Hitotsubashi Journal of Economics 56 (2015), pp.259-279.

AMBIGUITY BETWEEN PIRATE INCENTIVE AND COLLECTIVE DESIRABILITY WITHIN SEMI-DELEGATION PATTERN*

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Received March 2014; Accepted April 2015

Abstract

This paper extends 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. It is found that owners face a prisoner's dilemma when the spillover is very small or when the products are sufficiently differentiated. Concerning behavior, managers act less aggressively in the pure market, where there are delegated-firms, than in the mixed market, where entrepreneurial and managerial firms co-exist. Furthermore, we highlight the existence of ambiguous areas where delegations make firms profitable, but unable to generate desirable welfare.

Keywords: incentive scheme, product differentiation, R&D spillover, semi-delegation
JEL Classification Codes: O31, L13, D43

I. *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

* This work is supported by the Research Funds of Huaqiao University (HQHRZD2014-03). We are grateful to Nicolas Le Pape, Thierry Penard and Bernard Franck for thoughtful comments and suggestions. We also thank Said Souam and Jean-Pascal Gayant. We have received helpful comments on earlier drafts of this article from participants at the AFSE and seminar participants at GAINS. We are grateful for the very painstaking efforts made by the editor and the referee in providing us with very valuable suggestions and comments. All remaining errors are mine.

shareholders, none of whom has a controlling interest. It can 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 stages, 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 shareholder's decision (delegate or not), to shed light on how the two above-mentioned factors affect the R&D effort, the level of output and the profit *via* the incentive scheme in the managerial firm, and to determine the circumstances under which managerial firms prevail over entrepreneurial firms in the context of semi-delegation, which has not received much attention.

Earlier work on delegation has shown that firms have a unilateral incentive to delegate tasks to independent agents. Representative studies, where the final stage choices are in quantities, include 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 the equilibrium output under the standard Cournot. Based on these mentioned pioneer authors, the strategic delegation has been enriched by many studies. Examples include, sequential entry [e.g., Church and Ware (1996)], mixed oligopoly [e.g., White (2001)], equivalence of price and quantity competition [e.g., Miller and Pazgal (2001)], relative performance measure [e.g., Fumas (1992), Aggarwal and Samwich (1999), Miller and Pazgal (2002)], mergers [e.g., Gonzalez-Maestre and Lopez-Cunat (2001), Ziss (2001), Banal-Estanol (2007)], cartel stability [e.g., Lambertini and Trombetta (2002)], choice of incentive scheme [e.g., Jansen et al. (2007)], wage bargaining [e.g., Szymanski (1994), Conlin and Furusawa (2000)], delegation to bureaucrats [e.g., Basu et al. (1997)], trade policy [e.g., Das (1997)], environmental damage control [e.g., Barcena-Ruiz and Garzon (2002)], and stackelberg strategic delegation [e.g., Kopel and Löffler (2008)].

Within this large body of literature, Zhang and Zhang (1997) introduce a model that combines elements from two distinct streams of literature: strategic delegation and R&D incentives under spillovers[1]. They consider a three-stage game, where the owners of firms delegate the choices of R&D investment and production quantity to managers. Managerial compensation is based on the performance measures (profits and sales). Each manager can make investments in R&D. These investments not only reduce their own production costs, but also lower the production costs of the rival firm due to spillover effects. 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 investments, higher outputs, and lower profits in equilibrium compared to the "No Delegation" case, when the 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 that 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

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

opened up an interesting avenue of research. Following these seminal studies, 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 that the owners prefer to not delegate their power when they are allowed to choose delegation and cost-reducing R&D jointly. The study of 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 that if an entrepreneurial firm competes against a managerial firm, the latter will achieve more or equal profits. Lambertini (2004) studies the asymmetric case where an entrepreneurial firm competes with a managerial firm with homogenous goods in a Cournot competition. He finds that the managerial firm exerts more R&D effort than the entrepreneurial firm. At the equilibrium, the managerial firm generates more 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 of “semi-delegation”. As in a great number of firms, although owners hire the manager to address operative problems, such as, choosing product price and product quantity, they still withhold the power that has an enormous effect on a firm’s development and orientation, such as R&D investment. Empirical evidence, theoretical findings and various examples can be used to illustrate semi-delegations. Barcena-Ruiz and Casado-Izaga (2005) study the delegation problem in a 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 (2014) investigate different scopes of delegation in a Cournot duopoly model and find that only short-run decisions are delegated and that 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), while 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 Martinez (1993, p.72) explain: Benneton approved the 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. We build a model where semi-delegation is designed, and it is reasonable that we assume that the owners take responsibility for R&D decisions and then decide whether to delegate short-run decisions. In our model, the differentiated products competition takes place as part of a delegation game, and 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 owners have 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. Until now, these authors have mostly studied the strategic delegation in the case of Cournot type quantity competition. Because in quantity-

[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.

setting games, owners realize strategic advantage by inducing managers to be more aggressive in the product market. Miller and Pazgal (2001) illustrate that 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, when firms compete in only one dimension and when the relative performance is regarded as the incentive scheme. In the present study, we use price-setting instead of Cournot structure to differentiate the analysis in a delegation game. The attractive feature of the Bertrand setup, compared to the Cournot market structure, stems from the fact that firms are able to change prices faster and at less cost than setting quantities because changing quantities requires an adjustment of inventories, which may necessitate a change in firms' capacity to 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 contracts, we adopt the scheme based on sales to avoid the negative value of optimal contracts. For example, if the relative performance were considered as the incentive scheme, the value of the optimal scheme would be negative. This means that even if the manager increases the rival's profit instead of the profit of the 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 factors and extrinsic factors. The former is the self-control element, in other words, what the owners can control, for example, (1) the choice of the different types of contract, namely the contracts rewarding managers on the basis of a combination of profits and revenues [e.g., Fershtman and Judd (1987), Sklivas (1987)], or a combination of profits and quantities [e.g., Vickers (1985)], or the schemes based on market or relative profits [e.g., Jansen et al. (2007)]; and (2) owners' behaviors related to intrinsic factors [e.g., Freshtman and Gandal (1994), Brod and Shivakumar (1999), Pal (2010)]. Extrinsic factors are factors that are out of control, such as the level of spillovers and the degree of product differentiation[3]. To the best of our knowledge, studies on delegation issues focusing on these extrinsic factors are rare. This framework aims to fill the gap and instruct owners on how to make better decisions based on the actual level of extrinsic factors.

In the present study, 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 and asymmetric) into account. The sequence of events that we consider is as follows: first, the owners decide the R&D investment level simultaneously and independently; then, the owners decide whether to employ a manager in charge of deciding prices on the owner's behalf; subsequently, only the owner who has adopted the delegation strategy can decide the incentive scheme of his manager; finally, the product prices are decided simultaneously by the decision-makers who could be either managers or owners. According to this timing, we find that 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 product differentiation and spillovers; the inverse outcome is verified in the symmetric case where there are exclusively either entrepreneurial firms or managerial firms. Furthermore, the conflict between individual and collective rationality is highlighted in this paper, we find that owners

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

face a prisoner's dilemma if the spillover is very small or if the products are sufficiently differentiated. This paper also illustrates that managers act less aggressively in the pure market where there are two delegated-firms than in the mixed market where entrepreneurial and managerial firms co-exist. It is found that the decision to delegate demonstrably depends upon the extent of spillovers. The influence of product heterogeneity, compared to spillovers, does not have a prominent impact on the owner's decision. Nevertheless, if there is no spillover effect, the impact of product differentiation becomes remarkable and clearly affects the owner's choice.

The welfare issue is another point that we pay attention to. It is argued that the gap of welfare among the different cases disappears (or becomes infinitesimal) when the spillover is large. Moreover, when the spillover is sufficiently small, the "No Delegation" strategy enhances more welfare if the products are comparatively differentiated, whereas if the goods are fairly similar, the "Delegation" strategy will be better in public view. In addition, combining the welfare implication with the outcomes regarding profit, we find ambiguous areas in which delegations can make firms profitable but cannot give rise to desirable welfare. Whether the delegation generates individual-collective unanimity or leads to individual-collective conflict depends on the two extrinsic factors highlighted in this paper.

The rest of the paper proceeds as follows. Section 2 describes the model, and section 3 briefly analyzes the benchmark case. Section 4 studies the equilibrium outcomes under semi-delegation (symmetric case and asymmetric case). In section 5, multiple comparisons are presented. Section 6 provides some concluding remarks.

II. *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.

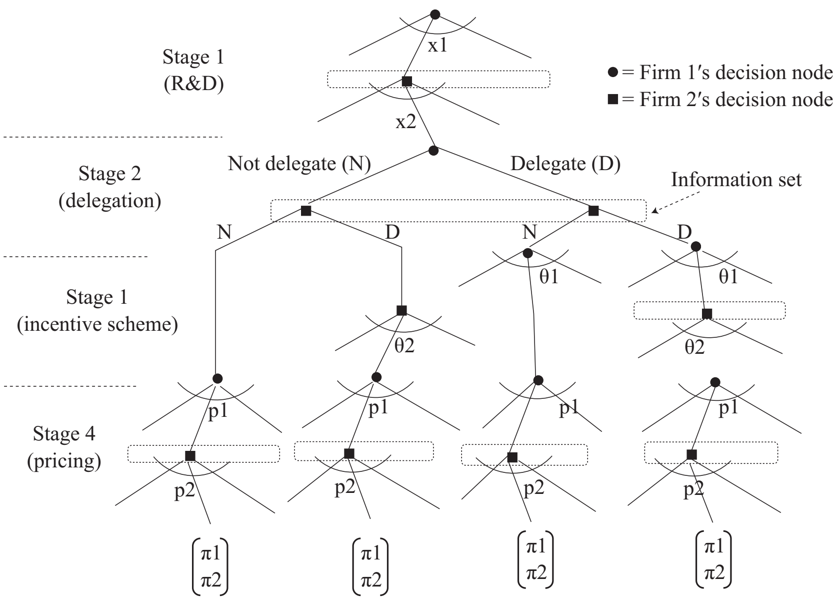
We assume that owners offer "*take-it-or-leave-it*" linear incentive schemes to their managers. When saying "Owner", we mean an individual or a group whose sole purpose is to maximize the profits of the firm; "Manager" refers to an agent that the owner hires to make real time operating (price) decisions. 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 π_i, S_i and C_i are profit, sales revenue and effective production cost respectively. Clearly, maximizing $A_i+B_iR_i$ and maximizing R_i are equivalent. The incentive parameter θ_i is chosen by the owner of firm i. Note that θ_i just affects the manager's perspective on cost. If $\theta_1<1$, it signifies that the manager of firm i 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 manager considers θ_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 $\theta_i>1$, the owner of firm i penalizes sales maximization and overcompensates the manager at the margin of profit. This type of incentive scheme induces the manager to be less aggressive in the product market, and the manager is supposed to reduce sales in order to keep high price in the product market.

Concerning cost function, each firm has the same initial cost indexed by c_0, which can be reduced by investing in R&D. Due to spillovers, R&D investment x_i not only benefits the investing firm i, but also leads to lower unit costs for rival firm j. Let j ($j=1$, 2 and $i \neq j$) refer to the 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 spillover effect. 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 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 $\beta \in (0, 1]$ is a product differentiation parameter which inversely indicates the strength of product heterogeneity.

The timing of the game is as follows:

[**Stage 1**] the owners decide the R&D investment level simultaneously and independently;
[**Stage 2**] the owners choose whether to employ a manager in charge of deciding prices on the owner's behalf *(If the manager is not employed, the price decision will be decided by the owners at stage 4)*;
[**Stage 3**] only the owner who has adopted the semi-delegation strategy can decide the incentive scheme of his manager *(the incentive schemes cannot be renegotiated, and they become common knowledge once they are signed)*;
[**Stage 4**] the product prices are decided simultaneously by the decision-makers who could be either managers or owners.

FIGURE 1. TIMING OF THE GAME



According to this timing (Fig.1), our game obviously has four different cases. For simplicity, we use the letter N representing “No Delegation”, the letter D standing for “Delegation”. The first one is that the owners take responsibility for both R&D decision and price decision. Because neither owner hires the manager, it can be denoted by NN. The second refers to the case in which both owners delegate the price decisions to managers, it will be denoted by DD. The rest are those in which one owner delegates the price decision, while another owner takes the price decision by himself, thereby they can be regarded as ND and DN respectively.

III. *Benchmark (NN)*

Because neither owner delegates the price decision to managers in this benchmark 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 solve the model backwards beginning with the last stage in which the owners decide the prices, simultaneously and independently. Owner i chooses the price p_i to maximize the 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:

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

with

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

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

The owners decide the level of R&D investment to maximize their profits in the first stage. The optimal R&D efforts are shown as follows:

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

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

then we find the equilibrium price and the equilibrium profit:

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

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

It is clear that the R&D effort x_i^{NN}, the price p_i^{NN} and the profit π_i^{NN} are always positive for $\beta\in(0, 1]$ and $\lambda\in[0, 1)$.

IV. *Semi-delegation*

1. Symmetric Case: Both Owners Delegate the Price Decisions (DD)

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

Given x_i^{DD}, x_j^{DD}, θ_i^{DD} and θ_j^{dd}, the price decided by firm i is:

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

At stage 3, the owners endogenously design the managerial incentive scheme, given the R&D efforts. We can easily rewrite both π_i^{DD} and π_j^{DD} as a function of x_i^{DD} and x_j^{DD}, then the contract parameter θ_i^{DD} can be found. Plugging all these into the profit functions would yield the profit of firms 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 their profits. The R&D investment, contract, price and profit in equilibrium are derived respectively.

R&D investment:

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

with

$$\begin{aligned}\Theta_1&=4\beta(\beta^5-\beta^4-4\beta^3+4\beta^2+4\beta-4)\\ \Theta_2&=4\beta(\beta^5-4\beta^4-\beta^3+14\beta^2-6\beta-12)+32\\ \Theta_3&=\beta^6-10\beta^5-4\beta^4+16\beta^3+24\beta^2-32\end{aligned}$$

Note that the R&D investment (x^{DD}) is always positive, and the relationship $x^{DD}>x^{NN}$ holds true all the time. Consequently, the 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 numerical analyses, it is found the incentive parameter (θ^{DD}) is always higher than 1, the owners overcompensate the managers for profits by penalizing sales. This outcome coincides with the result obtained by Fershman and Judd (1987) which demonstrates $\theta_i>1$.

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

$$\Psi_1=4\beta^8-24\beta^6+48\beta^4-32\beta^2$$
$$\Psi_2=-24\beta^7+128\beta^5-224\beta^3+128\beta$$
$$\Psi_3=\beta^8+12\beta^6+8\beta^4-128\beta^2+128$$

It is straightforward to show that the profit of managerial firm (DD) is always greater than the profit of entrepreneurial firm (NN), regardless of spillovers and product differentiation. In other words, strategic semi-delegation is always beneficial to firms in the symmetric case.

2. Asymmetric Cases: Only One Owner Delegates the Price Decision (ND and DN)

Assume in the asymmetric case, firm j is managerial while firm i is entrepreneurial. The objective functions at the production stage (Stage 4) are:

$$\pi_i=p_iq_i=(c_0-x_i-\lambda x_j)q_i-\frac{1}{2}x_i^2$$
$$R_j=\theta_j\pi_j+(1-\theta_j)S_j$$

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 their own R&D efforts to seek for profit-maximization, where the R&D efforts are respectively determined as follows:

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

$$x_j^{ND}=\frac{(\beta\lambda-2+\beta^2)(\beta c_0-c_0+1)(\Upsilon_5\lambda^2+\Upsilon_6\lambda+\beta^3-\beta^2+4)}{\Upsilon_1\lambda^4+\Upsilon_2\lambda^3+\Upsilon_3\lambda^2+\Upsilon_4\lambda+\beta^6+2\beta^2-8} \tag{14}$$

with

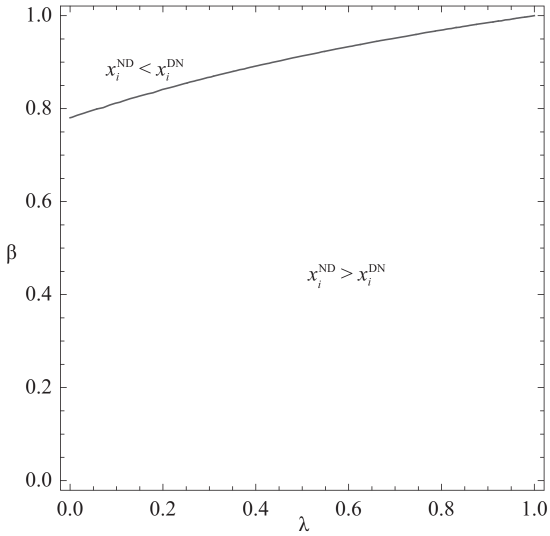
$$\begin{aligned}
\Upsilon_1&=\beta^6-3\beta^4+2\beta^2\\
\Upsilon_2&=\beta^7-8\beta^5+15\beta^3-8\beta\\
\Upsilon_3&=-3\beta^6+10\beta^4-12\beta^2+8\\
\Upsilon_4&=-\beta^7-2\beta^5+21\beta^3-24\beta\\
\Upsilon_5&=\beta^4+\beta^3-2\beta^2-2\beta\\
\Upsilon_6&=-\beta^4-4\beta^3-\beta^2+6\beta+4
\end{aligned}$$

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

$$\begin{cases}
x_i^{ND}>x_i^{DN} & \text{if } \beta<\dfrac{\sqrt{17}-1}{4} \text{ and } 0\leq\lambda<1\\[2ex]
x_i^{ND}<x_i^{DN} & \text{if } \beta>\dfrac{\sqrt{17}-1}{4} \text{ and } 0\leq\lambda<\dfrac{2\beta^2+\beta-2}{2-\beta^2}\\[2ex]
x_i^{ND}>x_i^{DN} & \text{if } \beta>\dfrac{\sqrt{17}-1}{4} \text{ and } \dfrac{2\beta^2+\beta-2}{2-\beta^2}\leq\lambda<1
\end{cases}$$

According to Fig.2, the owner of entrepreneurial firm has more interest to invest in R&D, when the goods are sufficiently heterogeneous $\left(\beta<\frac{1}{4}(\sqrt{17}-1)\right)$. By contrary, when products are similar $\left(\beta>\frac{1}{4}(\sqrt{17}-1)\right)$ and the spillover is not large enough $\left(\lambda<\frac{2\beta^2+\beta-2}{2-\beta^2}\right)$, the owner of managerial firm will spend more on R&D. Because of the introduction of the product differentiation, we carry on a more general analysis, compared to the work of Lambertini (2004) which finds the managerial firm exerts more R&D effort than the entrepreneurial firm. We find that R&D investment exerted by entrepreneurial firm can be greater than that exerted by managerial firm, when products are sufficiently differentiated. Furthermore, we retrieve the outcome which coincides with the main result of Lambertini (2004), in the extreme case where the goods are homogenous ($\beta=1$).

FIGURE 2. R&D INVESTMENT IN THE ASYMMETRIC CASE



After having characterized the equilibrium R&D investment, we list the incentive parameter of managerial firm j, the corresponding prices and profits, respectively:

Incentive parameter:

$$\theta_j^{ND}=\frac{\Phi_1\lambda^4+\Phi_2\lambda^3+\Phi_3\lambda^2+\Phi_4\lambda+\Phi_5}{\Phi_1\lambda^4+\Phi_2\lambda^3+\Phi_6\lambda^2+\Phi_7\lambda+\Phi_2} \tag{15}$$

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 numerical analyses, it is found that the incentive parameter (θ^{ND}) is always higher than 1. The incentive parameters in the different cases will be compared in section 5.2.

Price:

$$p_i^{ND}=\frac{\Psi_1\lambda^4+\Psi_2\lambda^3+\Psi_3\lambda^2+\Psi_4\lambda+\Psi_5}{\Psi_6\lambda^4+\Psi_7\lambda^3+\Psi_8\lambda^2+\Psi_9\lambda+\beta^6+2\beta^2-8} \tag{16}$$

$$p_j^{ND}=\frac{\Psi_1\lambda^4+\Psi_2\lambda^3+\Psi_{10}\lambda^2+\Psi_{11}\lambda+\Psi_{12}}{\Psi_6\lambda^4+\Psi_7\lambda^3+\Psi_8\lambda^2+\Psi_9\lambda+\beta^6+2\beta^2-8} \tag{17}$$

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

Profit:

$$\pi_i^{ND}=\frac{\Omega_1\Omega_2^2(\beta c_0-c_0+1)^2}{2\Omega_3^2} \tag{18}$$

$$\pi_j^{ND}=\frac{\Omega_4\Omega_5^2(\beta c_0-c_0+1)^2}{2\Omega_3^2} \tag{19}$$

with

$$\Omega_1=-\left[(4\beta^2-4\beta^4+\beta^6)\lambda^2-(16\beta-20\beta^3+6\beta^5)\lambda+\beta^4+8\beta^2-16\right]$$
$$\Omega_2=\beta(\beta+1)\lambda^2+(\beta^3-3\beta-2)\lambda-\beta^3-2$$
$$\Omega_3=(\beta^6-3\beta^4+2\beta^2)\lambda^4+(\beta^7-8\beta^5+15\beta^3-8\beta)\lambda^3+(-3\beta^6+10\beta^4-12\beta^2+8)\lambda^2 +(-\beta^7-2\beta^5+21\beta^3-24\beta)\lambda+2\beta^2+\beta^6-8$$
$$\Omega_4=-[\beta^2\lambda^2+2\beta(\beta^2-2)\lambda+\beta^4-4]$$
$$\Omega_5=(\beta^4+\beta^3-2\beta^2-2\beta)\lambda^2+(-\beta^4-4\beta^3-\beta^2+6\beta+4)\lambda+\beta^3-\beta^2+4$$

It is found that $\pi_i^{ND}(=\pi_j^{DN})>\pi_i^{DN}(=\pi_j^{ND})$, and the profit of entrepreneurial firm is always greater than that of managerial firm regardless of product differentiation and spillovers. However, the inverse outcome appears in the symmetric case ($\pi_i^{NN}<\pi_i^{DD}$). The primary reason is on account of the high value of the incentive parameter. The contract θ is always higher than 1, which signifies that the initial marginal cost is distorted and turns into θc_0. Due to the augmentation of cost, the managerial firm has to raise the price. Consequently, the entrepreneurial firm prevails against[4] the managerial firm in terms of profit, because of the

[4] Although Lambertini (2004) has analyzed the similar asymmetric case, the results are comparatively different.In a

marginal cost advantage.

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

V. *Analysis and Results*

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

1. R&D Investment

Although we cannot arrange all x_Ω^Ψ with $\Psi = NN, DD, ND, DN$ and $\Omega = i, j$, it is possible to find the greatest value.

Result 1: *Under all situations, it is found*

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

and the greatest value of x_Ω^Ψ is x_Ω^{DD}.

When both owners choose semi-delegation strategy, they will spend more on R&D, compared to the benchmark case and the asymmetric cases.

2. Incentive Scheme

Because the owners always take responsibility for R&D investment decisions, there are only two possible types of incentive schemes: the incentive parameter in the case of two managerial firms is denoted by θ^{DD}, and the incentive parameter when the entrepreneurial firm and the managerial firm co-exist is denoted by θ^{ND}.

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

This ranking always holds true for $\lambda \in [0, 1)$ and $\beta \in (0, 1]$. In contrast with the quantity-

Cournot game and absence of product differentiation, he finds at equilibrium the managerial firm earns higher profit than the rival entrepreneurial firm.

setting competition[5], the incentive parameter in the price-setting game is always higher than 1, 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, owners induce managers to act less aggressively in markets where there are only delegated-firms than in markets where entrepreneurial and managerial firms co-exist.

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" (Fig.3), the strategies for each owner of firms 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 the firm at the market price stage, and they are computed in the previous section. We investigate the Sub-game Perfect Nash Equilibrium (henceforth SPNE) of the whole game in terms of profit.

FIGURE 3. PROFIT MATRIX

		Firm j	
		Delegation	No Delegation
Firm i	Delegation	π^{DD} , π^{DD}	π^{DN} , π^{ND}
	No Delegation	π^{ND} , π^{DN}	π^{NN} , π^{NN}

Result 3:

- *when* $\lambda \in (0.0709115, 1)$*, there is a unique SPNE in pure strategies,* (D, D) *will be dominant strategy;*
- *when* $\lambda \in (0.0557069, 0.0709115]$*, the game has two SPNEs in pure strategies, namely* (D, D) *and* (N, N)*;*

[5] 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.

FIGURE 4. $\lambda \neq 0$

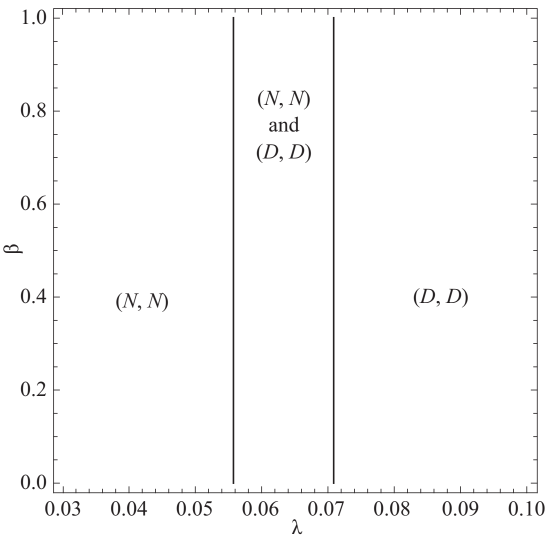
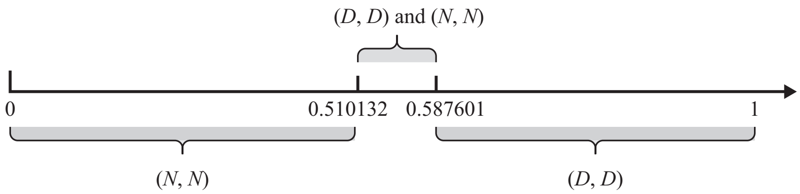


FIGURE 5. $\lambda = 0$



- *when* $\lambda \in (0, 0.0557069]$*, both owners prefer to choose "No Delegation",* (N, N) *is SPNE in pure strategies;*
- *when* $\lambda = 0$*, there are three possibilities:*
- *if* $\beta \in (0.587601, 1]$*,* (D, D) *will be SPNE in pure strategies;*
- *if* $\beta \in (0.510132, 0.587601)$*, there are two SPNEs, they will be respectively* (D, D) *and* (N, N)*;*
- *if* $\beta \in (0, 0.510132]$*,* (N, N) *will be SPNE in pure strategies.*

See also Fig.4 and Fig.5.

The profit of the managerial firm is greater than the profit of the owner-managed firm. The intuition of this result is the following. In the symmetric (DD) case, the owner chooses a high positive weight on profits and a high negative weight on sales in the manager's contract. This action punishes managers for aggressive behavior in the market and keeps the price high, which in turn leads to more profit for the owner if a manager is hired, when the spillover is sufficiently large ($\lambda > 0.0709115$). Therefore, in many situations, owners prefer delegating to making a price decision by themselves.

Moreover, result 3 highlights the situation where the spillover is very small. When $\lambda \leq 0.0709115$, "Delegation" is no longer the dominant strategy. Evidently, whether to delegate or not demonstrably depends upon the extent of spillovers. The influence of product heterogeneity, compared to spillovers, does not have a prominent impact on the owner's decision. Nevertheless, if there are no spillovers in the market ($\lambda = 0$), the impact of product differentiation becomes remarkable.

Kräkel (2004) notes that when there is minimal spillover, "Delegation" is considered as a dominant strategy; and in the case of maximal spillover, each owner prefers "No Delegation". This outcome is valid only in the quantity-setting game with homogenous goods. In our model, even if the spillover parameter is maximal, owners will choose "Delegation" due to the higher profit achieved by managers; moreover, when there is minimal spillover ($\lambda = 0$), owners prefer "No Delegation" strategy because of the 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-spillover, it is easy to find

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

This condition ensures that the equilibrium outcome is "No Delegation". However, the "Delegation" strategy *Pareto* dominates equilibrium play. This payoff structure illustrates the owners' dilemma by highlighting the conflict between individual and collective rationality: although "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[6]. If the condition does not hold true, precisely when the spillover is sufficiently large or the products are less differentiated in the absence of spillover, the problem of "prisoner's dilemma" disappears; there will be conformity between individual and collective incentives, because the owners are collectively better off by delegating the price decision to managers.

4. Welfare Analysis

Assume that the utility function of the consumer is:

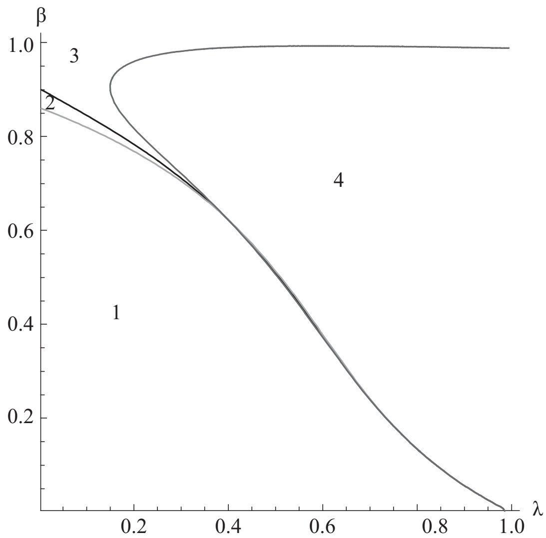
$$U = \sum_{i=1}^{n} \alpha q_i - \frac{1}{2}\left(\sum_{i=1}^{n}(q_i)^2 + 2\varphi \sum_{i \neq j}^{n} q_i q_j\right) + I \tag{20}$$

where q_i is the output of firm *i*, q_j is the output of firm *j*; *I* represents the numeraire good, and it is assumed to be zero for simplicity. The parameters α and φ are noted as follows:

$$\varphi = \frac{1}{2\beta}[(1+4\beta^2)^{\frac{1}{2}} - 1] \tag{21}$$

[6] 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.

Figure 6. Four Regions



$$\alpha=1+\varphi=1+\frac{1}{2\beta}[(1+4\beta^2)^{\frac{1}{2}}-1] \tag{22}$$

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

$$PS=\pi_i+\pi_j \tag{23}$$

$$CS=U-(p_i q_i+p_j q_j) \tag{24}$$

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

We can find the expression of social welfare described by two parameters β and λ. Consider them as variables[7], we plot the following figure (Fig.6).

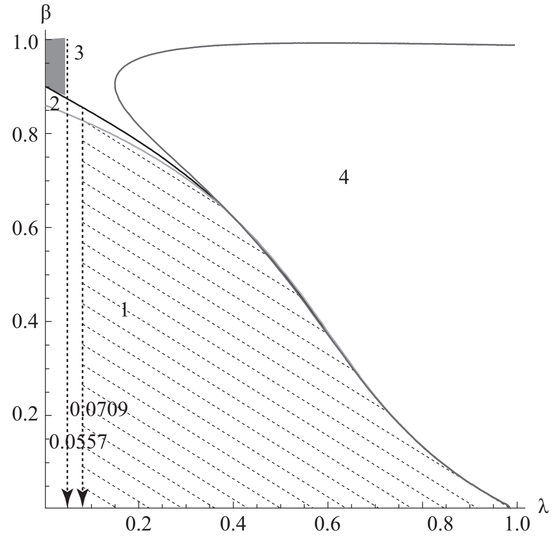
Result 4:

- *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* : $W^{DD}>W^{ND}>W^{NN}$

Result 4 shows that whether the strategic semi-delegation enhances the welfare not only depends on the level of spillovers, but also on the extent of product heterogeneity. This result is comparatively different from the traditional literature concerning the theory of delegation. For instance, in the context of full delegation within the quantity-setting game (Kopel and Riegler, 2006), the social welfare increases due to delegation when there are no spillovers in the market; the delegation can decrease the welfare if spillovers exist and the basic unit production costs

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

FIGURE 7. CONFLICT AREAS



are sufficiently low.

We find that when the level of spillovers is 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, "Delegation" is not the strategy that generates higher welfare, whereas the semi-delegation strategy is the best choice in terms of social welfare when the goods are fairly similar. Intuitively, we know that due to delegation, the increase of profit might over-compensate a decrease in the consumer rent when products are similar. Under this circumstance, semi-delegation could be welfare-enhancing. Conversely, if the goods are sufficiently differentiated, both owners delegate the price decision to managers and provide incentives for less aggressive behavior of managers. Semi-delegation would lead to much more loss in terms of consumer surplus, but higher profits for the firms. Because the increase in profits is lower than the decrease in the consumer rent, the strategic delegation decreases the social welfare.

As we know, from the viewpoint of owners, the decision to delegate does not depend on the degree of product differentiation except for the case where there are no spillovers ($\lambda=0$). By contrast, from the public viewpoint, the semi-delegation decision is necessarily related to the differentiation of products.

Combining the Result 4 with the outcomes in terms of profit (Result 3), we find that there are two ambiguous areas. In these areas, strategic semi-delegation makes firms more profitable but cannot give rise to desirable welfare. For instance, in Fig.7, the yellow area lying to the left side of region 3 depicts that strategic semi-delegation is beneficial in terms of welfare but not advantageous to firms. This area corresponds to traditional manufacturing (high similarity and low spillover), such as furniture manufacturing (traditional handicrafts) and art manufacturing. In these industries, the strategic semi-delegation can improve social welfare; hence, the government should give some support using subsidies, so that companies have an incentive to hire professional managers to achieve a Win-Win situation. By contrast, the dashed area corresponds to modern manufacturing, such as the appliance manufacturing industry in which companies are mostly delegated-firms. In the dashed area, owners prefer to delegate, but this action damages the social welfare. Therefore, the government should strengthen the supervision of these enterprises to ensure that consumers do not suffer.

VI. *Conclusion*

This framework focuses on the issue of strategic semi-delegation in the presence of both product differentiation and R&D spillovers. The paper explains how shareholders' decisions are influenced by extrinsic factors and tries to shed light on how extrinsic factors affect R&D effort, price and profit *via* the incentive scheme. Moreover, this paper examines the circumstances in which managerial firms prevail over entrepreneurial firms in the context of semi-delegation, an issue that has not received much attention. The results of this model provide important implications for the real practice of delegation.

Furthermore, our findings provide some guidelines for future empirical research on the effects of 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 employment 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) how different costs of carrying out R&D affect the benefits of delegation; and (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 determine to what extent our main results are valid in oligopolistic markets under more general demand functions.

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