Letter

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Investment Secrecy and Competitive R&D

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Abstract: Secrecy about investment in research and development (R&D) can promote greater technological change and higher social welfare in competitive industries. In a duopoly where each firm has private information about its actual production technology (or cost) and firms engage in cost-reducing R&D with uncertain outcomes prior to engaging in price competition, the equilibrium outcome when firms do not observe the R&D investment chosen by the rival (investment secrecy) yields higher investment, social welfare, and industry profit compared to the outcome when R&D investment levels of firms are publicly observable. Government intervention to secure disclosure of R&D investments may be counterproductive; trade secret laws that protect privacy of information related to R&D inputs or investment may be helpful.

Keywords: Cost-reducing technology, Duopoly, Incomplete information, Price competition, Secrecy, Strategic investment

1 Introduction

Firms improve their production technology through a variety of means, many of which are unobservable to the outside world. This is, in particular, true for a very significant proportion of innovations and other production efficiency gains that arise through learning, internal research and development (R&D), and accumulation of organizational capital. As many of these gains are not patentable, firms prefer to retain privacy of information about their actual cost and technology structure. More interestingly, it is difficult for existing rivals, potential competitors, and other stakeholders in the industry to readily acquire information about efforts and inputs expended in the R&D process of a firm. In competitive markets, the absence of observability of R&D investment or

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efforts undertaken by other firms is likely to influence the strategic incentive to invest, the extent of actual technological improvements, and the eventual market outcomes. This leads to an important question about the effect of privacy of such information on technological change and social welfare. If such secrecy is not socially desirable, then there would be a case for public policy to discourage secrecy and promote sharing and disclosure of information about R&D investments made by the firms. This paper attempts to analyze the potential impact of secrecy of the level of R&D investment made by the firms in a market characterized by privacy of information about the actual cost structure of the firms i. e., their actual production technology.

My paper draws on the seminal work of Gal-or (1986) who finds that firms strategically competing in prices do not have any incentive to disclose information about their own cost of production. In this paper, I assume that firms keep their final outcome of process innovation secret and primarily focus on the role of (exogenously given) secrecy of strategic R&D investment. Moreover, in contrast to this paper, the existing literature has largely focused on issues related to the observability of cost or R&D outcomes. Thomas (1997) examines the incentive for cost-reduction by a single firm in an industry where firms differ in their initial cost and shows that this unilateral incentive for cost-reduction is higher when information about actual production cost is privately held.

In particular, the paper analyzes an *ex ante* symmetric homogenous good duopoly where firms engage in process innovation (that reduces production cost) and price competition. The firms simultaneously decide whether to invest in cost-reduction and after this, they compete in prices. The realized cost-reduction is uncertain and depends on the amount of investment. Each firm observes its own realized production cost outcome prior to price setting but remains unaware of the actual outcome of the R&D investment made by its rival. I compare the incentive to invest in cost-reduction and the market outcome generated in this extensive form with the secrecy of investment to the equilibrium outcome of an alternative extensive form where the level of R&D investment is publicly observed before price setting. The realized cost i. e., the outcome of R&D is assumed to be private information in both extensive forms.

The main result of the paper is the equilibrium outcome under secrecy of R&D investments yields higher social welfare than public observability of (or information sharing about) investment. Further, secrecy may yield higher total amount R&D investment and higher expected profit for firms.

One implication of this is that there may not be any case for public policy to encourage information sharing arrangements among competing forms about R&D investments. Further, there is some benefit from the protection of information about expenditures, inputs or efforts going into firms' R&D processes through trade secret laws[1] and deterrence of competitive intelligence gathering activities[2] related to R&D investment or inputs.

The paper is organized as follows. Section 2 describes the model. In Section 3, I discuss the pricing and investment outcomes under incomplete information when R&D investment is secret and when it is publicly observable.

2 The Model

I consider an oligopolistic market with two *ex ante* identical firms that compete in prices and produce a physically homogenous product. The production technology of each firm can be of two potential types: high-cost (H) and low-cost (L): Each firm produces at constant unit cost. The unit production cost of a high-cost type (defined by c_H) is greater than that of a low-cost type (defined by c_L) i. e., $0 < c_L < c_H$. There is a unit mass of risk neutral consumers in the market. Consumers have unit demand i. e., each consumer buys at most one unit of the good. Each consumer is willing to pay V for a unit produced by either firm. I assume that $V > c_H$.

Firms are initially endowed with high-cost technology i. e., each firm incurs a unit production cost of c_H. Firms can invest in R&D of a new cost-reducing technology. However, the outcome of the investment is uncertain, and the probability of success is positively related to the cost of investment. The cost of investment is given by $A\mu_i$ where the R&D efficiency parameter, A, can be interpreted as the maximum possible cost of investment that a firm can incur and $\mu_i \in [0, 1] \forall i = 1, 2$ is the investment or alternatively can be interpreted as the probability of successful R&D. In particular, a firm successfully installs the low-cost technology with probability μ_i and remains the high-cost type with probability $1 - \mu_i$. I assume that $0 < A < (c_H - c_L)$[3].

In the first stage, the firms simultaneously decide how much to invest (viz., $A\mu_i$)[4]. It is evident that the more a firm invests in cost-reducing technological R&D, the higher is the probability of being successful i. e., becoming a low-cost type firm. I consider two possible scenarios after the firms decide on their R&D investment in the first stage. (1) The investment decisions become publicly

1 In the US, state governments choose to adopt conveniently modified versions of the Uniform Trade Secret Acts (1979).

2 See Bagnoli and Watts (2015) among others.

3 If $A > (c_H - c_L)$ then firms do not invest in the equilibrium under incomplete information.

4 Alternatively, one can think that the firms choose the probability of successful investment in cost-reducing technology i. e., μ_i.

observable but the firms remain unaware of the final outcome of the investment made by the rival firms; in the rest of the paper, I refer to this as the "*incomplete information with observable investment*". The alternative scenario is where (2) the investment decision of each firm remains private knowledge (secret) and thus, a firm neither observes the rival's investment decision nor the final outcome of the rival's investment; this is referred as the "incomplete information with unobservable investment". I denote the investment outcomes and the *ex ante* expected profits under incomplete information with observable investment as well as with unobservable investment with superscript *IO* and *IU* respectively. The realizations of the production technology after investment are independent across firms, and there is no spill over. In the next stage, firms choose prices simultaneously. Finally consumers observe the prices charged by the firms, decide whether to buy, and from which firm to buy.

3 Observability vs Secrecy

After the strategic investment decisions in the first stage, a firm gets to know the actual outcome of its own investment in the cost-reduction, but does not learn anything about the rival's R&D outcome. Therefore, when the firms simultaneously choose price of their product they are not aware of each other's marginal cost of production i. e., a firm does not know whether the rival has successfully adopted the low-cost technology.

To begin with, I solve the second stage (incomplete information) subgame where firms choose prices simultaneously with the private knowledge of their own production technology[5]. Without any loss of generality, I assume that $\mu_i \geq \mu_j \forall i, j = 1, 2$ where $i \neq j$ i. e., firm i is more likely to successfully install the new low-cost technology than firm.

Lemma 1 (Price equilibrium under incomplete information): *The high-cost type charges a price equal to its own unit production cost* $(p_H = c_H)$ *and the low-cost type randomizes over an interval* $\left(p_L \in \left[(1-\mu_j)c_H + \mu_j c_L, c_H\right]\right)$ *with probability distributions*

$$F_i(p) = \frac{1}{\mu_i} - \frac{(1-\mu_j)}{\mu_i}\frac{(c_H - c_L)}{(p - c_L)} \text{ and } F_j(p) = \frac{1}{\mu_j} - \frac{(1-\mu_j)}{\mu_j}\frac{(c_H - c_L)}{(p - c_L)}$$

5 Spulber (1995) and Routledge (2010) consider Bertrand price competition under asymmetric information about rival's cost when firms face downward sloping market demand.

$\forall i, j = 1, 2$ *where* $i \neq j$ *and* $\mu_i \geq \mu_j$. *The ex ante expected profits are*

$$\pi_i = \mu_i(1 - \mu_j)(c_H - c_L) \text{ and } \pi_j = \mu_j(1 - \mu_j)(c_H - c_L). \quad [1]$$

Proof: First, note that there does not exist any Bayesian price equilibrium in pure strategies. The reason is as follows. The low-cost type has competitive advantage over the high-cost type since $V - c_L > V - c_H$; thus, if the investing firm becomes low-cost type it enjoys market power and steals all business in the state when the rival (investing firm) remains high-cost type, but also has an incentive to undercut the rival in case it is of low-cost type too (i. e., the rival has adopted the low-cost technology successfully). In the unique price equilibrium, the low-cost type randomizes price over an interval $[\underline{p}, c_H]$ to balance these incentives. If $\mu_i > \mu_j$, the low-cost type of firm i has a mass point on the upper bound; in other words, firm i has higher probability of charging the upper bound (c_H) of the price distribution than firm j does. Further, firm i of low-cost type charges the upper bound (c_H) when it believes that the rival j has remained a high-cost type with probability $(1 - \mu_j)$. Therefore, the equilibrium profit of the low-cost type firm i is

$$\pi_L = (1 - \mu_j)(c_H - c_L)$$

for any price $p \in [\underline{p}, c_H]$. Note that the low-type of firm j earns the same profit (π_L), but there is no mass point[6] on the upper bound (c_H) for firm j. Also, if $\mu_i = \mu_j$ then there is no mass point on the upper bound of low-cost type of either firm. The low-cost type charges $\underline{p}$ only when the rival is of high-cost type for sure; this implies that $\pi_L = (\underline{p} - c_L)$. This yields the lower bound of the mixed strategy price support $\underline{p} = (1 - \mu_j)c_H + \mu_j c_L$.

At any price $p \in [(1 - \mu_j)c_H + \mu_j c_L, c_H]$ the low-cost type firm can sell to the entire market if either the rival is of high-cost type or it is not undercut by the low-cost rival. Thus, the low-cost firm earns expected profit of the dirty type i. e., $\pi_L = (1 - \mu_j)(c_H - c_L)$; this implies that the profit of the low-cost type of firm i is

$$(1 - \mu_j)(p - c_L) + (1 - F_j(p))\mu_j(p - c_L) = \pi_L = (1 - \mu_j)(c_H - c_L)$$

where $(1 - \mu_j)$ (in the left-hand side) is the probability that the rival of firm j remains high-cost type and $(1 - F_j(p))\mu_j$ (in the left-hand side) implies that though the rival firm j has become low-cost type but it does not undercut the

6 This essentially means that since firm j has a lower probability of being successful in adopting the low-cost technology compared to its rival firm i, firm j charges the upper bound of the price interval (i. e., c_H) with zero probability.

firm i i. e., does not charge a price below p; similarly, the profit of the low-cost type of firm j is

$$\left(1-\mu_i\right)(p-c_L)+(1-F_i(p))\mu_i(p-c_L)=\pi_L=\left(1-\mu_j\right)(c_H-c_L).$$

Thus, I get

$$F_i(p)=\frac{1}{\mu_i}-\frac{\left(1-\mu_j\right)}{\mu_i}\frac{(c_H-c_L)}{(p-c_L)} \text{ and } F_j(p)=\frac{1}{\mu_j}-\frac{\left(1-\mu_j\right)}{\mu_j}\frac{(c_H-c_L)}{(p-c_L)}.$$

Note that $F_i(p)=F_j(p)$ if $\mu_i=\mu_j$. The high-cost type charges its own marginal cost and earns zero profit in the equilibrium i. e., $\pi_H=0$. I calculate the expected profits of firm i and firm j as

$$\pi_i=\mu_i\pi_L+(1-\mu_i)\pi_H=\mu_i\left(1-\mu_j\right)(c_H-c_L)$$

and

$$\pi_j=\mu_j\pi_L+\left(1-\mu_j\right)\pi_H=\mu_j\left(1-\mu_j\right)(c_H-c_L)$$

respectively $\forall i,\, j=1,\, 2$ where $i\neq j$ and $\mu_i\geq\mu_j$. ■

A firm earns a strictly positive expected profit because of its strictly positive investment. Moreover, the expected profit of the firm with higher investment depends on the probability of failure of the rival with lower investment, but not the vice versa; because the low-cost type of the firm with higher as well as lower investment earn the same expected profit over the (same) price interval. Note that the Bayesian pricing equilibrium is the same irrespective of the observability of the firms' strategic investment decisions.

First, I consider the case where the strategic investment decisions become **observable**. In the first stage, firm i chooses μ_i to maximize expected profit given that rival firm j has chosen μ_j :

$$\max_{\mu_i}\Pi_i=\max_{\mu_i}(\pi_i-A\mu_i)=\begin{cases}\max_{\mu_i}\mu_i[(1-\mu_i)(c_H-c_L)-A] \text{ s.t. } 0\leq\mu_i\leq\mu_j\\ \max_{\mu_i}\mu_i\left[\left(1-\mu_j\right)(c_H-c_L)-A\right] \text{ s.t. } \mu_j\leq\mu_i\leq1\end{cases} \quad [2]$$

The following proposition describes the Bayesian Nash investment equilibrium under incomplete information with observable investment.

Proposition 1: *Under incomplete information with* ***observable*** *investment, firms choose* $\mu_i^{IO}=1$ *and* $\mu_j^{IO}=\frac{1}{2}\left(1-\frac{A}{(c_H-c_L)}\right)$ $\forall i,\, j=1,\, 2$ *where* $i\neq j$ *in the Bayesian Nash investment equilibrium.*

Proof: I evaluate the best response function of each firm (i. e., given μ_j the best possible investment firm i can make) and then find the Nash equilibrium of the investment game. Suppose arg $\max_{\mu_i} \pi_i - A\mu_i = \mu_i^\star$ and $\Pi_i^\star = \max_{\mu_i} \pi_i - A\mu_i$. For the first part of eq. [2]

$$\mu_i^\star = \begin{cases} \mu_j & \text{if } \mu_j \le \frac{1}{2}\left(1 - \frac{1}{(c_H - c_L)}\right) \\ \frac{1}{2}\left(1 - \frac{A}{(c_H - c_L)}\right) & \text{if } \mu_j > \frac{1}{2}\left(1 - \frac{A}{(c_H - c_L)}\right) \end{cases} \quad [3]$$

$$\Pi_i^\star = \begin{cases} \mu_j\left[(1-\mu_j)(c_H - c_L) - A\right] & \text{if } \mu_j \le \frac{1}{2}\left(1 - \frac{A}{(c_H - c_L)}\right) \\ \frac{\left[(c_H - c_L) - A\right]^2}{4(c_H - c_L)} & \text{if } \mu_j > \frac{1}{2}\left(1 - \frac{A}{(c_H - c_L)}\right) \end{cases} \quad [4]$$

Observe that for any $\mu_j \ge \mu_i$, the *ex ante* expected profit of firm i (Π_i) is maximized when $\mu_i = \frac{1}{2}\left(1 - \frac{A}{(c_H - c_L)}\right)$. However, when $\mu_j \le \frac{1}{2}\left(1 - \frac{A}{(c_H - c_L)}\right)$ then the relevant *ex ante* expected profit function of firm i is given by the second part of eq. [2] i. e., $\Pi_i = \mu_i\left[(1-\mu_j)(c_H - c_L) - A\right]$. In this case, given that $\mu_j \ge \mu_i$ and $\mu_j \le \frac{1}{2}\left(1 - \frac{A}{(c_H - c_L)}\right)$ the profit maximizing value of μ_i is equal to the value of μ_j. Consider the second part of eq. [2].

$$\mu_i^\star \begin{cases} = 1 & \text{if } 0 \le \mu_j < \left(1 - \frac{A}{(c_H - c_L)}\right) \\ \in \left[1 - \frac{A}{(c_H - c_L)}, 1\right] & \text{if } \mu_j = \left(1 - \frac{A}{(c_H - c_L)}\right) \\ = \mu_j & \text{if } \left(1 - \frac{A}{(c_H - c_L)}\right) < \mu_j \le 1 \end{cases} \quad [5]$$

$$\Pi_i^\star = \begin{cases} (1-\mu_j)(c_H - c_L) - A > 0 & \text{if } 0 \le \mu_j < \left(1 - \frac{A}{(c_H - c_L)}\right) \\ 0 & \text{if } \mu_j = \left(1 - \frac{A}{(c_H - c_L)}\right) \\ \mu_j\left[(1-\mu_j)(c_H - c_L) - A\right] < 0 & \text{if } \left(1 - \frac{A}{(c_H - c_L)}\right) < \mu_j \le 1. \end{cases} \quad [6]$$

The last part of eq. [5] can be explained by the similar argument as that of the first part of eq. [3]. To find the best response function of firm i for any given μ_j, I compare the derived expected profits of firm i in eqs [4] and [6].

Note that $(1-\mu_j)(c_H-c_L)-A>\mu_j\left[(1-\mu_j)(c_H-c_L)-A\right]$ which means that if $0\le\mu_j\le\frac{1}{2}(1-\frac{A}{(c_H-c_L)})$ the best response of firm i is $\mu_i^\star=1$. Also $(1-\mu_j)(c_H-c_L)-A\ge\frac{[(c_H-c_L)-A]^2}{4(c_H-c_L)}$ for $\mu_j\le\left(1-\frac{((c_H-c_L)+A)^2}{4(c_H-c_L)^2}\right)$ which implies that $\mu_i^\star=1$ if $\frac{1}{2}(1-\frac{A}{(c_H-c_L)})\le\mu_j\le\left(1-\frac{((c_H-c_L)+A)^2}{4(c_H-c_L)^2}\right)$. However, $(1-\mu_j)(c_H-c_L)-A\le\frac{[(c_H-c_L)-A]^2}{4(c_H-c_L)}$ for $\mu_j\ge\left(1-\frac{((c_H-c_L)+A)^2}{4(c_H-c_L)^2}\right)$; thus, best response of firm i is $\mu_2^\star=\frac{1}{2}(1-\frac{A}{(c_H-c_L)})$ if $\left(1-\frac{((c_H-c_L)+A)^2}{4(c_H-c_L)^2}\right)\le\mu_j\le1$ To summarize, the reaction function of firm i under incomplete information with observable investment is given by

$$\mu_i^{IO}(\mu_j)=\begin{cases}1 & \text{if } 0\le\mu_j\le\left(1-\dfrac{((c_H-c_L)+A)^2}{4(c_H-c_L)^2}\right)\\ \dfrac{1}{2}\left(1-\dfrac{A}{(c_H-c_L)}\right) & \text{if } \left(1-\dfrac{((c_H-c_L)+A)^2}{4(c_H-c_L)^2}\right)\le\mu_j\le1\end{cases}\qquad[7]$$

$\forall i,j=1,2$ *where* $i\ne j$. Two asymmetric[7] Bayesian Nash equilibria of the investment game under incomplete information with observable investment are

$$\mu_i^{IO}=1,\ \mu_j^{IO}=\frac{1}{2}\left(1-\frac{A}{(c_H-c_L)}\right)\qquad[8]$$

which yield the following *ex ante* expected profits for firm i and firm j

$$\prod_i^{IO}=\frac{(c_H-c_L)-A}{2},\ \prod_j^{IO}=\frac{[(c_H-c_L)-A]^2}{4(c_H-c_L)}.\qquad[9]$$

■

Figure 1 depicts the reaction functions of the firms (denoted by eq. [7]). In the asymmetric Bayesian Nash equilibria (represented by E_1 and E_2), one of the firms chooses investment such that it becomes low-type with probability one $(i.e., \mu_i^{IO}=1)$; alternatively the firm invests maximum possible amount (A). Whereas the other firm invests less, remains high-cost type with a strictly positive probability, and earns less profit. Both firms make strictly positive investment to generate uncertainty about the cost structure and thus, in turn,

7 It is easy to prove why symmetric equilibrium does not exist. Assume that $\mu_i=\mu_j=\tilde{\mu}$. Given $\mu_j=\tilde{\mu}$, firm i has a strictly positive incentive to deviate to $\mu_i>\tilde{\mu}$ since firm i earns higher expected profit if it decides to invest more than its rival.

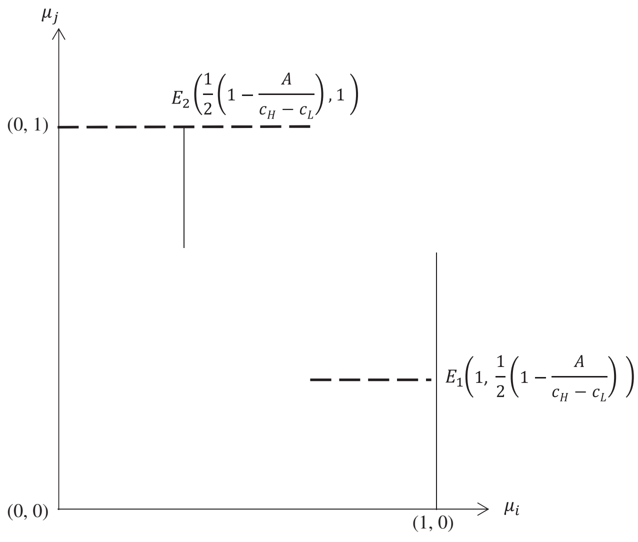

Figure 1: Equilibrium under incomplete information with observable investment.

earn strictly positive expected profit. Further, increase in cost differential $(c_H - c_L)$ increases market power and profitability of the low-cost type which in turn creates higher strategic incentive to invest.

Finally, I study the equilibrium investment behavior when the investment in cost-reducing technology remains private knowledge. In other words, a firm knows its own type but is unaware of both the investment and the actual outcome of the rival. Note that in this multistage imperfect information game, the nature of pricing equilibrium outcomes is similar to that of the incomplete information one discussed in Lemma 1.

Proposition 2: *Under incomplete information with* ***unobservable*** *investment, firms choose* $\mu_i^{IU} = \mu_j^{IU} = \left(1 - \frac{A}{(c_H - c_L)}\right)$ $\forall i, j = 1, 2$ *where* $i \neq j$ *in the Bayesian Nash investment equilibrium.*

Proof: Suppose $\mu_i = \mu_j = \bar{\mu}$ is a Nash equilibrium. Given $\mu_j = \bar{\mu}$, if firm i deviates to $\mu_i \neq \bar{\mu}$ then the rival firm j does not observe this deviation and believes that firm i has chosen $\bar{\mu}$. Thus, the low-cost type of firm i randomizes over a price interval $p \in [(1-\bar{\mu})\, c_H + \bar{\mu} c_L,\, c_H]$ and earns $(1-\bar{\mu})(c_H - c_L)$. If it deviates to μ_i, the *ex ante* expected profit of firm i i. e., $\pi_i = \mu_i \pi_L + (1-\mu_i)\pi_H$, is given by

$$\pi_i = \mu_i \,(1-\bar{\mu})\,(c_H - c_L).$$

The expected profit from deviation is maximized at

$$\mu_i \begin{cases} =1 & \text{if } 0 \le \bar{\mu} < \left(1 - \dfrac{A}{(c_H - c_L)}\right) \\ \in [0,\,1] & \text{if } \bar{\mu} = \left(1 - \dfrac{A}{(c_H - c_L)}\right) \\ =0 & \text{if } 1 \ge \bar{\mu} > \left(1 - \dfrac{A}{(c_H - c_L)}\right) \end{cases}$$

Similarly, if $\mu_i = \bar{\mu}$ I can find the profit from deviation for firm j and the value of μ_j that maximizes the expected profit from deviation. Thus, neither firm has no incentive to deviate if

$$\mu_i^{IU} = \mu_j^{IU} = \bar{\mu} = \left(1 - \frac{A}{(c_H - c_L)}\right).$$

In this case, the *ex ante* expected profit of each firm is

$$\pi_i^{IU} = \pi_j^{IU} = A\left(1 - \frac{A}{(c_H - c_L)}\right).$$

Next, I check whether $\mu_i = 1$ and $\mu_j = 0$ is a Nash equilibrium. In this case, $p_i = p_j = c_H$, $\pi_i = [(c_H - c_L) - A]$ and $\pi_j = 0$. Given $\mu_i = 1$, if firm j deviates i. e., $\mu_j > 0$ then it earns strictly positive profit; further, this expected profit from deviation is maximized at $\mu_j = 1$. Therefore, I can conclude that $\mu_i = 1$ and $\mu_j = 0$ is not a Nash equilibrium. ■

From the above propositions, one can make the following observations:

(1) When the investment decisions remain secret, both firms engage is symmetric investment behavior in the equilibrium unlike the case where investment is observable i. e., $\mu_j^{IO} = \frac{1}{2}\left(1 - \frac{A}{(c_H - c_L)}\right) \le \mu_i^{IU} = \mu_j^{IU} = \left(1 - \frac{A}{(c_H - c_L)}\right) \le \mu_i^{IO} = 1 \forall i,\, j = 1,\, 2$ where $i \neq j$.

(2) The *ex ante* expected profit earned by each firm under secrecy is higher than that of under observable investment i. e., $\pi_i^{IU} \ge \pi_i^{IO}\ \forall i = 1,\, 2$ if $\frac{(c_H - c_L)}{2} \le A < (c_H - c_L)$

(3) The aggregate (or industry level) investment in R&D under secrecy is higher compared to no secrecy (about the investment behavior) when $\frac{(c_H - c_L)}{3} \le A < (c_H - c_L)$.

(4) The aggregate (or industry level) *ex ante* expected profit under secrecy is higher $\frac{3(c_H - c_L)}{7} \le A < (c_H - c_L)$.

(5) Social surplus is maximized when a firm charges its own marginal cost. Thus, the expected total surplus is equal to

$$\left(\mu_i\mu_j + \mu_i\left(1-\mu_j\right) + \mu_j\left(1-\mu_i\right)\right)\left(V - c_L\right) + \left(1-\mu_i\right)\left(1-\mu_j\right)\left(V - c_H\right) - A\left(\mu_i + \mu_j\right)$$

which is maximized at $\mu_i^S = \mu_j^S = \left(1 - \frac{A}{(c_H - c_L)}\right)$ $\forall i,\ j = 1,\ 2$ where $i \neq j$. Observe that the firm's equilibrium investment behavior under secrecy maximizes the social surplus. However, needless to say that the incomplete information equilibrium will be less desirable for the consumers as consumer surplus is definitely lower under the incomplete information compared to the socially optimal one.

4 Conclusion

I find that the *ex ante* total expected profit of the industry as well as the social welfare are higher when strategically competing firms keep their R&D investments in cost-reducing technology secret compared to the case when such information is public observable. This implies that the government intervention to secure disclosure of R&D investments may be counterproductive and the trade secret laws that protect privacy of information related to R&D inputs or investment may be conducive to innovation.

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