, if the goods are sufficiently differentiated, both owners delegate the price-decision to managers and provide incentives for less aggressive behavior of managers. Delegation would lead to much more loss in terms of consumer surplus, but higher profits for the firms. Since the increase of firm profits is lower than the decrease of the consumer rent, the social welfare decreases due to delegation.

As we know, from the viewpoint of firm's profit, whether to delegate doesn't depend on the degree of product differentiation except for the case where there is no spillovers ($\lambda = 0$). By contrast, the delegation decision is necessarily related to the differentiation of product from the public viewpoint.

Combining the above results with the outcomes in terms of profit, we find that there are the ambiguous areas. In these areas, the strategic delegation makes firms more profitable, but it cannot give rise to desirable welfare. For instance, in Figure 7, the yellow zone lying in left side of region 3 depicts that strategic delegation being beneficial in terms of welfare, is not advantageous to firms. This zone corresponds to the traditional manufacturing (high similarity and low spillovers), such as furniture manufacturing (traditional handicrafts), art manufacturing. In these industries, strategic delegation can improve social welfare, hence the government should give some support by subsidy, in order that companies have an incentive to hire professional managers to achieve Win-Win situation. By contrast, the dashed zone corresponds to a modern manufacturing, such as appliance manufacturing industry in which companies are mostly delegated firm. In the dashed area, owners prefer to delegate, but this action damages the social welfare. Thereby, the government should strengthen the supervision to these enterprises in order to ensure that consumers do not suffer.

# 6 Conclusion

This framework focuses on the issue of strategic delegation in the presence of both product differentiation and R&D spillovers, and the results of this model provide important implications for the real practice of delegation. We explain how the shareholders'decisions are influenced by the extrinsic factors, and try to shed light on how the extrinsic factors affect the R&D effort, the price and the profit *via* the incentive scheme. We also dig out under which circumstance managerial firms prevail over entrepreneurial firms in the context of semi-delegation which is not paid much attention before.

Our findings provide some guidelines for future empirical research on the effects of firms'owners managerial incentives on oligopolistic firms'R&D investments and market performance, which is so far scant and inconclusive. Empirical analyses should start with the high-technology industries, regarding the effects of the employ of managerial contracts as an incentive mechanism to increase R&D investments.

In addition, there are several possible extensions we find worth pursuing, *e.g.*, (1) different costs of carrying out R&D affect the benefits of delegation, (2) the effect of different performance measures (relative profit, output, sales, *etc*.) can be studied in this framework. Of course, it remains for future research to be checked to which extent our main results are valid in oligopolistic markets under more general demand function.

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