Commitment, First-Mover-, and Second-Mover Advantage

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Summary: In this paper we are studying the question under which circumstances a firm with a first-mover advantage may get leapfrogged by a follower. At the market stage we assume a Stackelberg structure, i.e. the leader commits to a quantity and the follower then reacts to it. It is well-known that the leader has a first-mover advantage. In our model, we additionally allow the owners of both firms to select the internal organization and the production technology before quantities are determined and produced. That is, leader and follower can additionally use two other commitment strategies alternatively or in combination: investing in (process) R&D and delegating quantity decisions to managers. Despite the symmetry of options for the two firms, we find that there is a unique equilibrium in which both firms invest in process R&D, only the follower delegates, and the follower can overcome the first-mover advantage of the quantity leader and obtain a higher profit than the leader. Although seemingly similar, our analysis reveals that there are some important differences between the two commitment devices “cost-reducing R&D” and “delegation to managers”.

Keywords: First Mover advantage; Strategic Delegation, Research and Development

JEL-Classification: L13, L2, O31
1 Introduction and motivation

The advantages of being a first-mover in the market and the strategic effects of commitment have been topics of increasing interest among academics and practitioners alike. The well-known story of Hernan Cortes, who in 1518 successfully fought against the Aztecs, illustrates the effect of being committed. The Aztecs greatly outnumbered Cortes’ troops, but by ordering their ships to be burned, Cortes left no possibility to retreat, and his troops had to win the battle in order to survive (Besanko et al. 2007). In his book The Strategy of Conflict the 2005 Nobel prize winner Thomas Schelling introduced the notion of “commitment” and gave several examples for the functioning of strategies of commitment and their importance (Schelling 1960, and more recently Schelling 2006). In the business world being a first mover and to commit to a particular market strategy is usually associated with innovativeness and good performance (e.g. Kerin et al. 1992, Lieberman and Montgomery 1988). Tellis and Golder (2001, p. 3) write that “...the firm that pioneers or first enters a market is believed to have enormous advantages in terms of success, enduring market share, and long-term market leadership.” The German firm Neumann, a leading manufacturer of high-end microphones for studios, tries to sustain its competitive advantage by being first with a new technology. According to a recent Economist report it invested 1.4 mio. Euro to develop digital microphones. Neumann’s president of marketing and sales, Wolfgang Fraissenet, is quoted by saying “Someone will do it, so we decided it should be us.” (The Economist, 2006). Another example is the Austrian Airlines Group’s first-mover-strategy into the Eastern European Market. In recent press releases CEO Alfred Ötsch announced that Austrian is expanding its Eastern European network (Weissmann 2007). In addition to its 16 existing East European destinations, where Austrian is pioneering the market, it is now also the first-mover in Iraq, where it is flying to the Kurdish town of Irbil since December 2006.1 With this strategy Austrian Airlines is trying to achieve a sustainable competitive advantage against its bigger rivals. The logic behind this reasoning is supported by the results in Chen and McMillan (1992), who find that such hard-to-reverse moves in the airline industry cause competitors to react softly.

On the other hand, as the study of Tellis and Golder (2001) demon-

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1 According to Austrian Airlines’s CMO Josef Burger, it took three years of negotiations about landing rights and technical equipment and considerable up-front investments in marketing, technical and human resources. AUA’s first-mover strategy is based on a regional advantage with respect to other airlines. Vienna International Airport, Austrian Airlines’s hub, is close enough to Iraq so that the kurdish destinations can be reached with smaller airplanes like the A-319.
strates, being first-to-market is not always a profitable strategy (see also Lieberman and Montgomery 1998, Suarez and Lanzolla 2005, or Cottrell and Sick 2002, Stalter 2002). Among the numerous examples are JVC’s Video Home System (VHS), which won the standard war against the first-mover BetaMax, and Microsoft Word, which superseded WordStar in the market for word-processing software. To give a more recent example, General Motors and Volkswagen were the early leaders in the China car market, but in the last years got leapfrogged by entrants like Hyundai and Chery. Market shares, sales, and overall profits plummeted due to this increase in competition (Roberts et al. 2005). Cho et al. (1998) give a detailed account on how (even) late-comers in the semi-conductor industry in Japan and Korea can eventually achieve market dominance.

In this paper we consider a simple game-theoretic multi-stage model which captures a situation where a leading (first-to-market) firm is getting leapfrogged by a follower. We identify a possible mechanism which leads to this result. In our model the leading firm commits itself to a particular production quantity and the follower selects its quantity as an optimal response to it. Hence, at the market stage the two firms are in a situation of the Stackelberg-leader-follower-type. It is well-known that in such a situation the leader produces more than the follower and obtains a higher profit. In our model though, additionally, before quantity decisions are made, the owners of both firms, leader and follower, can select the firms’ internal organization and the firms’ production technology. The choice of its internal organization is captured by allowing the owners of the firm to choose between delegating the production decision to a manager (and writing a suitable incentive contract) or not delegating. The choice of production technology is modelled by assuming that the owners can make a costly investment in R&D which results in a reduction of the per unit production costs. In the literature review given below it will become clear that these modeling approaches are standard. Using this framework, we will address the following main research question: Can the first-mover sustain its first-mover advantage if the setup is enriched symmetrically for both firms? One is inclined to assume that the answer is affirmative, since the first-mover in the market has an advantage and both firms can invest in R&D and/or delegate. However, it turns out that the opposite is true: the follower leapfrogs the leader.

The paper is structured as follows. In the next section we briefly review

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2 According to this Business week report, Bernd Leisser, VW China’s president, says the reason is a "mistake of the past". The commitments these two companies have made in previous years now restrict them in adapting their strategies to changed market conditions.

3 The former case might be referred to as managerial firm, the latter as entrepreneurial firm.
the related literature and connect the findings there to our work. Section 3 describes our model. We then present the main insights of our analysis in sections 4-7 and give an analytical as well as a graphical explanation. Section 8 deals with a welfare analysis. We end the paper with some conclusions and suggestions for future research possibilities.

2 Literature Review

Beginning with the model introduced by Stackelberg (1934), which demonstrates that the leading firm can obtain higher profits than the follower by committing to a high production quantity, a lot of work has been devoted to find out under which circumstances such a commitment effect can be achieved and a first-mover advantage preserved. Gal-Or (1985) has shown that the first mover (the leader) gains higher profits only if the actions of the leader and the follower are strategic substitutes. Bagwell (1995) and Vardy (2004) show that the first-mover advantage is completely lost if the first mover’s choice is imperfectly observed or if there are observation costs. On the other hand, Maggi (1999) demonstrates that the value of commitment is restored when the leader possesses private information.

Strategic effects can not only result from being the first mover in the market, but also, for example, from investing in R&D, investing in production capacity, choosing a certain capital structure, or from delegating decisions to managers. The goal of such type of commitment strategies is to influence the future behavior of its rivals and to improve its own competitive position. Researchers have investigated the effects of these commitments in Cournot, Bertrand and Stackelberg setups. Brander and Spencer (1983) introduce a duopoly model where both firms can invest in (process) R&D, resulting in reduced costs of production, before the firms compete in quantities in the market. They show that the incentives for firms to overinvest are quite strong, leading to higher quantities, lower prices and lower profits. If only one firm can invest, then this firm can gain an advantage by being the cost leader. Dixit (1980) assumes that one firm can sink costs in advance by investing in capacity, thereby trying to deter entry from rival firms. Brander and Lewis (1986) demonstrate that there are important linkages between financial and

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4See also Amir and Stepanova (2006) and Henkel (2002). For exact definitions of the terms strategic substitutes and strategic complements, see Bulow et al. (1985).
5See also Dixon (1985); see Lamberti and Rossini (1998) for competition between a labor-managed and a profit-maximizing firm.
6See also Dixit (1979) and Ware (1984). For a survey, see Neven (1989). For investments in absorptive capacity and entry deterrence, see Wiethaus (2005), and for the effect of lifetime employment contracts as an entry deterring device, see Ohnishi (2001).
output decisions. Firms which take on more debt have an incentive to select output choices which have higher returns in good states and lower returns in bad states, since in the case of bankruptcy the bondholders become the residual claimants. The internal organization of a firm also has strategic commitment effects. If the owners of a firm delegate decisions to managers who are compensated on the basis of performance measures like production output, revenue, or market shares (in addition to profits), then the managers are more aggressive and offer higher production quantities with respect to the standard owner-managed Cournot situation. Basu (1995) shows that if owners are free to delegate quantity decisions to managers, then the equilibrium can be asymmetric with one firm delegating and the other not delegating. The firm which is delegating can achieve the same position as a Stackelberg leader and can, in this situation of quantity competition, obtain a first-mover advantage. Goel (1990) introduces a Stackelberg model where the leader invests in R&D and the followers are able to benefit from the leader’s investment due to spillovers. The analysis yields the rather intuitive result that the leader invests less the higher the spillovers or the higher the number of followers. In a recent paper, Liu (2005) studies the trade-off between flexibility and commitment in a Stackelberg model with uncertainty. He finds that the first-mover advantage can be sustained only when the realized demand is close to expected demand. Otherwise, the value of flexibility dominates the value of commitment and leadership can become a disadvantage. Lambertini and Primavera (2000) consider a general setup, where firms can use delegation and cost-reducing activities either alternatively or jointly before their quantities are offered in a Cournot market. They find that the use of R&D investment by owner-managed firms is a dominated strategy, firms always delegate control to managers, while firms do not necessarily use delegation and R&D investments jointly in equilibrium. Kopel and Riegler (2006a, b) elaborate on a model introduced by Zhang and Zhang (1997), where the owners of the firms can choose to delegate the decisions on R&D levels and production quantities offered in a Cournot market to managers. In their analysis they find that – depending on the unit production costs before cost-reducing R&D – owners use the managers as some sort of commitment

7Brander and Lewis call this the limited liability effect now well-known in agency theory. For more recent accounts on the relation between capital structure and output market decisions, see e.g. Wanzenried (2003). Lyandres (2006) develops a simple model and provides empirical evidence which support the model’s predictions.

8See e.g. Fershtman (1985); Vickers (1985); Fershtman and Judd (1987); Sklivas (1987); Jansen et al. (2004). The firms are using the managers as a commitment device. Like in a prisoner’s dilemma, delegation is a dominant strategy. However, if both firms delegate, the owners are worse off than without delegation.
device to be more (less) aggressive at the market stage, and as a consequence earn higher (lower) profits in comparison to the entrepreneurial case. Finally, some authors have looked at the endogenous choice of the leader and follower role. Lambertini (2000b) studies a model where firms can choose (i) between the leader and the follower role, (ii) between delegation and no delegation, (iii) between the selection of prices and quantities. In his setup he finds that in equilibrium all firms decide to delay, act as Cournot competitors, and that owners delegate control to managers. Lambertini (2000a) studies a model where the issue of timing is addressed in a game between managerial firms. De Bondt and Henriques (1995) investigate a setup where the firms choose to be a leader or follower at the R&D stage instead of at the quantity stage. They characterize the solution in the presence of (asymmetric) spillovers.

Taken together, these contributions provide a detailed picture of the effects of being a first-mover and the impact of making a commitment by investing in R&D and/or delegating tasks to agents. The aspect, which is missing in the literature, and the one which we address in the present paper, is the following: if both, leader and follower, have access to the two commitment strategies (i) selecting the production technology by investing in (process) R&D and (ii) changing the internal organization of the firm by delegating decisions to managers, and can either employ them alternatively or jointly, which outcome can be observed in equilibrium? In order to answer this question, we consider a simple Stackelberg model with homogeneous products and allow both firms to invest in cost-reducing R&D and/or to delegate the quantity decision to managers. Hence, we link the body of literature which assumes a leader-follower structure at the market stage with work which investigates the impact of commitment by investments in cost-reducing R&D and delegating decisions to managers.

The results of our analysis are briefly as follows. First, we find that the Stackelberg leader will never delegate the quantity decision to a manager. Second, investment in cost-reducing R&D is a dominant strategy for the leader. Third, and finally, there is a unique equilibrium, in which both firms invest in process R&D, only the follower delegates, and the follower can overcome the first-mover advantage of the quantity leader and can obtain a higher profit than the leader. Our analysis will reveal that there are some important differences between the two commitment devices “cost-reducing R&D” and “delegation to managers”.

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9See also the seminal work by Hamilton and Slutsky (1990).
3 The model

We consider a Stackelberg model at the market stage where the leader and the follower offer a homogeneous product.\(^{10}\) In what follows we will denote the Stackelberg leader as firm \(L\) and the follower as firm \(F\). Both firms have (a priori) the same production unit costs of \(A\). The inverse demand function is \(p = a - Q\), with \(Q = q_L + q_F\) as the industry output. We will study the following multi-stage game.

**Innovation-Delegation Stage:** In the first stage, the owners of the leader firm and the follower firm have the option to reduce production costs by investing in (process) R&D. If an amount of \(x_L\) for firm \(L\) and \(x_F\) for firm \(F\) is spent, then effective unit production costs are

\[
c_L = A - x_L, \quad c_F = A - x_F,
\]

where \(a > A > x_L, x_F\). Research is costly and in our model the R&D cost functions are represented by \(r x_L^2/2\) and \(r x_F^2/2\), where the parameter \(r > 0\) measures the R&D efficiency. The leader’s profit is given by

\[
\pi_L = (a - (q_L + q_F))q_L - (A - x_L)q_L - \frac{r x_L^2}{2}
\]  

(1)

For the profit of the follower the indices \(L\) and \(F\) have to be swapped. The owners of the firms can also delegate the quantity decision to managers, either as an alternative to or jointly with investing in R&D. The managers are compensated on the basis of profits and quantities sold, i.e. the compensation functions are \(U_L = \pi_L + \alpha_L q_L\) and \(U_F = \pi_F + \alpha_F q_F\), where the incentive parameters \(\alpha_L\) and \(\alpha_F\) are determined by the owners such that their own profits are maximized.\(^{11}\) The total compensation of the manager is given by \(A_i + B_i U_i, i \in \{L, F\}\), where \(A_i, B_i\) are appropriately selected by the owners such that the total compensation equals the reservation utility of the managers. In what follows for simplicity we assume that the reservation utility is zero (see also Kräkel 2004, Fershtman and Judd 1987). Notice that if the value of the incentive parameter is zero, then the managers act just the

\(^{10}\)Since we are interested under which circumstances a leader can be leapfrogged by a follower, we assume that the leader and follower role are determined exogenously and that the distribution of roles is common knowledge. We will comment on the endogenous choice of roles in the concluding section.

\(^{11}\)With this assumption we follow Vickers (1985). Fershtman and Judd (1985) suggest to use a combination of profits and sales revenues instead. Our results do not change for this alternative compensation scheme.
same way as the owner would. On the other hand, selecting $\alpha_L > 0$ ($\alpha_F > 0$) motivates the manager to act more aggressive in the product market by offering a higher quantity. All the decisions concerning delegation and investment in R&D at this stage are made simultaneously by the owners.

**Quantity Stage (Stackelberg Competition):** Given the selection of the R&D investments and the values of the incentive parameters, in the case of delegation the manager of the leading firm chooses the production quantity such that the manager’s compensation is maximized. The manager of the follower firm observes this quantity and subsequently determines its optimal production quantity. After this the market clears for a price determined by the inverse demand function. In the no delegation case the decisions are made by the owners.

Taken together, the owners of the leader and the follower have the following options. They can delegate production and invest in R&D (henceforth DI), delegate production but make no investment in R&D (DN), do not delegate but invest in R&D (OI), or just determine production quantities themselves without R&D investment (ON).\(^\text{12}\) Hence, our game has 16 subgames, where each of these subgames can be solved by backwards induction. In order to guarantee interior (and unique) solutions for all the subgames, we will assume that $r \geq 3$ and $1 \leq a/A \leq 4$. Once the corresponding subgames have been solved and the payoffs for the owners derived, the normal form game depicted in Figure 1 can then be used to determine the overall equilibrium of our game.\(^\text{13}\)

Throughout the paper, the standard Stackelberg (sub)game ONON, where neither the leader $L$ nor the follower $F$ innovates or delegates and the only commitment is by being the first to market will serve as a benchmark. It is well-known that in this game the Stackelberg leader has a first-mover advantage, i.e. offers a higher quantity than the Stackelberg follower and obtains higher profits. The equilibrium quantities and profits are given by

$$q_{ONON}^L = \frac{a - A}{2} > q_{ONON}^F = \frac{a - A}{4}$$

\(^{(2)}\)

$$\pi_{ONON}^L = \frac{(a - A)^2}{8} > \pi_{ONON}^F = \frac{(a - A)^2}{16},$$

\(^{(3)}\)

\(^{12}\)The letter O stands for "owner managed", D for "delegation", I for "innovation" and N for "no innovation".

\(^{13}\)In an appendix we give the detailed solutions for all the subgames which are not treated in the text.
respectively. The question which arises is if the first-mover can sustain this advantage if both firms, the leader and the follower, have access to the same commitment strategies, namely delegation and process innovation.

4 The equilibrium of the game

It might come as a surprise that despite the fact that the owners’ options are symmetric, the follower can leapfrog the leader. It turns out that the overall equilibrium is given by the solution of subgame $OIDI$, i.e. the leader invests in R&D, but does not delegate, and the follower invests in R&D and delegates the production decision. The equilibrium values of quantities, R&D levels, incentive parameter and profits of subgame $OIDI$ are

$$
x_{OIDI}^L = \frac{2(a - A)(-3 + r)}{6 + r(-17 + 6r)}, \quad x_{OIDI}^F = \frac{3(a - A)(-2 + r)}{6 + r(-17 + 6r)}
$$

$$
\alpha_{OIDI}^L = \frac{2(a - A)(-2 + r)r}{6 + r(-17 + 6r)}, \quad \alpha_{OIDI}^F = \frac{3(a - A)r(-2 + r)}{6 + r(-17 + 6r)}
$$

$$
q_{OIDI}^L = \frac{2(a - A)r(-3 + r)}{6 + r(-17 + 6r)}, \quad q_{OIDI}^F = \frac{3(a - A)r(-2 + r)}{6 + r(-17 + 6r)}
$$

$$
\pi_{OIDI}^L = \frac{2(a - A)^2r(-3 + r)^2(-1 + r)}{(6 + r(-17 + 6r))^2}, \quad \pi_{OIDI}^F = \frac{3(a - A)^2r(-2 + r)^2(-3 + 2r)}{2(6 + r(-17 + 6r))^2},
$$

and we have

$$
\pi_{OIDI}^F > \pi_{OIDI}^L.
$$

In the next section we will try to develop an intuition for this result. In order to achieve this, we will look at the incentives of the leader and the
follower (i) to invest in cost-reducing R&D and (ii) to delegate the production quantity decision to a manager. With respect to (i), it will turn out that both leader and follower always have an incentive to invest in R&D and that by investing in R&D the leader can even improve its position with respect to the standard Stackelberg outcome. This is not too surprising, as reduced costs lead to improved competitive positions for both, leader and follower, but the leader’s higher market share results in even higher profits. Concerning (ii), we will see that the Stackelberg leader never has an incentive to choose commitment by delegation. The reason is that by delegating the production decision, a firm can achieve the Stackelberg leader role (Basu 1995). However, if a firm is already Stackelberg leader, it can no longer profit from delegation. The follower, however, can always improve its position by delegation, and, in fact, by delegating the production decision the follower can even leapfrog the leader. Finally, when both options – investment in R&D and delegation – are combined, the leader can not regain the first-mover advantage. We will demonstrate why commitment by delegation and commitment by investing in R&D are quite different in their effects.

5  Incentives of the leader and follower to commit by investing in R&D

We first consider the incentives of the leader and the follower to invest in cost-reducing R&D (subgame OIOI). In the quantity stage, given the R&D investments $x_L$ and $x_F$, the owner of the follower firm observes the quantity chosen by the leader manager and selects quantity $q_F$ such that the profit

$$\pi_F = (a - (q_L + q_F))q_F - (A - x_F)q_F - \frac{1}{2}rx_F^2$$

is maximized. Solving the first order condition yields the reaction function

$$q_F = \frac{a - A + x_F}{2} - \frac{1}{2}q_L.$$

The follower can shift its own reaction function outwards by committing itself to a higher investment in R&D. Note that the production quantity of the follower depends on $q_L$, but since it is independent of the leader’s investment in R&D, the follower’s quantity choice can not be influenced directly by the leader’s commitment variable. The leader selects its quantity $q_L$ such that profits are maximized, which yields
\[ q_L(x_L, x_F) = \frac{a - A + 2x_L - x_F}{2}. \]

Observe that the leader’s quantity depends negatively on the follower’s R&D investment \( x_F \). Inserting \( q_L(x_L, x_F) \) into the follower’s reaction function, we obtain \( q_F(x_L, x_F) \). Using these expressions, we get the reduced-form profit functions at the innovation stage. The reduced-form profit function in general form can be written as \( \pi_L(q_L(x_L, x_F), q_F(x_L, x_F), x_L) \) for the leader and \( \pi_F(q_L(x_L, x_F), q_F(x_L, x_F), x_F) \) for the follower. It is important to realize that they directly depend on the strategic commitment variable (through the quadratic cost term). The next proposition describes the incentives of both firms to invest in R&D.

**Proposition 1** Both, leader and follower, have an incentive to invest in cost-reducing R&D.

**Proof.** To determine the leader’s incentive for R&D investments we look at the derivative

\[
\frac{d\pi_L}{dx_L} = \frac{\partial \pi_L}{\partial x_L} + \left( \frac{\partial \pi_L}{\partial q_L} + \frac{\partial \pi_L}{\partial q_F} \frac{\partial q_F^*}{\partial q_L} \right) \frac{\partial q_L^*}{\partial x_L},
\]

where the * denotes equilibrium quantities. The term in parenthesis is zero, since at the quantity stage the leader determines its production quantity such that

\[
\frac{d\pi_L}{dq_L} = \frac{\partial \pi_L}{\partial q_L} + \frac{\partial \pi_L}{\partial q_F} \frac{\partial q_F^*}{\partial q_L} = 0.
\]

Hence, the strategic effect vanishes (and in this sense no overinvestment occurs), but the first term capturing the direct effect is non-zero. Calculating the partial derivative yields

\[
\frac{\partial \pi_L}{\partial x_L} = q_L - r x_L,
\]

which shows that for sufficiently small investments this derivative (and therefore the overall investment incentive effect) is positive. Of course, the first term of this expression is the gain due to the resulting cost reduction from investing in R&D and the second term represents the associated marginal costs of this investment. Consequently, the optimal level of R&D investment for the leader is given by \( x_L = q_L/r \). For the follower we get

\[
\frac{d\pi_F}{dx_F} = \frac{\partial \pi_F}{\partial x_F} + \frac{\partial \pi_F}{\partial q_L} \frac{\partial q_L^*}{\partial x_F} \leq 0 \quad < 0
\]

> 0
Therefore, the follower overinvests in R&D with respect to the investment level without strategic effects.

The subgame-perfect quantities, R&D investment levels and profits in subgame OIOI are given by

\[ q_{OIOI}^L = \frac{2(a - A)r(-3 + 2r)}{r(8r - 17) + 6}, \quad q_{OIOI}^F = \frac{2(a - A)r(-2 + r)}{r(8r - 17) + 6} \]
\[ x_{OIOI}^L = \frac{2(a - A)(2r - 3)}{r(8r - 17) + 6}, \quad x_{OIOI}^F = \frac{3(a - A)(r - 2)}{r(8r - 17) + 6} \]
\[ \pi_{OIOI}^L = \frac{(a - A)^2r(3 - 2r)^2(-1 + r)}{(r(8r - 17) + 6)^2} \]
\[ \pi_{OIOI}^F = \frac{(a - A)^2r(-2 + r)^2(-9 + 8r)}{2(r(8r - 17) + 6)^2}. \]

As our proposition predicts, the follower overinvests in R&D, whereas the leader does not. Interestingly though, despite selecting such an aggressive strategy, the follower is not able to overcome the first-mover advantage. It is now easy to see that the following relations hold:

\[ \pi_{OIOI}^L > \pi_{NON}^L > \pi_{NON}^F > \pi_{OIOI}^F \]
\[ q_{OIOI}^L > q_{NON}^L > q_{NON}^F > q_{OIOI}^F \]
\[ x_{OIOI}^L > x_{OIOI}^F. \]

Although the leader does not overinvest, the leader’s R&D investment is higher than the follower’s. As a consequence, on top of being committed to a higher market share, the leader also has a cost advantage. Taken together, this leads to a quantity which is even higher than the Stackelberg leader’s quantity \( q_{NON}^L \). Since quantities are strategic substitutes, the follower reduces its quantity even below the level of the Stackelberg follower \( q_{NON}^F \). The profit of the leader in a situation where cost-reducing R&D is possible is then even higher than the profit \( \pi_{NON}^L \). In Figure 2 we depict the leader’s isoprofit-curve \( \pi_{NON}^L \) and the follower’s reaction curve \( q_{RF}^O \) together with the Stackelberg outcome \( S_{NON} \). The isoprofit curve \( \pi_{NON}^L \) reaches its maximum in the point where it intersects with the reaction curve \( q_{RF}^O \) of the leader. By investing in R&D, the follower shifts the reaction curve outwards to \( q_{RF}^O \). The leader also invests in R&D and this shifts the isoprofit-curves to the right (since the profits directly depend on the R&D investment). The leader’s profit is maximized in the point \( S_{OIOI} \) where the

\[ ^{14}\text{This can be deduced from the relations } x_{OIOI}^L = q_{OIOI}^L / r \text{ and } x_{OIOI}^F > q_{OIOI}^F / r. \]
isoprofit-curve $\pi_{L}^{OIOI}$ is tangent to the follower’s reaction curve. In this case the leader’s equilibrium quantity increases, whereas the follower’s equilibrium quantity decreases. The leader’s profit increases, $\pi_{L}^{OIOI} > \pi_{L}^{NON}$, whereas the follower’s profit decreases.

— Insert Figure 2 about here —

6 Incentives of the leader and follower to commit by delegation

Let us now consider the incentives of the leader and the follower to delegate the production decisions (subgame DNDN). In the quantity stage, the follower manager observes the quantity chosen by the leader manager and selects quantity $q_{F}$ such that the compensation

$$U_{F}(\alpha_{L}, \alpha_{F}, q_{L}, q_{F}) = (a - (q_{L} + q_{F}))q_{F} - Aq_{F} + \alpha_{F}q_{F}$$

is maximized, where $\alpha_{F}, \alpha_{L}$ and $q_{L}$ have been determined at the previous stages. Solving the first order condition yields the reaction function

$$q_{F} = \frac{a - A + \alpha_{F}}{2} - \frac{1}{2} q_{L}.$$

Obviously, the follower can shift its own reaction function to the right by making its manager more aggressive, i.e. by selecting a higher incentive parameter.\footnote{A higher $\alpha_{F}$ lowers the production costs “perceived” by the manager. This can be easily seen by re-writing the compensation function $U_{F}$. Consequently, this has the same effect as a reduction in real production costs of an owner-managed firm.} Note also that the production quantity of the follower depends on $q_{L}$, but is independent of the leader’s incentive parameter $\alpha_{L}$. Consequently, the follower’s quantity choice can not be influenced directly by the leader’s commitment variable. The leader manager anticipates the reaction of the follower manager and selects its quantity such that compensation $U_{L}$ is maximized. Solving the first order condition gives the optimal quantity

$$q_{L}(\alpha_{L}, \alpha_{F}) = \frac{a - A + 2\alpha_{L} - \alpha_{F}}{2}.$$
Observe that the leader’s quantity depends negatively on the follower’s incentive parameter $\alpha_F$. Inserting $q_L(\alpha_L, \alpha_F)$ into the follower’s reaction function, we obtain $q_F(\alpha_L, \alpha_F)$. Using these expressions, we get the reduced-form profit functions for the leader and the follower at the delegation stage, $\pi_L(q_L(\alpha_F, \alpha_L), q_F(\alpha_F, \alpha_L))$ and $\pi_F(q_L(\alpha_F, \alpha_L), q_F(\alpha_F, \alpha_L))$ respectively. It seems that so far the two commitment options, investment in R&D and delegating the production decision, have quite similar effects. Note however, that in contrast to the case where the firms invest in cost-reducing R&D the reduced-form profit functions do not directly depend on the strategic commitment variable. This makes the incentives for commitment by investing in R&D quite different from the incentives for commitment by delegation, as the next proposition shows.

**Proposition 2** The first mover never has an incentive to delegate the output decision to a manager. In contrast to this, the follower always hires a manager who acts aggressively on the market.

**Proof.** The follower manager selects the quantity such that $U_F = \pi_F + \alpha_F q_F$ is maximized. The first order condition reads

$$
\frac{dU_F}{dq_F} = \frac{\partial \pi_F}{\partial q_F} + \alpha_F = 0.
$$

This condition yields the optimal production quantity of the follower as determined by its manager, $q_F^*(\alpha_F, \alpha_L, q_L)$. Substituting leads to the leader manager’s payment function $U_L(\alpha_F, \alpha_L, q_F(q_L), q_L)$ and to the following first order condition for the leader manager at the quantity stage,

$$
\frac{dU_L}{dq_L} = \frac{\partial U_L}{\partial q_L} + \frac{\partial U_L}{\partial q_F} \frac{\partial q_F^*}{\partial q_L} = \frac{\partial \pi_L}{\partial q_L} + \alpha_L + \frac{\partial \pi_L}{\partial q_F} \frac{\partial q_F^*}{\partial q_L} = 0.
$$

(5)

To determine the delegation incentives of the leader, we write the FOC at the delegation stage as

$$
\frac{d\pi_L}{d\alpha_L} = \frac{\partial \pi_L}{\partial \alpha_L} + \left( \frac{\partial \pi_L}{\partial q_L} + \frac{\partial \pi_L}{\partial q_F} \frac{\partial q_F^*}{\partial q_L} \right) \frac{\partial q_F^*}{\partial \alpha_L}.
$$

Since $\alpha_L$ has no direct effect on $\pi_L$, the first term is zero and taking (5) into account, the first order condition reads

$$
\frac{d\pi_L}{d\alpha_L} = -\alpha_L \frac{\partial q_F^*}{\partial \alpha_L} \leq 0.
$$

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The nonpositivity follows since the two terms always have opposite signs. Therefore $\alpha_L = 0$, i.e. the leader has no incentive to delegate (or no incentive to “overinvest”).

On the other hand, the follower’s FOC at the delegation stage reads
\[
\frac{d\pi_F}{d\alpha_F} = \frac{\partial\pi_F}{\partial \alpha_F} + \frac{\partial\pi_F}{\partial q^*_L} \frac{\partial q^*_L}{\partial \alpha_F} + \frac{\partial\pi_F}{\partial q^*_F} \frac{\partial q^*_F}{\partial \alpha_F}.
\]

Obviously, for $\alpha_F = 0$ the derivative is positive, which shows that that the owner of the follower firm always has an incentive to delegate the production decision to a manager and select $\alpha_F > 0$ in equilibrium.

The result that the leader does not delegate the production decision, but the follower does, can be directly derived as follows. Inserting $q_L(\alpha_L, \alpha_F)$ into the follower’s reaction function, and then substituting the resulting expressions into the leader’s profit function results in
\[
\pi_L(\alpha_L, \alpha_F) = \frac{-4\alpha_L^2 + (-a + A + \alpha_F)^2}{8}.
\]

This shows that the leader’s profit depends negatively on its own compensation parameter and, therefore, the owner’s optimal choice is $\alpha_L^{DNDN} = 0$. The leader never wants to use delegation as a commitment device, since it does not increase profits.\(^\text{16}\) Given this insight, the follower profit is
\[
\pi_F(0, \alpha_F) = \frac{1}{16} ((a - A)^2 + 2\alpha_F(a - A) - 3\alpha_F^2)
\]

and from the first order conditions, the optimal value of the incentive parameter is obtained as
\[
\alpha_F^{DNDN} = \frac{a - A}{3} > 0.
\]

In contrast to the leader, the follower induces its manager to be more aggressive on the product market and, in this sense, “overinvests”. The quantities and profits in the subgame-perfect equilibrium of subgame DNDN are given by
\[
q_L^{DNDN} = \frac{a - A}{3}, q_F^{DNDN} = \frac{a - A}{2},
\]
\[
\pi_L^{DNDN} = \frac{(a - A)^2}{18}, \pi_F^{DNDN} = \frac{(a - A)^2}{12}.
\]

\(^\text{16}\) Bonatti and Martina (2004) and Lambertini (2000a, b) report similar observations for their models.
Obviously, we have $q_{DNDN}^F = q_{ONON}^F > q_{DNDN}^L > q_{ONON}^L$ and $\pi_{ONON}^L > \pi_{DNDN}^F > \pi_{ONON}^F > \pi_{DNDN}^L$. In other words, by delegating the production decision to a manager, the follower can actually take over the leader’s role. By using the manager as a commitment device, the follower produces the same quantity as the leader in the standard Stackelberg game (subgame ONON), which is higher than the quantity produced by the leader in subgame DNDN. As a consequence, the follower obtains a higher profit than the leader. This somehow surprising result can be understood by recalling that the leader’s and the follower’s reduced-form profits at the delegation stage do not directly depend on the compensation parameters. Geometrically this means that the shape of the leader’s isoprofit curves is the same as in the subgame without delegation (see Figure 3). Since neither the follower’s quantity nor the follower’s profit can be directly influenced by the leader’s strategic commitment, the leader can not gain from any strategic effect at the delegation stage and, consequently, sets $\alpha_L = 0$. In contrast to the leader’s situation, the follower can gain from delegation. Note that the leader selects its quantity by solving a constrained optimization problem: it can only select quantities which are on the follower’s reaction function. However, the follower is able to shift this reaction function outwards by increasing the commitment variable $\alpha_F$. This makes the follower’s manager stronger, increases $q_F$ and at the same time decreases $q_L$ (since quantities are strategic substitutes). In Figure 3 we illustrate these arguments. The leader’s isoprofit-curve $\pi_{ONON}^L$ and the follower’s quantity reaction function $q_{ONON}^{RF}$ are shown together with the Stackelberg outcome $S_{ONON}$. By delegating the production decision to a manager, the follower shifts the reaction curve outwards to $q_{DNDN}^{RF}$ and the leader’s profit is maximized in the point $S_{DNDN}$ where the isoprofit-curve $\pi_{DNDN}^L = \pi_{ONDN}^L$ is tangent to this reaction curve\textsuperscript{17}. Note that the isoprofit-curves $\pi_{ONON}^L$ and $\pi_{ONDN}^L$ both have a maximum at their intersection with the leader’s reaction curve $q_{RL}^{ON}$, and this yields a shift of the equilibrium to the left. Consequently, the leader’s equilibrium quantity is reduced, whereas the follower’s equilibrium quantity is increased. Similarly, the leader’s profit decreases since $\pi_{ONDN}^L < \pi_{ONON}^L$, whereas the follower’s profit increases (the follower’s new equilibrium quantity is closer to the follower’s monopoly quantity).

\textsuperscript{17}Since the leader selects $\alpha_L = 0$, the solutions of subgames DNDN and ONDN coincide.
kind of problem in both cases. There is, however, one important difference which results from a rather innocuously-looking assumption. In the case of R&D investments, the leader’s profit function depends on the level of its own R&D investment. In the case of delegation, however, the total compensation paid to the manager enters the leader’s profit function as a constant. This is due to the common (and often implicitly made) assumption that the labor market for managers is assumed to be competitive, and consequently, the total compensation paid to the manager equals the (constant) reservation utility. Geometrically, this means that in the case of R&D the shape and location of the isoprofit curves change with varying levels of R&D investment, whereas in the case of delegation it does not (compare Figures 2 and 3). As a consequence, by investing in R&D the leader can select a point on the reaction curve where $q_L > q_F$ and $\pi_F > \pi_L$ simultaneously.

7 Incentives to use investments in R&D and delegation in combination

Until now we have considered the two commitment strategies in isolation, and we have demonstrated that the leader can improve its competitive position by investing in R&D, but the leader can not use delegation to its advantage (and even gets leapfrogged by the follower). The question arises how this trade-off works out if both, leader and follower, can use such strategies in combination. Let us therefore consider the incentives of the leader and the follower to make combined use of investment in R&D and delegation of the production decisions (subgame DIDI). Using backwards-induction we can solve the quantity stage and this yields

\begin{align*}
q_L(\alpha_L, \alpha_F, x_L, x_F) &= \frac{a - A + 2(\alpha_L + x_L) - (\alpha_F + x_F)}{2} \\
q_F(\alpha_L, \alpha_F, x_L, x_F) &= \frac{a - A - 2(\alpha_L + x_L) + 3(\alpha_F + x_F)}{4}.
\end{align*}

Using these expressions, we get the reduced-form profit functions at the delegation/innovation stage. The reduced-form profit function in general form can be written as $\pi_L(q_L(\alpha_L, \alpha_F, x_L, x_F), q_F(\alpha_L, \alpha_F, x_L, x_F), x_L)$ for the leader and $\pi_F(q_L(\alpha_L, \alpha_F, x_L, x_F), q_F(\alpha_L, \alpha_F, x_L, x_F), x_F)$ for the follower. The next proposition looks at the incentives to delegate and innovate.

**Proposition 3** Both, leader and follower, have an incentive to invest in cost-reducing R&D, but do not overinvest. The first mover has no incentive
to delegate the output decision to a manager, whereas the follower hires a manager who acts aggressively on the market.

**Proof.** Using similar arguments as before, we obtain the following FOC at the delegation-innovation stage

\[
\frac{d\pi_L}{dx_L} = \frac{\partial \pi_L}{\partial x_L} + \left( \frac{\partial \pi_L}{\partial q^*_L} + \frac{\partial \pi_L}{\partial q^*_F} \right) \frac{\partial q^*_L}{\partial x_L} \\
\frac{d\pi_L}{d\alpha_L} = \frac{\partial \pi_L}{\partial \alpha_L} + \left( \frac{\partial \pi_L}{\partial q^*_L} + \frac{\partial \pi_L}{\partial q^*_F} \right) \frac{\partial q^*_L}{\partial \alpha_L} \\
\frac{d\pi_F}{dx_F} = \frac{\partial \pi_F}{\partial x_F} + \frac{\partial \pi_F}{\partial q^*_F} \frac{\partial q^*_F}{\partial x_F} + \frac{\partial \pi_F}{\partial q^*_L} \frac{\partial q^*_L}{\partial x_F} \\
\frac{d\pi_F}{d\alpha_F} = \frac{\partial \pi_F}{\partial \alpha_F} + \frac{\partial \pi_F}{\partial q^*_F} \frac{\partial q^*_F}{\partial \alpha_F} + \frac{\partial \pi_F}{\partial q^*_L} \frac{\partial q^*_L}{\partial \alpha_F}
\]

Using the leader manager’s first order condition and noticing that \(\frac{\partial \pi_L}{\partial \alpha_L} = 0\), the first two conditions can be written as

\[
\frac{d\pi_L}{dx_L} = \frac{\partial \pi_L}{\partial x_L} - \alpha_L \frac{\partial q^*_L}{\partial x_L} \\
\frac{d\pi_L}{d\alpha_L} = -\alpha_L \frac{\partial q^*_L}{d\alpha_L}
\]

It is now obvious that again the leader does not delegate (\(\alpha_L = 0\)) and chooses the level of investment in R&F such that \(x_L = q_L/r\), i.e. no overinvestment due to strategic considerations occurs since \(\frac{d\pi_L}{dx_L} = \frac{\partial \pi_L}{\partial x_L}\). Furthermore, with respect to the conditions for the follower, notice that \(\frac{\partial q^*_L}{\partial \alpha_F} = \frac{\partial q^*_L}{\partial x_F}\) and \(\frac{\partial q^*_F}{\partial \alpha_F} = \frac{\partial q^*_F}{\partial x_F}\), since the reaction functions only depend on the sum of both strategic variables. Therefore, since \(\frac{\partial \pi_F}{\partial \alpha_F} = 0\) it immediately follows that when the incentive parameter is selected such that the FOC is fulfilled, the level of investment in R&F is determined such that \(\frac{d\pi_F}{dx_F} = \frac{\partial \pi_F}{\partial x_F} = q_F - rx_F = 0\). Furthermore, from similar arguments as given in Proposition 2 it follows that \(\alpha_F \neq 0\). Hence, the follower delegates the production decision to a manager and invests in R&D, but does not overinvest. 

The proposition shows that the leader again can not obtain an advantage by delegating the production decision, but has an incentive to invest in R&D. The follower delegates the production decision and also invests in R&D. Since the production quantity of the leader depends only on the sum of R&D investments and incentive parameter, see (6), both instruments have (in the
margin) the same strategic effect. The follower strategically “overinvests” in delegation, since it is less expensive than investing in R&D.\footnote{Recall that the participation constraint is binding and the reservation utility is constant (for simplicity scaled to zero). If the variable bonus for the manager is increased, the participation constraint still holds, since the fixed salary $A_F$ can be adjusted.}

If we now turn to the overall equilibrium of the game, we see that no matter what the follower does, it is always beneficial for the leader to innovate, independent of the R&D efficiency. We have

$$\pi_{LION} > \pi_{NON}, \pi_{LOIOI} > \pi_{ONOIO}, \pi_{LOIDN} > \pi_{ONDN}, \pi_{LOIDI} > \pi_{ONDI},$$

and therefore investing in process R&D is a dominant strategy for the leader. Furthermore, it is always beneficial for the follower to delegate and innovate, as a response to this, i.e.

$$\pi_{OFIDI} > \pi_{OFION}, \pi_{OFIOI} > \pi_{OFIOD}, \pi_{OFIDO} > \pi_{OFIOI}.$$ 

Consequently, in the overall equilibrium of the game the leader invests in process innovation (but does not delegate) and the follower invests in process innovation and delegates the production decision to a manager. By using both commitment strategies, the follower can overcome the market leaders first-mover advantage despite the leader’s R&D investment efforts, i.e. $\pi_{FIOIDI} > \pi_{LIOIDI}$. In Figure 4 we illustrate the situation. Although the leader reduces costs by investing in R&D, the first-mover advantage cannot be sustained. In the equilibrium $S^{IOIDI}$ we have $\pi_{FIOIDI} > \pi_{LIOIDI}$ and $q_{FIOIDI} > q_{LIOIDI}$, i.e. the follower earns a higher profit and offers a larger quantity than the quantity leader.

--- Insert Figure 4 about here ---

8 Welfare Analysis

We now turn to the question if the commitment by investing in R&D and by delegating output decision to a manager leads to an overall increase in welfare, where we measure welfare in the usual way as the sum of consumer rent and firms’ profits in equilibrium. In order to answer this question, we are considering the R&D investment level and the output level which are obtained under the assumption that the social planer keeps both production
facilities active. It is easy to see that by equating price and marginal costs the following R&D level $\bar{X}$ and the industry output level $\bar{Q}$ are obtained:

$$\bar{X} = \frac{a - A}{-1 + 2r}, \quad \bar{Q} = \frac{2r(a - A)}{1 - 2r}.$$  

Industry output and R&D level in the overall equilibrium of our game are

$$X^{OIDI} = \frac{(a - A)(-12 + 5r)}{6 + r(-17 + 6r)}, \quad Q^{OIDI} = \frac{(a - A)r(-12 + 5r)}{6 + r(-17 + 6r)}.$$  

Given our parameter restrictions, the industry output in equilibrium is smaller than the level $\bar{Q}$. More interestingly, however, is the fact that the equilibrium industry R&D investment level $X^{OIDI}$ is higher than $X$. The combination of the follower’s incentive to invest in R&D in order to overcome the leader’s first-mover advantage and the incentive of the market leader to defend its first-mover advantage lead to overinvestment in R&D with regard to the R&D level $\bar{X}$. As far as welfare is concerned it turns out that commitment is welfare-enhancing with respect to this benchmark. This is due to the higher industry output and higher R&D investment levels, which result in lower prices. On the other hand, commitment by R&D and delegation of production decisions leads to a reduction in the firms’ profits.

## 9 Conclusions

Being first-to-market is often associated with improved performance. Hence, researchers in industrial economics have focused primarily on early-mover advantages and have offered reasons why a first mover might achieve favorable competitive positions e.g. due to the erection of entry barriers. However, empirical and anecdotal evidence shows that the first-movers in the market can not always sustain their advantage and may get leapfrogged by second-to-market firms or even late entrants. Therefore, several more recent studies try to identify the sources of advantages and disadvantages of first-mover and follower strategies; see e.g. Kerin et al. (1992), Lieberman and Montgomery (1988, 1998), Cho et al. (1998). For example, Gal-Or (1985) has shown that the slope of the reaction functions play a decisive role: the leader’s payoff is higher (lower) than the follower’s payoff if the reaction function of the follower is downward-sloping (upward-sloping). More recently, Okuguchi (1999) provides sufficient conditions on the cost and market demand functions and compares Cournot and Stackelberg outcomes.

In this paper we have also considered a Stackelberg structure and we have identified sources of first-mover advantages and disadvantages. Our
model shows that, although investment in cost-reducing R&D strengthens the first-mover’s competitive position, by combining the technology choice and selection of internal organization the second-mover nevertheless can leapfrog the leader. Despite the fact that the leader also has the option of choosing the internal organization, the commitment to being a first-mover at the market stage destroys the value of this option.

Our model has been kept intentionally simple. One topic which we believe to be interesting to pursue is the endogeneity of leader and follower roles (see Hamilton and Slutsky 1990, Dowrick 1986, Lambertini 2000b). Preliminary results indicate that in a differentiated-products model where firms compete in prices, can invest in R&D, and delegate production decisions, a Stackelberg structure emerges as an equilibrium outcome. Furthermore, both firms have higher profits than in the corresponding equilibrium without access to R&D and delegation. We will report more details of our study in a future paper.

10 Appendix

Subgame ONDN: Only follower commits by delegation

Recall that the leader always chooses $\alpha_L = 0$, so that subgame ONDN has the same solution as the subgame DNDN analyzed in the text.

Subgame ONOI: Only follower commits by R&D

The outcome of this subgame is

$$q_{ONOI}^F = \frac{3(a - A)}{-9 + 8r}, q_{ONOI}^L = \frac{2(a - A)(-3 + 2r)}{-9 + 8r}, q_{ONOI}^L = \frac{2(a - A)r}{-9 + 8r},$$

$$\pi_{ONOI}^L = \frac{2(a - A)^2(3 - 2r)^2}{(9 - 8r)^2}, \pi_{ONOI}^F = \frac{(a - A)^2r}{2(-9 + 8r)}.$$  

It is easy to see that the follower earns a higher profit if $3 \leq r \leq \frac{2}{11}(13 + \sqrt{41}) \simeq 3.64$. The market leader has a first-mover advantage if costs are identical for both firms. However, the follower can invest in process R&D and, thereby, reduce its production costs. If the R&D efficiency is sufficiently high, i.e. the parameter $r$ sufficiently small, then the follower can overcome the first-mover advantage of the market leader.

Subgame ONDI: Follower commits by delegation and R&D
The solution of this subgame is

\[ x_{ONDI}^F = \frac{a - A}{2r - 3}, \quad \alpha_{ONDI}^F = \frac{2r(a - A)}{6r - 9}. \]

\[ q_{ONDI}^L = \frac{2(a - A)(r - 3)}{6r - 9}, \quad q_{ONDI}^F = \frac{r(a - A)}{2r - 3}. \]

\[ \pi_{ONDI}^L = \frac{2(a - A)^2(r - 3)^2}{9(2r - 3)^2}, \quad \pi_{ONDI}^F = \frac{(a - A)^2r}{6(2r - 3)}. \]

where we have \( \pi_{ONDI}^L < \pi_{ONDI}^F \) for all \( r \geq 3 \). The follower offers a higher quantity than the leader and obtains a higher profit than the firm which is first to the market.

Subgame OION: Leader commits by R&D

Needless to say that if the leader has the possibility to invest in R&D, but the follower neither commits by delegation nor invests in R&D, then the leader will improve its position with respect to the Stackelberg case. The solution is

\[ x_{OION}^L = \frac{a - A}{2(-1 + r)} \]

\[ q_{OION}^L = \frac{(a - A)r}{2(-1 + r)} > \frac{(a - A)(-2 + r)}{4(-1 + r)} = q_{OION}^F. \]

\[ \pi_{OION}^L = \frac{(a - A)^2r}{8(-1 + r)} > \frac{(a - A)^2(-2 + r)^2}{16(-1 + r)^2} = \pi_{OION}^F. \]

Subgame OIDN: Leader commits by R&D, follower by delegation

The subgame perfect outcome of this subgame is

\[ x_{OIDN}^L = \frac{a - A}{-4 + 3r}, \quad \alpha_{OIDN}^F = \frac{(a - A)(r - 2)}{-4 + 3r}. \]

\[ q_{OIDN}^L = \frac{(a - A)r}{-4 + 3r}, \quad q_{OIDN}^F = \frac{3(a - A)(-2 + r)}{2(-4 + 3r)}. \]
\[ \pi_{ONDN} = \frac{(a-A)^2(-1+r)r}{2(4-3r)^2}, \pi_{OIDN} = \frac{3(a-A)^2(-2+r)^2}{4(4-3r)^2}. \]

A comparison of the profits yields the following result: if R&D efficiency is sufficiently high, i.e. \( 3 \leq r \leq 5 + \sqrt{13} \approx 8.61 \) holds, then the market leader obtains higher profits. Otherwise, R&D costs are getting so high that the follower gets higher profits in equilibrium. An overall comparison of the resulting profits for the different strategy combinations yields the following insight. For low values of \( r \) (i.e. high R&D efficiency) we get

\[ \pi_{OIOI} > \pi_{ONON} > \pi_{OIDN} > \pi_{ONDN} > \pi_{ONON} > \pi_{OIOI} > \pi_{OIDN}. \]

On the other hand, for high values of \( r \) the order changes to

\[ \pi_{OIOI} > \pi_{ONON} > \pi_{ONDN} > \pi_{OIDN} > \pi_{OIOI} > \pi_{OIDN} > \pi_{ONON}. \]

Quite intuitively it turns out that for low values of \( r \) investment in process R&D is a very effective commitment strategy, but loses its appeal with increasing \( r \). At a value of \( r = \frac{1}{5}(25 + \sqrt{145}) \approx 4.63 \) delegation becomes the more effective strategy. It should be noted, however, that (following the literature) we assumed that while reducing unit costs by investing in R&D is costly, delegating production decision to managers is not (due to a competitive labor market so that the manager’s reservation utility is constant).

11 References


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Figure 2: Leader and follower commit by investing in process R&D
Figure 3: Follower commits by delegation
Figure 4: Leader and follower invest in process R&D and follower delegates