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R&D investment as a signal in corporate takeovers

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Abstract

Critics of takeovers usually argue that takeover threats may reduce target firms' R&D intensity. However, we find that under takeover threats, target firms may nevertheless increase R&D investment in order to signal their compatibility with the acquiring firm. The identity of the acquired firm depends on the market size and target firms' efficiency and compatibility. Target firms may affect this result investing in R&D. Through R&D investments, these firms signal potential outsiders the kind of competition they may face and force them to accept lower takeover offers.

Keywords: takeover, signaling, bargaining power, fitting company

JEL Classification: L11, D82, C78

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1 Introduction

There is little doubt about the positive effects of R&D investments on the growth and competitive position of firms (see, for example, Baysinger and Hoskisson, 1989, or Franko, 1989). R&D activity is crucial not only because it may generate innovations but also because it develops firms' ability to absorb and exploit existing technologies. Therefore, it is worth analyzing the factors and characteristics of the market that may increase firms' R&D intensity. In this paper, we focus on the effects of takeover threats on target firms' incentives to invest in R&D.

There is still an open debate in the literature about the consequences of takeover threats on R&D investments. The "managerial myopia" argument establishes that managers facing takeover threats might have incentives to sacrifice long-term investments, such as R&D investments, by short-term investments. They argue that R&D investments are difficult to be evaluated in the market, so that the fear of being bought at an undervalued price, leads managers to focus more heavily in short-term investments. Under this theory, firms that focus in a long-term objective are more susceptible to receive a tender offer (Narayanan, 1985; Stein, 1988).

There is not clear empirical evidence sustaining the "managerial myopia" argument. Pugh, Page and Jahera (1992) find evidence that supports such theory, but Meulbroek et al (1990), Mahoney et al (1997), Garvey and Hanka (1999), and a study by the Office of the Chief Economist of the Securities and Exchange Commission (1985) find no evidence. Moreover, this latter study finds that the market places a positive value on announcements of long-term investments such as R&D.

Although empirical studies suggest that firms facing takeover threats may invest in R&D, no satisfactory theoretical explanation has been provided yet. Canoy, Riyanto and Van Cayseele (2000) assume that by decreasing R&D investments and concentrating on short-term investments, managers can increase firms' value and deter a possible takeover. This deterrence decision depends on the bargaining power of the acquiring firm. In particular, they assume that if a takeover occurs, the incumbent manager is dismissed and his compensation depends on the bargaining position of the acquiring firm. If the acquiring firm has too much bargaining power, the manager of the acquired firm will have incentives to deter the takeover and focus on short-term investments. So, according to these authors, increases in R&D are strongly dependent on low bargaining power of the acquiring firm.

The purpose of this paper is to provide an alternative and complementary analysis of R&D intensity under takeover threats. So far, the effects of takeover threats on target firms' R&D investments have been individually analyzed. However, firms compete in the market. Changes in the market structure, such as the acquisition of a rival, also affect other firms' profits. We show that target firms might have incentives to invest in R&D (even in the extreme case that the acquiring firm has all the bargaining power) in order to influence not only their own offers of acquisition but also the others' and induce a particular market structure.

We argue that firms may strategically use R&D investments to signal their ability to fit well. Mergers and acquisitions are more likely to work when a company chooses a partner that fits well, rather than one that is merely available. Important costs may appear in terms of organizational problems if firms do not carefully choose their potential partners. Sometimes firms tend to underestimate these costs and unprofitable acquisitions take place. For example, this happened when Wells Fargo bought First Interstate in 1996 since thousands of the banks' customers left because of missing records, queues and administrative snarl-ups. Another example is the acquisition of US Healthcare by Aetna. Aetna, an insurer, bought US Healthcare, a health-maintenance organization, partly for its computer systems, which could shift out the best doctors. But the two firms had terrible problems in combining their back offices (The Economist, 1999a). A study published by the Bank for International Settlements (BIS) in 1999 showed that bank profitability had fallen in 12 countries despite a wave of consolidation. The BIS highlights the importance of choosing a right partner and blames acquiring firms for systematically underestimating organizational problems (The Economist, 1999b).

We consider three firms with different marginal costs competing in a homogenous output oligopoly. We assume that the most efficient firm makes bids to acquire one of the other two. Target firms accept an offer of acquisition if they are offered at least what they would obtain in case of rejection, that is, their outside option. Once the takeover has been achieved, the acquiring firm must decide whether to close one of the plants, or to transfer its technology to the acquired firm and operate both plants in competition with each other. By competing against themselves, plants capture some sales from their rivals and increase the firm's profits. This possibility was first introduced by Kamien and Zang (1990). They claim that the automobile industry provides a clear example

of divisionalized firms in which divisions compete with each other. Tombak (2002) also considers this possibility. He provides three specific examples of sequential acquisitions in which the brands of the acquired firms were retained in the product market: the cases of American Tobacco Co., Swedish Match and two funeral home and cemetery companies in North America, Service Corporation International and The Loewen Group.

Clearly, the decision on whether or not to shut down the acquired plant will strongly depend on the ability of the target firm to absorb new technologies. This ability can be understood as a measure of how the two firms fit.

There is a substantial number of papers that argue that R&D investments not only generate new technologies but also enhance firms' ability to assimilate and exploit existing technologies (see, for example, Cohen and Levinthal (1989), Cassiman and Veugelers (1999) or Kamien and Zang (2000)). Teece (1977), analyzing the characteristics of the transferee that affect the cost of transferring technological know-how, distinguishes the R&D activity: "When unusual technical problems are unexpected encountered, an in-house R&D capability is likely to be of value". Following the same argument, Oshima (1973) argues that the R&D intensity of Japanese firms facilitated the low cost importation of foreign technology and Mansfield *et al* (1977) find that diffusion occurs more rapidly in more R&D intensive industries.

Firms' strategic use of R&D investments may explain why some firms with financial problems keep on increasing their R&D expenditures over revenues, willing to be acquired at a good price. This is, for example, the case of Genta Inc., which although suffering important financial problems, kept on increasing its R&D expenditures during 2001 until it signed a \$480 million deal with Aventis S.A. in 2002.¹ Another recent example is Novartis' tender offer for Lek, a pharmaceutical firm that has been increasing its R&D investments as percentage of sales in the last years.²

We start studying optimal takeovers in a symmetric information framework in which target firms' abilities to absorb new technologies are assumed to be common knowledge. We find that the identity of the acquired firm strongly depends on target firms' efficiency and compatibility and the market size. If the market size is big enough, it may be optimal for the most efficient firm to buy the less efficient company, since it accepts lower offers

¹Published in *Chemical & Engineering News*, vol.80, no 18, p.10. May 6, 2002.

²Published in *Slovenia Business Week*, no 6/2003. February 10, 2003.

of acquisition. Secondly, we consider the type of one of the target firms to be privately known. We analyze the incentives for this firm to invest in R&D in order to signal its ability to absorb new technologies before the takeover process begins. This decision depends on the other firm's type, the cost of R&D investments and the market size. In particular, this firm only invests in R&D if the cost of R&D is low enough and no other target firm is compatible with the acquiring firm. We also come to prove that firms may have incentives to invest in R&D even if they are not finally bought, since they may change their outside option through R&D investments.

The rest of the paper is organized as follows. Section 2 presents the model. A symmetric information case is analyzed in section 3. In section 4, we study target firm's incentives to invest in R&D in order to signal its type in an asymmetric information framework. Finally, section 5 summarizes the main results and presents the conclusions.

2 The model

Consider three asymmetric firms that produce in a homogenous output market. Firms differ in their marginal cost. Firm 1 is the most efficient one while firm 3 is the less efficient. We assume a special structure for firms' marginal costs:³

$$c_2 = c_1 + \Delta < c_3 = c_1 + 2\Delta,$$

where Δ is a positive parameter that measures firms' asymmetries.

The inverse demand function is represented by $P = a - bQ$, where Q denotes the total market quantity and a and b are positive parameters. In order to guarantee that the model is well defined, we assume that $(a - c_1) > 6\Delta$.

Firm 1 might be interested in buying one of its competitors (monopoly is not allowed). We assume that this firm has all the bargaining power and makes offers to share potential joint profits to the other two firms. If a takeover is achieved, the acquiring firm might be interested in operating both its own plant and the acquired's in competition with each other. We assume that if the acquiring firm decides to operate both plants in the market, it transfers its technology to the acquired one.⁴ However, transferring technological know-

³Similar structure is assumed in Barros (1998) and Lopes (2000).

⁴We assume that only takeovers that improve the market efficiency are allowed by the antitrust authority, that is, firm 1 is not allowed to operate an inefficient plant.

how may have a considerable associated cost.⁵ This cost can be understood as a measure of how the two firms fit. It is assumed to be a fixed cost, proportional to the difference in marginal costs and the ability of the acquired firm to absorb new technologies, that is $s_i(c_i - c_1)$, where s_i is inversely related with firm i 's ability to absorb new technologies, for every firm $i \neq 1$.

Let us denote by $\bar{\Pi}^{1+i}$ the total profits that can be obtained if firm 1 buys firm i and leaves both plants operating. $\bar{\Pi}_j^{1+i}$ represents the profits earned by firm j when firm 1 buys firm i and operates both plants. If firm 1 buys firm i and operates both plants, joint profits for these firms and outsider's profits are given by:

$$\begin{aligned} \bar{\Pi}^{1+i} = & \underset{q_i}{Max}\{(a - bq_i - bq_j - bq_1 - c_1)q_i\} + \underset{q_1}{Max}\{(a - bq_i - bq_j - bq_1 - c_1)q_1\} \\ & - s_i(c_i - c_1), \end{aligned} \quad (1)$$

$$\bar{\Pi}_j^{1+i} = \underset{q_j}{Max}\{(a - bq_i - bq_j - bq_1 - c_j)q_j\} \text{ with } i \neq j \neq 1. \quad (2)$$

Denote by $\underline{\Pi}^{1+i}$ joint profits obtained by firm 1 and firm i , when firm i is acquired and its plant is shut down. $\underline{\Pi}_j^{1+i}$ indicates firm j 's profits when firm 1 buys firm i and closes its plant. In this case, joint profits for firm 1 and firm i and outsider's profits can be formally written as:⁶

$$\underline{\Pi}^{1+i} = \underset{q_1}{Max}\{(a - bq_1 - bq_j - c_1)q_1\}, \quad (3)$$

$$\underline{\Pi}_j^{1+i} = \underset{q_j}{Max}\{(a - bq_1 - bq_j - c_j)q_j\} \text{ with } i \neq j \neq 1. \quad (4)$$

When deciding whether or not to close the acquired plant, firm 1 faces a trade off. It is optimal to operate both plants, if the cost of transferring technological know-how is low enough, that is, if firms 1 and i are compatible enough. On the other hand, if transfer costs are excessive, that is, firms 1 and i are not compatible, it is optimal for firm 1 to operate just its own plant.

Firm 1's decision on whether or not to shut down one of the plants affects outsider's profits. If firm 1 operates both plants, the outsider will have to compete against two efficient firms. On the contrary, if firm 1 decides to operate just its own plant, the outsider

⁵Teece (1977), in a study of 26 technological transfers, estimates that transfer costs average 19% of total project costs (ranging from 2% to 59% of total project costs).

⁶For simplicity, no shut down cost is considered. Results extend to the case in which shut down costs are relatively small comparing with technology transfer cost.

faces one less competitor. Denoting by Π_j firm j 's Cournot profits when no takeover is performed and taking this case as a benchmark, the outsider is worse off if firm 1 leaves both plants operating, $\bar{\Pi}_j^{1+i} < \Pi_j$, while it is better off when one of the plants is shut down, $\underline{\Pi}_j^{1+i} > \Pi_j$.

For the sake of simplicity, we assume that firm i 's ability to absorb new technologies can only take two different values, $s_i \in \{0, S_i\}$, where S_i is so large that if firm 1 buys firm i , it is optimal for firm 1 to operate just its own plant. Therefore, firms can only be two types, either completely compatible, $s_i = 0$, or totally incompatible, $s_i = S_i$. Firm 2's ability to absorb new technologies is common knowledge while firm 3's ability is privately known. All firms 1 and 2 know about firm 3's ability is the proportion $p_c \in (0, 1)$ of compatible types, $s_3 = 0$.

We assume firm 3 may be interested in signaling its type investing in R&D. Let k be the cost of R&D investments. Through R&D investments, firm 3 can improve its ability to absorb new technologies.⁷ However, R&D technology is not out of failure. We assume, after investing in R&D, firm 3 becomes a fitting company with probability $q \in [0, 1]$.⁸

The timing of the game is as follows: In the first stage, firm 3 decides whether to invest in R&D or not. In the second period, firms 1 and 2 update their beliefs about firm 3's type and firm 1 makes simultaneous "take or leave it" offers to acquire firm 2 or firm 3. In the third stage, firms 2 and 3 simultaneously either accept or reject firm 1's offer of acquisition. In the next period, if a takeover has been performed, firm 3 reveals its true type and firm 1 decides whether to close one plant or transfer its technology to the acquired firm and leave both plants operating. In the last stage, plants compete à la Cournot and firms obtain their profits. The game is solved by backward induction.

In order to better understand the main insights of the model let us start analyzing

⁷For simplicity reasons, we do not consider any change in firms' efficiency after investing in R&D. Recall that the goal of the paper is to study the effects of takeover threats on target firms' R&D investments. We will prove that even if firms cannot improve their efficiency through R&D, they may have incentives to increase their R&D activity to signal their type. If firms improve their efficiency through R&D investments, they will have more incentives to invest in R&D, but this is not a direct effect of takeover threats.

⁸Note that if $q = 0$, firm 3 cannot improve its ability through R&D investments and we have a pure signaling model, like the one of Spence (1973). On the contrary, if $q = 1$, firm 3 becomes surely compatible investing in R&D and we have a signaling model à la Aoki and Reitman (1992). This probability q affects the way firms 1 and 2 update their beliefs about firm 3's type if firm 3 invests in R&D.

the symmetric information case, that is, the case in which both firm 2 and firm 3's compatibilities are common knowledge.

3 The symmetric information case

In this section we consider that both firm 2 and firm 3's abilities to absorb new technologies are commonly known. Given firms 2 and 3's abilities, firm 1 proposes simultaneous "take or leave it" offers to share potential joint profits to each of the other firms. Firms 2 and 3 simultaneously either accept or reject firm 1's offer. If none of the firms accept, no takeover takes place and all firms remain independent. If only one firm accepts, firm 1 buys that firm and the other firm remains alone. If both firms accept, the antitrust authority forces firm 1 to choose just one of the firms, so firm 1 acquires the one that provides higher profits. If it comes to be irrelevant for firm 1 to buy either firm 2 or firm 3, we assume that firm 1 buys firm 2.

Firms 2 and 3 accept the takeover if they are offered at least the profits they would obtain if they reject. We assume that if it is indifferent to firms 2 and 3 to accept or reject, they just accept. Firm i 's best response function depends on firm j 's decision. If firm j rejects, it is optimal for firm i to accept whenever it is offered at least the same profit that it would obtain if no takeover is performed. On the other hand, if firm j accepts, it is optimal for firm i to accept whenever it is offered at least the same profits that it would obtain in the situation in which firm 1 buys firm j , or whenever the profits that firm 1 obtains when buying firm j are higher than the profits obtained when acquiring firm i . Recall that if both firms accept, firm 1 is forced to choose just one of the firms. Even if firm i accepts, if firm 1 obtains higher gains buying firm j , it will for sure buy this latter firm. Since firm i knows it will not be bought anyway, it is indifferent to firm i to accept or reject firm 1's offer, and by assumption it accepts.

Let $(1 - x_1^{1+i}) \in [0, 1]$ be the share of joint profits that firm 1 offers to firm i . Firms 2 and 3's decisions of acceptance or rejection yield four possible Nash equilibria, as it is stated in the following lemma.

Lemma 1 *Under symmetric information, firms 2 and 3's decisions on accepting or rejecting firm 1's offers of acquisition yield four possible mutually exclusive Nash equilibria.*

The conditions that must be satisfied for each of these Nash equilibria to arise are summarized in Table 1.

Firm 2 Firm 3	ACCEPTS	REJECTS
ACCEPTS	If $x_1^{1+3} \Pi^{1+3} > x_1^{1+2} \Pi^{1+2}$ and $(1-x_1^{1+3}) \Pi^{1+3} \geq \Pi_3^{1+2}$ or if $x_1^{1+2} \Pi^{1+2} \geq x_1^{1+3} \Pi^{1+3}$ and $(1-x_1^{1+2}) \Pi^{1+2} \geq \Pi_2^{1+3}$.	If $x_1^{1+2} \Pi^{1+2} \geq x_1^{1+3} \Pi^{1+3}$, $(1-x_1^{1+2}) \Pi^{1+2} < \Pi_2^{1+3}$ and $(1-x_1^{1+3}) \Pi^{1+3} \geq \Pi_3$.
REJECTS	If $x_1^{1+3} \Pi^{1+3} > x_1^{1+2} \Pi^{1+2}$, $(1-x_1^{1+3}) \Pi^{1+3} < \Pi_3^{1+2}$ and $(1-x_1^{1+2}) \Pi^{1+2} \geq \Pi_2$.	If $(1-x_1^{1+i}) \Pi^{1+i} < \Pi_i$ for every firm $i = 2, 3$.

Table 1: Conditions for every possible mutually exclusive Nash equilibrium for firms 2 and 3 under symmetric information

Firm 1 bids anticipating any of the four possible Nash equilibria for firms 2 and 3. If firm 1 wants any of the other firms to accept, it will propose the minimum share to induce an acceptance. Since firm 1 has all the bargaining power, firms 2 and 3 will receive an offer of acquisition which is equivalent to their outside option. Firms' outside options do not depend on their own type but on the answer and type of the other firm. If firm j is compatible, the worst situation for firm i corresponds to firm j 's acceptance. On the other hand, if firm j is not a fitting company, the worst situation for firm i occurs when firm j rejects, for every firm $i \neq j \neq 1$.

Firm 1's optimal decision of buying either firm 2 or firm 3 depends not only on the type and efficiency of each firm but also on the market size. Firm 2 is more efficient than firm 3 and thus a tougher rival to be kicked out of the market. However, firm 2 requires an offer of higher profits to be acquired. If the market is large enough it may be optimal for firm 1 to leave such a tough rival in the market and acquire a cheaper firm. All possibilities are analyzed in the following lemma.

Lemma 2 *Under symmetric information, firms 1's optimal decision of acquisition depends on the market size and target firms' efficiency and compatibility. All possibilities are summarized in Table 2.*

Firm 2 Firm 3	COMPATIBLE ($s_2 = 0$)	INCOMPATIBLE ($s_2 = S_2$)
COMPATIBLE ($s_3 = 0$)	Firm 1 buys firm 2 if the market is small enough and firm 3 otherwise.	Firm 1 buys firm 2 if the market is small enough and firm 3 otherwise.
INCOMPATIBLE ($s_3 = S_3$)	Firm 1 always buys firm 2.	Firm 1 buys firm 2 if the market is small enough, firm 3 if the market is not small enough and no firm if the market is sufficiently large.

Table 2: Firm 1's optimal decision of acquisition under symmetric information

If both firms 2 and 3 own fitting plants, it is optimal for firm 1 to make offers to be accepted by both firms. In this way, firms' outside option profits are reduced and so is the final amount paid by firm 1 to acquire any of the other companies. If the market size is not large enough firm 1 prefers to buy firm 2. However, if the market is large enough, firm 1 prefers to buy firm 3 at a lower cost and compete against firm 2. If firm 2 is a fitting company but firm 3 is not compatible, firm 1 always buys firm 2. In such a case, firm 1 would prefer firm 3 to reject the offer, in order to reduce the amount to be paid to firm 2.⁹ Even if firm 2 is not compatible and firm 3 fits, it might be optimal for firm 1 to buy firm 2 instead of firm 3 if the market is not large enough. If neither firm 2 nor firm 3 are compatible, firm 1 buys firm 2 if the market is small, firm 3 if the market is not small enough and none of these firms if the market is sufficiently large.

Firm 3's compatibility influences not only the share offered by firm 1 but also firm 2's incentives to accept, that is, firm 3's outside option. Joint profits when firm 1 buys firm 3 are higher if firm 3 owns a fitting plant. However, the amount of profits that firm 3 requires to be bought does not depend on its own type but on its outside option. Both types have the same outside option, so firm 1 has to offer a higher share of joint profits to incompatible firms. On the other hand, firm 3's type affects the profits that firm 2 would

⁹However, this is not possible unless the market is large enough. Recall that for firm 3 to reject firm 1's offer, it must be sure that if it accepts, firm 1 will buy it. Otherwise, it will be indifferent to firm 3 to accept or reject, and it will accept (see Proof of Lemma 2 in Appendix for further explanation).

obtain if firm 1 finally buys firm 3. Firm 2's profits would be much lower if firms 1 and 3 fit well, so it will accept more easily an offer from firm 1.

In an asymmetric information framework, firm 2's type is common knowledge but firm 3's compatibility is privately known. By investing in R&D, firm 3 can improve its true type and affect other firms' beliefs. Firm 3 may invest in R&D even if it is not willing to be acquired, in order to affect firm 2's decision and change its own outside option. In the next section we will analyze under which conditions it is optimal for firm 3 to invest in R&D and how other firms should update their beliefs over firm 3's type.

4 The asymmetric information case: equilibria of the signaling game

In this section, we consider that firm 2's ability to absorb new technologies is of common knowledge while firm 3's type is privately known. In the first stage of this game, firm 3 decides whether to invest in R&D to improve or just signal its type to the other firms. We assume that, once firm 3 has or has not invested in R&D, firms 1 and 2 will update their beliefs accordingly. Firm 3's profits depend not only on its true type but also on the other two firms' beliefs. Let us denote by $\Pi_3(s_3 = 0, p)$ the profits obtained by compatible firm 3 when other firms think it is compatible with probability p , and by $\Pi_3(s_3 = S_3, p)$ the profits obtained by firm 3 when it is not compatible but firms 1 and 2 think it is compatible with probability p .

Firm 3 may be interested in lying about its true type and affecting both its outside option and the offer received from firm 1.¹⁰ Firm 3's true type affects its incentives to accept or reject the share offered by firm 1. An incompatible type demands better offers than a compatible type, so that it will surely reject offers that any compatible firm would reject or would be indifferent between accepting or rejecting. In contrast, a compatible type may accept offers that an incompatible type would surely reject. Firm 3's profits depending on its true type and other firms' beliefs are analyzed in the following lemma.

Lemma 3 *If firms 1 and 2 think that firm 3 is compatible with probability $p \in [0, 1]$, then*

¹⁰The offers that firm 3 receives from firm 1 are based on firm 1's beliefs about firm 3's type. We assume that no punishments may be imposed as a consequence of firm 3's lies, since firm 3's true type cannot be verified by a third party.

it is better for this firm to be compatible, $\Pi_3(s_3 = S_3, p) \leq \Pi_3(s_3 = 0, p)$. In particular, if other firms think that firm 3 is compatible with probability 1, firm 3's profits are independent of its true type, $\Pi_3(s_3 = S_3, p = 1) = \Pi_3(s_3 = 0, p = 1)$.

Results from Lemma 3 are quite intuitive. On the one hand, if firms 1 and 2 believe that firm 3 is compatible with probability p , it is better for firm 3 to be a fitting company. The intuition is that both compatible and incompatible firms will have the same outside option, since outside options do not depend on firms' true type but on the other firms' beliefs. Both types will receive the same offer to share potential joint profits. If compatible firm 3 receives an offer that an incompatible type would accept, then it will also accept such an offer and will obtain more than in its outside option. Moreover, if compatible firm 3 receives an offer that an incompatible type would reject, then it may also accept such an offer and be again better off. On the other hand, once firms 1 and 2 think that firm 3 is compatible, it is indifferent for 3 to be or not a fitting company. In this case, no matter its true type, firm 3 will have the same offer and outside option that a compatible type would have under symmetric information. Although an incompatible firm will reject such offers, it will obtain the same profits that a compatible type would obtain in its outside option (exactly what a fitting firm would obtain in equilibrium either if it accepts or rejects).

We have already compared firm 3's profits for both types when firms 1 and 2 believe that it is compatible with a certain probability. However, firm 3 may also have incentives to lie about its true type in order to affect its outside option.

Lemma 4 *If firm 3 is not compatible, it prefers the other firms to think that it is compatible, $\Pi_3(s_3 = S_3, p = 0) \leq \Pi_3(s_3 = S_3, p = 1)$. However, if firm 3 is compatible, it may be interested in making the other firms think that it is not compatible, $\Pi_3(s_3 = 0, p = 1) \geq \Pi_3(s_3 = 0, p = 0)$.*

Firstly, if firm 3 is not compatible, it prefers firms 1 and 2 to think that it is a compatible type since, this may help to change its outside option. To be more precise, suppose, for example, that firm 2 is incompatible. In this case, the worst situation for firm 3 would be the case in which firm 2 rejects, since $\Pi_3 < \underline{\Pi}_3^{1+2}$. If firm 2 thinks that firm 3 is compatible, it will more easily accept an offer from firm 1, and firm 3 will be better off. Secondly, if firm 3 is compatible, it might be interested in pretending to be an

incompatible company. On the one hand, if firm 3 lies it will receive higher offers to share joint profits. But, on the other hand, by lying about its true type, firm 3 may change its outside option in an adverse sense. If, for example, firm 2 is not compatible and thinks that firm 3 is also incompatible, firm 2 will more easily reject an offer from firm 1, which is the worst situation for firm 3.

Once we have analyzed firm 3's profits as a function of its true type and the other firms' beliefs, let us study its incentives to invest in R&D. By investing in R&D, an incompatible type may improve its ability to absorb new technologies and become a compatible firm. We will show that for any positive cost of R&D, no equilibrium in which one type invests and the another does not can be found, no matter the probability q for an incompatible company to become a fitting firm through R&D investments.

Proposition 1 *For any probability $q \in [0, 1]$ of the R&D technology and positive cost k , there exists no separating equilibrium of the signaling game.*

By investing in R&D, an incompatible company may improve its ability to absorb new technologies and perfectly fit with firm 1. A situation in which a fitting company invests in R&D but an unsuited firm does not, cannot be an equilibrium of the signaling game. If firm 3 invests in R&D, firms 1 and 2 will think that it is a compatible firm. Even if an incompatible firm cannot improve its ability through R&D investments, we know from Lemma 3 that it gains the same amount than a fitting company, given that firms 1 and 2 will think that it is compatible. So it is not possible that a fitting company has incentives to invest in R&D and an incompatible type does not. A situation in which an incompatible type invests but a fitting firm does not, cannot be an equilibrium either. In this case, if firm 3 invests other firms will think that it is compatible with probability q . We know from Lemma 3 that it is preferable for firm 3 to be compatible if other firms think that it is indeed compatible with a certain probability. However, by assumption, a compatible type has no incentives to invest in R&D. On the other hand, an incompatible firm cannot be interested in investing in R&D since, even if it manages to improve its type, R&D investment is not worth.

If the cost of R&D investments is low enough, both types of firm 3 may be interested in investing. A compatible type cannot improve its ability, so it will invest just to signal its type to firms 1 and 2. An incompatible type will invest to make the other firms think that it is a compatible company, thereby improving its ability.

Proposition 2 *There exists a pooling equilibrium in which both types of firm 3 invest in R&D if and only if the following condition is satisfied:*

$$0 < k < \text{Min} \{ \Delta \Pi_3(s_3 = 0|I); \Delta \Pi_3(s_3 = S_3|I) \}, \quad (5)$$

where $\Delta \Pi_3(s_3|I)$ is the difference in firm 3's profits when investing in R&D, with $s_3 \in \{0, S_3\}$.

We have already shown that the signaling game described along the paper may only have pooling equilibria. Proposition 2 shows that if the costs of R&D investments are low enough, we can find pooling equilibria in which both types of firm 3 invest in R&D. Even in this case, firms 1 and 2 may be able to update their beliefs about firm 3's type, since they know that there exists a probability $q \in [0, 1]$ for firm 3 to improve its ability to absorb new technologies and become a compatible firm. In the extreme case that $q = 0$, R&D investments are not informative at all and firms 1 and 2 could not update their prior beliefs. However, if $q = 1$, R&D investments fully reveal firm 3's type and the pooling equilibrium in which both types invest leads to a symmetric information situation.

Let us now study under which circumstances the necessary and sufficient condition for pooling equilibria in which both types of firm 3 invest is satisfied. Firm 3 invests in R&D if the profits obtained after investing are higher than the profits it would obtain if it does not invest. Thus, we need to characterize firm 3's profits in an asymmetric information framework. The first step consists in analyzing firm 1's minimum offer for acquiring firms 2 and 3 under every possible Nash equilibria. Then, we can obtain firm 3's profits in each possible case. Secondly, we will discuss the characteristics of firm 1's optimal offer that lead to an equilibrium in which both types of firm 3 invest in R&D. The first step is summarized in the following lemma.

Lemma 5 *Given firm 2's true type and firms 1 and 2's non-deterministic beliefs that firm 3 is compatible $p \in (0, 1)$, firm 1's minimum offers of acquisition in each possible Nash equilibria yield the following profits for firm 3, with $\Pi_3^{1+2} \in \{ \overline{\Pi}_3^{1+2}, \underline{\Pi}_3^{1+2} \}$ and $\overline{\Pi}^{1+3} > \underline{\Pi}^{1+3}$:*

Firm 2 Firm 3	ACCEPTS	REJECTS
COMPATIBLE ($s_3 = 0$): ACCEPTS INCOMPATIBLE ($s_3 = S_3$): ACCEPTS	$\Pi_3(s_3 = 0, p) = \Pi_3(s_3 = S_3, p) = \Pi_3^{1+2}$ or $\Pi_3(s_3 = 0, p) = \frac{\Pi_3^{1+2}}{\underline{\Pi}^{1+3}}$ and $\Pi_3(s_3 = S_3, p) = \Pi_3^{1+2}$	$\Pi_3(s_3 = 0, p) = \frac{\Pi_3}{\underline{\Pi}^{1+3}} \bar{\Pi}^{1+3}$ and $\Pi_3(s_3 = S_3, p) = \Pi_3$
COMPATIBLE ($s_3 = 0$): REJECTS INCOMPATIBLE ($s_3 = S_3$): REJECTS	$\Pi_3(s_3 = 0, p) =$ $\Pi_3(s_3 = S_3, p) = \Pi_3^{1+2}$	$\Pi_3(s_3 = 0, p) =$ $\Pi_3(s_3 = S_3, p) = \Pi_3$
COMPATIBLE ($s_3 = 0$): ACCEPTS INCOMPATIBLE ($s_3 = S_3$): REJECTS	$\Pi_3(s_3 = 0, p) =$ $\Pi_3(s_3 = S_3, p) = \Pi_3^{1+2}$	$\Pi_3(s_3 = 0, p) =$ $\Pi_3(s_3 = S_3, p) = \Pi_3$

Table 3: Firm 3's profits in each possible Nash equilibrium for firms 2 and 3 under asymmetric information

Firm 1 holds all the bargaining power, so it offers the minimum share to ensure acceptance in any of the possible Nash equilibria. However, irrespective of firm 1's offers, there are situations which are impossible to be sustained as a Nash equilibrium. This is the case of a situation in which firm 2 rejects the offer, but firm 3 accepts if it is not compatible and rejects if it is compatible. Such a situation is not possible, since any offer accepted by an incompatible firm will be also accepted by a fitting company. Similar arguments may be applied to a situation in which firm 2 accepts the offer, but firm 3 rejects if it is compatible and accepts if it is not compatible.

In most cases included in Lemma 5, firm 1 is interested in buying firm 2 or a compatible firm 3, so that the offers for firm 3 are the ones that a compatible company would receive. Firm 3 rejects such offers if it is not compatible, unless it is sure that it will not be bought anyway, in which case it is indifferent to firm 3 to accept or reject, and it will accept by assumption. There are three exceptions. The first one corresponds to the case in which all the firms reject the offers. In such a case, firm 1 buys none of the firms. The other two exceptions refer to the situation in which both types of firm 3 accept the offers. In this case, firm 1 buys firm 3 irrespective of its ability to fit well. In these cases, firm 3 receives an offer that an incompatible firm would accept. Notice that if firm 3 is compatible, it will also accept such an offer, since it will gain more than in its outside option.

The existence of pooling equilibria in which both types of firm 3 invest in R&D depends

on firm 1's optimal offers of acquisition. For condition (5) of Proposition 2 to be satisfied we need different values of firm 3's profits for different beliefs. If firm 2 is a fitting company, it is never optimal for firm 1 to buy firm 3 when it is not compatible. Firm 3's profits are always equivalent to what it would obtain if firm 2 is bought and condition (5) never holds. This is formally stated in the following proposition.

Proposition 3 *If firm 2 is a fitting company, $s_2 = 0$, firm 3 never invests in R&D.*

Proposition 3 reflects an intuitive result. Since firm 2 owns a compatible plant, whenever firm 1 buys firm 2, it transfers its technology and operates both its own plant and the acquired's in mutual competition. Thus, the worst situation for firm 3 is firm 2's acceptance. Irrespective of the market size, it is optimal for firm 1 to buy either firm 2 or firm 3, if it is sure to be compatible.¹¹ In all cases, firm 1 makes an acceptable offer to firm 2. By investing in R&D, firm 3 reinforces even more this result. Firm 3's R&D investments increase its probability to be compatible and leads firm 2 to more easily accept firm 1's offer of acquisition.

If firm 2 is not a fitting company, firm 3 might have incentives to invest in R&D. In this case, the worst situation for firm 3 is firm 2's rejection of firm 1's offer. If it is optimal for firm 1 to offer a share to be rejected by firm 2, firm 3 may have incentives to invest in R&D and force firm 2 to accept more easily. That is why pooling equilibria in which both types of firm 3 invest in R&D may exist.

Proposition 4 *If firm 2 is not compatible, $s_2 = S_2$, there may exist pooling equilibria in which both types of firm 3 invest in R&D.*

Firm 3's decision on whether or not to invest in R&D depends not only on firm 2's type and the cost of R&D investments but also on the market size. To be more precise, given a market size $(a - c_1) \in (6\Delta, 29\Delta]$, there are values for p and q , resulting in pooling equilibria in which both types invest. In all cases, there are values for firm 1's beliefs in which it is optimal for firm 1 to offer firm 2 an offer to be rejected. Let us look at the following example to better understand the necessary conditions to be met for such pooling equilibria.

¹¹Notice that in the case in which both firm 2 and firm 3 accept, firm 1 must choose just one of these firms. In this case, if firm 1 has offered something to be rejected by incompatible firm 3 but accepted by compatible firm 3, firm 1 will realize that firm 3 is for sure compatible.

Example 1 Suppose firm 2 is not compatible, $s_2 = S_2$, and $(a - c_1) = 7$. Firstly, we have to obtain firm 1's optimal offers. To that end, we must compare firm 1's maximum profits in all possible Nash equilibria described in Lemma 5. In case that all firms accept, we must distinguish two different situations: either firm 1 buys firm 2, or firm 1 buys firm 3 irrespective of its type. In order to obtain firm 1's maximum profits, the following computations are needed: $\Pi_1 = \frac{6.25}{b}\Delta^2$, $\bar{\Pi}^{1+3} - \Pi_3 = \frac{7.75}{b}\Delta^2$, $\frac{\underline{\Pi}^{1+3} - \Pi_3}{\underline{\Pi}^{1+3}}\bar{\Pi}^{1+3} = \frac{7.7188}{b}\Delta^2$, $\underline{\Pi}^{1+3} - \Pi_3 = \frac{6.8611}{b}\Delta^2$, $\underline{\Pi}^{1+2} - \Pi_2 = \frac{6.75}{b}\Delta^2$, $\bar{\Pi}^{1+3} - \underline{\Pi}_3^{1+2} = \frac{7}{b}\Delta^2$, $\underline{\Pi}^{1+2} = \frac{9}{b}\Delta^2$, $\bar{\Pi}_2^{1+3} = \frac{1}{b}\Delta^2$, $\underline{\Pi}_2^{1+3} = \frac{2.7778}{b}\Delta^2$, $\frac{\underline{\Pi}^{1+3} - \underline{\Pi}_3^{1+2}}{\underline{\Pi}^{1+3}}\bar{\Pi}^{1+3} = \frac{6.875}{b}\Delta^2$, and $\underline{\Pi}^{1+3} - \underline{\Pi}_3^{1+2} = \frac{6.1111}{b}\Delta^2$.

Using these computations, we can calculate firm 1's maximum profits in all possible Nash equilibria, as summarized in Table 4.

Firm 2 Firm 3	ACCEPTS	REJECTS
COMPATIBLE ($s_3 = 0$): ACCEPTS INCOMPATIBLE ($s_3 = S_3$): ACCEPTS	[9 - p - 2.7778 (1 - p)] $b^{-1}\Delta^2$ or [6.875 p + 6.111 (1 - p)] $b^{-1}\Delta^2$	[7.718 p + 6.861 (1 - p)] $b^{-1}\Delta^2$
COMPATIBLE ($s_3 = 0$): REJECTS INCOMPATIBLE ($s_3 = S_3$): REJECTS	6.75 $b^{-1}\Delta^2$	6.25 $b^{-1}\Delta^2$
COMPATIBLE ($s_3 = 0$): ACCEPTS INCOMPATIBLE ($s_3 = S_3$): REJECTS	[7 p + 6.75 (1 - p)] $b^{-1}\Delta^2$	[7.75 p + 6.25 (1 - p)] $b^{-1}\Delta^2$

Table 4: Firm 1's maximum profits in each possible Nash equilibrium under asymmetric information, for $s_2 = S_2$ and $(a - c_1) = 7$

Comparing firm 1's maximum profits in Table 4, we come to the conclusion that there is a threshold $\tilde{p} = 0.694$ above which firm 1 induces the Nash equilibrium in which all firms accept (and firm 1 buys firm 2), and below which firm 1 induces the Nash equilibrium in which firm 2 rejects but both types of firm 3 accept. In this latter Nash equilibrium, firm 3's profits for each type are given by $\Pi_3(s_3 = 0, p) = \frac{\Pi_3}{\underline{\Pi}^{1+3}}\bar{\Pi}^{1+3} = \frac{0.28125}{b}\Delta^2$ and $\Pi_3(s_3 = S_3, p) = \Pi_3 = \frac{0.25}{b}\Delta^2$. If all firms accept and firm 1 buys firm 2, firm 3's profits are given by $\Pi_3(s_3 = 0, p) = \Pi_3(s_3 = S_3, p) = \underline{\Pi}_3^{1+2} = \frac{1}{b}\Delta^2$.

Let us now analyze the existence of pooling equilibria in which any type of firm 3 invests in R&D. From Bayes' law, we have that $p^* = p_c + (1 - p_c)q$ is firms 1 and 2's posterior beliefs that firm 3 is compatible when it invests in R&D. Out-of equilibrium beliefs are

given by \bar{p} . If $p^* \geq 0.694$ and $\bar{p} \leq 0.694$, for k small enough, $0 < k < \frac{0.71875}{b} \Delta^2$, there exist pooling equilibria in which both types of firm 3 invest in R&D. In these pooling equilibria, optimal strategies for both types of firm 3 consist of investing in R&D and accepting firm 1's offer. If firm 1 observes that firm 3 invests, its optimal strategy is to offer firm 2 a share $(1 - x_1^{1+2}) = \frac{p^* \bar{\Pi}_2^{1+3} + (1-p^*) \underline{\Pi}_2^{1+3}}{\bar{\Pi}^{1+2}}$ and firm 3 a share high enough such that any type knows that even if it accepts, firm 1 will buy firm 2. On the contrary, if firm 1 observes no investment from firm 3, its optimal strategy is to offer firm 3 a share $(1 - x_1^{1+3}) = \frac{\underline{\Pi}_3}{\bar{\Pi}^{1+3}}$ and firm 2 a share low enough so as to be rejected. Finally, the optimal strategy for firm 2 is to accept firm 1's offer of acquisition.

Notice that the pooling equilibria provided in the example quoted above satisfies the intuitive criterion of Cho and Kreps (1987). The intuitive criterion eliminates those perfect Bayesian equilibria which do not result very "intuitive" or seem "unreasonable", imposing conditions on out-of equilibrium beliefs (recall that, in equilibrium, beliefs are given by Bayes' law). In particular, Cho and Kreps consider for a given type the most optimistic situation after a deviation. If even in this case this type does not have incentives to deviate, but the other type is willing to deviate, it is not reasonable to assign a positive probability to the first type. However, in our example, the most optimistic situation for both types is the one in which firms 1 and 2 think that firm 3 is compatible with a probability above \tilde{p} . In such a situation, both types will have incentives to deviate, since they would obtain the same result that they get after investing, without paying the R&D cost.

From Example 1, we can also conclude that firm 3 may invest in R&D with the aim of inducing firm 2's acceptance, and not just because it intends to become more attractive to firm 1. This is formally stated in the following corollary.

Corollary 1 *Firm 3 may have incentives to invest in R&D to become compatible even if it is not finally acquired.*

Firm 3 may invest in R&D to improve its ability to fit well even if it is not willing to be acquired. R&D investments can be used as a way to threaten firm 2 and force it to accept lower offers of acquisition. Thus, since firm 3 increases its outside option, it increases its profits, no matter if it is finally acquired or not.

5 Conclusions

The increasing number of takeover offers in U.S. during the eighties led to the adoption of a large number of state antitakeover laws and antitakeover amendments (see, for example, Roe, 1993). Critics of takeovers often complain that takeover threats may have a negative impact on R&D investment, damaging the economic health and competitive strength of firms, and thereby the national economy. In this paper, we try to provide an alternative and a complementary analysis of takeovers that does not sustain these criticisms. We find that takeover threats may nevertheless increase firms' R&D intensity, since firms might use R&D investment to signal their compatibility with the acquiring firm.

We consider three firms with different technology producing in a Cournot oligopoly. The most efficient firm might be interested in buying any of the other two. This decision strongly depends on the efficiency and compatibility of firms and the market size. Target firms' may invest in R&D to affect other firms' decisions. Through R&D investments these firms signal potential outsiders the kind of competition they may face and force them to accept lower takeover offers.

Firms are not alone in the market and profits are affected by any change in the level of competition, such as the acquisition of a rival. As target firms' profits depend not only on their own offers of acquisition but also on the others', firms may be interested in investing in R&D to influence not only their own offers but also the others' offers.

Finally, we have to point out that even though we have considered in the model that R&D investments do not generate new technologies but only enhance firms' abilities to absorb and exploit existing technologies, such investments are still worth for the economy and should be strongly encouraged. Indeed, these investments are precisely those which facilitate the low cost importation of foreign technology and the economic growth in Japan (Oshima, 1973).

Appendix

Proof of Lemma 2. If both firms 2 and 3 are compatible, whenever firm 1 buys any of these firms, it operates both plants. In this case, solving the maximization programs given by expressions (1) and (2), profits are given by $\bar{\Pi}^{1+i} = \frac{1}{8b}(a - 2c_1 + c_j)^2$ and $\bar{\Pi}_j^{1+i} = \frac{1}{16b}(a + 2c_1 - 3c_j)^2$, with $i \neq j \neq 1$. For each possible Nash equilibrium given by Lemma 1, firm 1 offers the minimum share to induce an acceptance and any share large enough to guarantee rejection. Using the conditions given by Lemma 1, with equality in case of acceptance, we have to compute firm 1's profits in any possible Nash equilibrium for firms 2 and 3 and compare them. Taking the Nash equilibrium that yields firm 1 the maximum profits, we get that firm 1's optimal offers of acquisition are such that if $(a - c_1) \in (6\Delta, 16.5\Delta]$, both firms 2 and 3 accept and firm 1 buys firm 2. However, if $(a - c_1) > 16.5\Delta$, both firms 2 and 3 accept and firm 1 buys firm 3.

If firm 2 is a fitting company, whenever firm 1 buys this firm, it operates both plants. Firms 1 and 2's joint profits and firm 3's profits are computed solving the maximization programs given by expressions (1) and (2), that is, $\bar{\Pi}^{1+2} = \frac{1}{8b}(a - 2c_1 + c_3)^2$ and $\bar{\Pi}_3^{1+2} = \frac{1}{16b}(a + 2c_1 - 3c_3)^2$. However, if firm 3 is not compatible, whenever a takeover is performed, firm 1 closes firm 3's plant. Remaining firms solve the maximization problems given by expressions (3) and (4), that is, $\underline{\Pi}^{1+3} = \frac{1}{9b}(a - 2c_1 + c_2)^2$ and $\underline{\Pi}_2^{1+3} = \frac{1}{9b}(a - 2c_2 + c_1)^2$. Computing firm 1's maximum profits for every Nash equilibrium and comparing them, we obtain that firm 1's optimal offers of acquisition are such that if $(a - c_1) \in (6\Delta, 7.35\Delta]$, both firms 2 and 3 accept and firm 1 buys firm 2. However, if $(a - c_1) > 7.35\Delta$, firm 2 accepts but firm 3 rejects so firm 1 buys firm 2.

If firm 2 is not compatible and firm 3 compatible, firms' profits in each case are given by $\underline{\Pi}^{1+2} = \frac{1}{9b}(a - 2c_1 + c_3)^2$, $\underline{\Pi}_3^{1+2} = \frac{1}{9b}(a - 2c_3 + c_1)^2$, $\bar{\Pi}^{1+3} = \frac{1}{8b}(a - 2c_1 + c_2)^2$, and $\bar{\Pi}_2^{1+3} = \frac{1}{16b}(a + 2c_1 - 3c_2)^2$. Computing firm 1's maximum profits for every possible Nash equilibrium and comparing them, we get that firm 1's optimal offers of acquisition are such that if $(a - c_1) \in (6\Delta, 7.95\Delta]$, both firms 2 and 3 accept and firm 1 buys firm 2. However, if $(a - c_1) > 7.95\Delta$, firm 3 accepts but firm 2 rejects so firm 1 buys firm 3.

If both firms 2 and 3 are not compatible, whenever firm 1 buys any of these firms, it operates just its own plant. Profits are given by $\underline{\Pi}^{1+i} = \frac{1}{9b}(a - 2c_1 + c_j)^2$ and $\underline{\Pi}_j^{1+i} = \frac{1}{9b}(a - 2c_j + c_1)^2$, with $i \neq j \neq 1$. Again, computing firm 1's maximum profits for every possible Nash equilibrium and comparing them, we obtain that firm 1's optimal offers of

acquisition are such that if $(a - c_1) \in (6\Delta, 6.6\Delta]$, firm 2 accepts but firms 3 rejects so firm 1 buys firm 2. If $(a - c_1) \in (6.6\Delta, 29\Delta]$, firm 3 accepts but firm 2 rejects so firm 1 buys firm 3. Finally, if $(a - c_1) > 29\Delta$, both firms 2 and 3 reject so no takeover is performed. This completes the proof. ■

Proof of Lemma 3. Firstly, we have to prove that $\Pi_3(s_3 = S_3, p) \leq \Pi_3(s_3 = 0, p)$. In this case, firms have the same outside option but different offers to share joint profits. A compatible firm always accepts offers that an incompatible company accepts, and it obtains higher profits than in its outside option. Moreover, a compatible firm may accept offers that an incompatible firm would reject, and again obtain higher profits than in its outside option.

Secondly, we have to prove that $\Pi_3(s_3 = S_3, p = 1) = \Pi_3(s_3 = 0, p = 1)$. By assumption, firms receive profits equivalent to their outside option. But, firm 3's outside option does not depend on its true type but on what the others think it is. An incompatible firm will always reject a compatible firm's offer but it will receive the same profits since firm 2 thinks it is a fitting company. ■

Proof of Lemma 4. Firstly, we have to prove that $\Pi_3(s_3 = S_3, p = 0) \leq \Pi_3(s_3 = S_3, p = 1)$. Suppose firm 2 is compatible. If $(a - c_1) \in (6\Delta, 16.5\Delta]$, we know from Lemma 2 that firm 1 buys firm 2, so $\Pi_3(s_3 = S_3, p = 0) = \bar{\Pi}_3^{1+2}$. If firm 3 lies and firms 1 and 2 think it is compatible, firm 2 receives an offer to be accepted. Even if firm 3 accepts its offer, firm 1 thinks it is compatible and prefers to buy 2, so $\Pi_3(s_3 = S_3, p = 1) = \bar{\Pi}_3^{1+2} = \Pi_3(s_3 = S_3, p = 0)$. If $(a - c_1) > 16.5\Delta$, again from Lemma 2, $\Pi_3(s_3 = S_3, p = 0) = \bar{\Pi}_3^{1+2}$. If firm 3 lies and firms 1 and 2 think it is compatible, firm 2 receives an offer to be accepted. However, firm 1 thinks that firm 3 is a fitting company, so it is offered a compatible firm's share. This share is not large enough for an incompatible firm to accept and firm 3 rejects. Then firm 1 is forced to buy firm 2 and $\Pi_3(s_3 = S_3, p = 1) = \bar{\Pi}_3^{1+2} = \Pi_3(s_3 = S_3, p = 0)$. Suppose firm 2 is not compatible. If $(a - c_1) \in (6\Delta, 6.6\Delta]$, we know from Lemma 2 that firm 1 buys firm 2 so $\Pi_3(s_3 = S_3, p = 0) = \underline{\Pi}_3^{1+2}$. If firm 3 lies and firms 1 and 2 think it is compatible, firm 2 receives an offer to be accepted. Even though firm 3 accepts its offer, firm 1 thinks it is compatible and prefers to buy 2, so $\Pi_3(s_3 = S_3, p = 1) = \underline{\Pi}_3^{1+2} = \Pi_3(s_3 = S_3, p = 0)$. If $(a - c_1) \in (6.6\Delta, 7.95\Delta]$, from Lemma 2, firm 2 rejects and firm 1 buys firm 3, so $\Pi_3(s_3 = S_3, p = 0) = \Pi_3$. If firm 3 lies and firms 1 and 2 think it is compatible, firm 2 receives an offer to be accepted. Even if firm

3 accepts its offer, firm 1 thinks it is compatible and prefers to buy 2 and close 2's plant, so $\Pi_3(s_3 = S_3, p = 1) = \underline{\Pi}_3^{1+2} > \Pi_3 = \Pi_3(s_3 = S_3, p = 0)$. If $(a - c_1) \in (7.95\Delta, 29\Delta]$, from Lemma 2, $\Pi_3(s_3 = S_3, p = 0) = \Pi_3$. If firm 3 lies and firms 1 and 2 think it is compatible, firm 2 receives an offer to be rejected. Firm 1 offers to 3 something that it would accept if it is compatible but, since firm 3 is incompatible, it rejects. Then no firm is bought and $\Pi_3(s_3 = S_3, p = 1) = \Pi_3 = \Pi_3(s_3 = S_3, p = 0)$. Finally, if $(a - c_1) > 29\Delta$, from Lemma 2, $\Pi_3(s_3 = S_3, p = 0) = \Pi_3$. If firm 3 lies and firms 1 and 2 think it is a fitting company, firm 2 receives an offer to be rejected. Firm 1 offers to firm 3 a share that a compatible firm would reject so an incompatible firm rejects as well and no takeover is performed, $\Pi_3(s_3 = S_3, p = 1) = \Pi_3 = \Pi_3(s_3 = S_3, p = 0)$.

Secondly, we have to prove that $\Pi_3(s_3 = 0, p = 1) \leq \Pi_3(s_3 = 0, p = 0)$. Suppose firm 2 is not compatible and $(a - c_1) \in (6.6\Delta, 7.95\Delta]$. We know from Lemma 2 that both firms 2 and 3 accept. Firm 1 buys firm 2 and closes 2's plant, so $\Pi_3(s_3 = 0, p = 1) = \underline{\Pi}_3^{1+2}$. If firm 3 lies and firms 1 and 2 think it is not compatible, firm 2 is offered a share to be rejected. If firm 3 is offered an incompatible firm offer to be accepted, $(1 - x_1^{1+3}) = 1 - \frac{\underline{\Pi}^{1+3} - \Pi_3}{\underline{\Pi}^{1+3}}$. Firm 3 accepts and firm 1 buys it, so $\Pi_3(s_3 = 0, p = 0) = \frac{\Pi_3}{\underline{\Pi}^{1+3}} \bar{\Pi}^{1+3}$. It is easy to show that $\Pi_3(s_3 = 0, p = 1) = \underline{\Pi}_3^{1+2} > \frac{\Pi_3}{\underline{\Pi}^{1+3}} \bar{\Pi}^{1+3} = \Pi_3(s_3 = 0, p = 0)$. Suppose now that firm 2 is still incompatible but $(a - c_1) \in (7.95\Delta, 29\Delta]$. From Lemma 2, we know firm 3 accepts but firm 2 rejects so firm 1 buys firm 3 and $\Pi_3(s_3 = 0, p = 1) = \Pi_3$. If firm 3 lies and firms 1 and 2 think it is not compatible, as in the previous case, firm 3 is bought and offered an incompatible firm's share, $\Pi_3(s_3 = 0, p = 0) = \frac{\Pi_3}{\underline{\Pi}^{1+3}} \bar{\Pi}^{1+3} > \Pi_3 = \Pi_3(s_3 = 0, p = 1)$. ■

Proof of Proposition 1. Let us do the proof by contradiction. Firstly, we will prove that a situation in which a compatible firm invests but an incompatible company does not, cannot be an equilibrium. From Bayes' rule, $prob(good/I) = 1$ and $prob(good/NI) = 1$. Its is optimal for a compatible firm to invest if and only if:

$$\Pi_3(s_3 = 0, p = 1) - k > \Pi_3(s_3 = 0, p = 0). \quad (\text{A})$$

It is optimal for an incompatible firm not to invest if and only if:

$$\Pi_3(s_3 = S_3, p = 0) > \Pi_3(s_3 = S_3, p = 1) - k. \quad (\text{B})$$

Conditions (A) and (B) yield to a contradiction since we know from Lemma 3 that $\Pi_3(s_3 = S_3, p = 1) = \Pi_3(s_3 = 0, p = 1)$ and $\Pi_3(s_3 = S_3, p = 0) \leq \Pi_3(s_3 = 0, p = 0)$.

Secondly, we have to prove that a situation in which an incompatible firm invests but a fitting company does not, cannot be an equilibrium. In this case, from Bayes' rule, $prob(good/NI) = 1$ and $prob(good/I) = q$. It is optimal for a compatible firm not to invest if and only if:

$$\Pi_3(s_3 = 0, p = 1) > \Pi_3(s_3 = 0, q) - k. \quad (C)$$

It is optimal for an incompatible firm to invest if and only if:

$$q\Pi_3(s_3 = 0, q) + (1 - q)\Pi_3(s_3 = S_3, q) - k > \Pi_3(s_3 = S_3, p = 1). \quad (D)$$

We know from Lemma 3 that $\Pi_3(s_3 = S_3, p = 1) = \Pi_3(s_3 = 0, p = 1)$. From conditions (C) and (D) we have that:

$$q\Pi_3(s_3 = 0, q) + (1 - q)\Pi_3(s_3 = S_3, q) > \Pi_3(s_3 = 0, p = 1) + k > \Pi_3(s_3 = 0, q),$$

which is only satisfied if $\Pi_3(s_3 = S_3, q) > \Pi_3(s_3 = 0, q)$. This contradicts Lemma 3. ■

Proof of Proposition 2. We have to prove that the situation in which both types of firm 3 invest in R&D may be an equilibrium of the signaling game. If an incompatible firm invests, there exists a probability q that this firm becomes compatible. From Bayes' rule, $prob(good/I) = p_c + (1 - p_c)q$. If firms do not invest, Bayes' rule cannot be applied. Let \bar{p} be firms 1 and 2's posterior belief that firm 3 is compatible when it does not invest in R&D, that is, $prob(good/NI) = \bar{p}$. It is optimal for a compatible firm to invest if and only if:

$$\Pi_3(s_3 = 0, p + (1 - p)q) - k > \Pi_3(s_3 = 0, \bar{p}). \quad (E)$$

It is optimal for an incompatible firm to invest if and only if:

$$q\Pi_3(s_3 = 0, p + (1 - p)q) + (1 - q)\Pi_3(s_3 = S_3, p + (1 - p)q) - k > \Pi_3(s_3 = S_3, \bar{p}). \quad (F)$$

Denoting by $\Delta\Pi_3(s_3 = 0|I) = [\Pi_3(s_3 = 0, p + (1 - p)q) - \Pi_3(s_3 = 0, \bar{p})]$, and by $\Delta\Pi_3(s_3 = S_3|I) = [q\Pi_3(s_3 = 0, p + (1 - p)q) + (1 - q)\Pi_3(s_3 = S_3, p + (1 - p)q) - \Pi_3(s_3 = S_3, \bar{p})]$, the result follows directly from conditions (E) and (F). ■

Proof of Lemma 5. Firstly, we argue that a situation in which firm 2 rejects but firm 3 accepts if it is not compatible and rejects if it is compatible cannot be sustained as a Nash equilibrium. This situation is not possible since any offer accepted by an incompatible firm will be also accepted by a fitting company. Similar argument can be

applied to the situation in which firm 2 accepts but firm 3 rejects if it is compatible and accepts if it is not compatible.

Let us analyze remaining possibilities:

- (a) Both firms 2 and 3 reject firm 1's offer of acquisition if and only if $(1-x_1^{1+3})\bar{\Pi}^{1+3} < \Pi_3$ and $(1-x_1^{1+2})\Pi^{1+2} < \Pi_2$. In this case, no firm is bought and $\Pi_3(s_3 = 0, p) = \Pi_3(s_3 = S_3, p) = \Pi_3$.
- (b) Firm 2 rejects and firm 3 accepts if it is compatible and rejects if it is not compatible. $x_1^{1+2}\Pi^{1+2} \geq x_1^{1+3}\bar{\Pi}^{1+3}$, $(1-x_1^{1+2})\Pi^{1+2} < p\bar{\Pi}_2^{1+3} + (1-p)\Pi_2$, and $(1-x_1^{1+3})\bar{\Pi}^{1+3} \geq \Pi_3 > (1-x_1^{1+3})\underline{\Pi}^{1+3}$. In equilibrium the last expression holds with equality and x_1^{1+2} is set high enough so that the first condition is satisfied. In this case, firm 1 buys firm 3 if it is compatible and no firm if it is not compatible so $\Pi_3(s_3 = 0, p) = \Pi_3(s_3 = S_3, p) = \Pi_3$.
- (c) Firm 2 rejects but both types of firm 3 accept if and only if $x_1^{1+2}\Pi^{1+2} \geq x_1^{1+3}[p\bar{\Pi}^{1+3} + (1-p)\underline{\Pi}^{1+3}]$, $(1-x_1^{1+2})\Pi^{1+2} < p\bar{\Pi}_2^{1+3} + (1-p)\underline{\Pi}_2^{1+3}$, and $(1-x_1^{1+3})\underline{\Pi}^{1+3} \geq \Pi_3$. In equilibrium the last expression holds with equality and x_1^{1+2} is set high enough so that the first condition is satisfied. In this case, firm 1 buys firm 3 independently of its type, and $\Pi_3(s_3 = 0, p) = \frac{\Pi_3}{\underline{\Pi}^{1+3}}\bar{\Pi}^{1+3}$ and $\Pi_3(s_3 = S_3, p) = \Pi_3$.
- (d) Firm 2 accepts but both types of firm 3 reject. We need $x_1^{1+3}[p\bar{\Pi}^{1+3} + (1-p)\underline{\Pi}^{1+3}] > x_1^{1+2}\Pi^{1+2}$, $(1-x_1^{1+3})\bar{\Pi}^{1+3} < \Pi_3^{1+2}$, and $(1-x_1^{1+2})\Pi^{1+2} \geq \Pi_2$. In equilibrium, the last expression holds with equality and x_1^{1+3} is set high enough so that the first condition is satisfied. However, there may be the case that, even if $x_1^{1+3} = 1$, the first condition cannot be satisfied. Then, a suboptimal strategy for firm 1 to induce this Nash equilibrium is to set $x_1^{1+3} = 1$ and $x_1^{1+2} = \frac{p\bar{\Pi}^{1+3} + (1-p)\underline{\Pi}^{1+3}}{\Pi^{1+2}} - \varepsilon$, with $\varepsilon \rightarrow 0$. In both cases, firm 1 buys firm 2 so $\Pi_3(s_3 = 0, p) = \Pi_3(s_3 = S_3, p) = \Pi_3^{1+2}$.
- (e) Firm 2 accepts and firm 3 accepts if it is compatible and rejects if it is not compatible. Since only one type accepts, firms 1 and 2 know that if firm 3 accepts it is compatible. Hence, we need $x_1^{1+3}\bar{\Pi}^{1+3} > x_1^{1+2}\Pi^{1+2}$, $(1-x_1^{1+3})\bar{\Pi}^{1+3} \geq \Pi_3^{1+2} > (1-x_1^{1+3})\underline{\Pi}^{1+3}$, and $(1-x_1^{1+2})\Pi^{1+2} \geq \Pi_2$. In equilibrium, expressions hold with equality. However,

there may be the case that with this strategy the first condition cannot be satisfied. Then, a suboptimal strategy for firm 1 to induce this Nash equilibrium is to set $x_1^{1+3} = \frac{\bar{\Pi}^{1+3} - \underline{\Pi}_3^{1+2}}{\bar{\Pi}^{1+3}}$ and $x_1^{1+2} = \frac{\bar{\Pi}^{1+3} - \underline{\Pi}_3^{1+2}}{\bar{\Pi}^{1+2}} - \varepsilon$, with $\varepsilon \rightarrow 0$. In both cases, firm 1 buys firm 2 or firm 3 if it accepts an offer of a compatible type, that is, $\Pi_3(s_3 = 0, p) = \Pi_3(s_3 = S_3, p) = \Pi_3^{1+2}$.

(f) Both firms 2 and 3 accept firm 1's offer of acquisition. Firms 1 and 2 cannot guess anything about firm 3's type if it accepts. We can distinguish two subcases:

- (f.1) If $x_1^{1+2}\bar{\Pi}^{1+2} \geq x_1^{1+3}[p\bar{\Pi}^{1+3} + (1-p)\underline{\Pi}^{1+3}]$ and $(1-x_1^{1+2})\bar{\Pi}^{1+2} \geq p\bar{\Pi}_2^{1+3} + (1-p)\underline{\Pi}_2^{1+3}$. In equilibrium, last expression holds with equality and x_1^{1+3} is set low enough so that the first condition is satisfied. In this case, firm 1 buys firm 2 and $\Pi_3(s_3 = 0, p) = \Pi_3(s_3 = S_3, p) = \Pi_3^{1+2}$
- (f.2) If $x_1^{1+3}[p\bar{\Pi}^{1+3} + (1-p)\underline{\Pi}^{1+3}] > x_1^{1+2}\bar{\Pi}^{1+2}$ and $(1-x_1^{1+3})\underline{\Pi}^{1+3} \geq \Pi_3^{1+2}$. In equilibrium, last expression holds with equality and x_1^{1+2} is set low enough so that the first condition is satisfied. In this case, firm 1 buys firm 3 independently of its type so $\Pi_3(s_3 = 0, p) = \frac{\Pi_3^{1+2}}{\underline{\Pi}^{1+3}}\bar{\Pi}^{1+3}$ and $\Pi_3(s_3 = S_3, p) = \Pi_3^{1+2}$.

This completes the proof. ■

Proof of Proposition 3. A necessary condition for a pooling equilibrium in which both types invest is that $\Pi_3(s_3 = 0, p_c + (1-p_c)q) > \Pi_3(s_3 = 0, \bar{p})$. In other words, we need $\Pi_3(s_3 = 0, p)$ to change for different values of p . Let us analyze firm 1's optimal offers. In each of the Nash equilibrium described in Lemma 5, firm 1's maximum profits are given by: (a) Π_1 , (b) $p(\bar{\Pi}^{1+3} - \Pi_3) + (1-p)\Pi_1$, (c) $p\frac{\underline{\Pi}^{1+3} - \underline{\Pi}_3}{\underline{\Pi}^{1+3}}\bar{\Pi}^{1+3} + (1-p)(\underline{\Pi}^{1+3} - \Pi_3)$, (d) $\bar{\Pi}^{1+2} - \Pi_2$ if $p\bar{\Pi}^{1+3} + (1-p)\underline{\Pi}^{1+3} > \bar{\Pi}^{1+2} - \Pi_2$, and $p\bar{\Pi}^{1+3} + (1-p)\underline{\Pi}^{1+3}$ otherwise, (e) $p(\bar{\Pi}^{1+3} - \bar{\Pi}_3^{1+2}) + (1-p)(\bar{\Pi}^{1+2} - \Pi_2)$ if $(a-c_1) > 6.83\Delta$, and $\bar{\Pi}^{1+3} - \bar{\Pi}_3^{1+2}$ otherwise, (f.1) $\bar{\Pi}^{1+2} - p\bar{\Pi}_2^{1+3} - (1-p)\underline{\Pi}_2^{1+3}$, (f.2) $p\frac{\underline{\Pi}^{1+3} - \underline{\Pi}_3^{1+2}}{\underline{\Pi}^{1+3}}\bar{\Pi}^{1+3} + (1-p)(\underline{\Pi}^{1+3} - \bar{\Pi}_3^{1+2})$.

It is easy to prove that $\underline{\Pi}^{1+3} > \Pi_1$ and $\bar{\Pi}^{1+2} - \Pi_2 > \Pi_1$. Then, firm 1's profits are always higher in case (d) than in case (a). We know that $\Pi_3 > \bar{\Pi}_3^{1+2}$, so firm 1's profits are always higher in case (f.2) than in case (c). It is also simple to prove that $\bar{\Pi}^{1+3} - \bar{\Pi}_3^{1+2} > \Pi_1$, and $\bar{\Pi}^{1+3} - \bar{\Pi}_3^{1+2} > \frac{\underline{\Pi}^{1+3} - \underline{\Pi}_3^{1+2}}{\underline{\Pi}^{1+3}}\bar{\Pi}^{1+3}$. Thus, firm 1's profits are always higher in case (e) than in cases (b) and (f.2).

Firm 1's optimal offers are such that the Nash equilibrium of cases (a), (b), (c) and (f.2) are never induced. In all remaining options, we know from Lemma 5, that $\Pi_3(s_3 =$

$0, p) = \bar{\Pi}_3^{1+2}$ for every $p \in (0, 1)$. From the proof of Lemma 4, we also know that $\Pi_3(s_3 = 0, p = 1) = \bar{\Pi}_3^{1+2}$, though $\Pi_3(s_3 = 0, p = 0) \geq \bar{\Pi}_3^{1+2}$. However, $p_c + (1 - p_c)q \geq p_c > 0$, so it is impossible that the necessary condition of Proposition 2 holds. ■

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