The impact of a hedging opportunity in a principal-agent setting with a potential market entrant

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Abstract
Corporate risk management has become increasingly common in several industries. This paper contributes to a better understanding of hedging incentives and related effects. The analysis is carried out within an agency setting that is combined with a market entry game. Hedging reduces noise and therefore agency costs but increases the threat of competition. Four different strategies turn out to be possibly optimal for an incumbent firm: (i) Not to hedge and to prevent entry of the competitor, (ii) to separate w.r.t. hedging and to allow entry when nature is good, (iii) to pool with hedging and to bear expected cost of entry, (iv) to hedge and to reduce the precision of the signal to avoid entry.

Keywords: hedging, derivatives, agency theory, asymmetric information

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1. INTRODUCTION

Over the past decade corporate financial policy has become an increasingly important issue for many companies. These companies use capital markets not only as a financing device but for strategic corporate trading. The continuing growth in markets for derivative securities such as forwards, futures, options or swaps to some extent reflects these trading activities. Given this tendency a better understanding of the economic effects of hedging appears to be useful in many respects. It allows companies to design elaborate financial strategies to their own benefit. It puts outside observers like potential investors and capital market authorities, like the SEC, in a position to judge observed hedging strategies appropriately. Finally it helps accounting standard setters to anticipate the consequences of certain accounting regulations on company level.

This paper contributes to the issue combining a principal agent setting with a market entry game. Within this setting I derive optimal hedging strategies and analyze the effects these strategies have on contracting, managerial effort, and the principal’s welfare.

The argument goes as follows: The owner of a company hires a manager to run his business. As the manager’s effort is unobservable, his compensation is a function of output rather than effort. Output, however, is an imperfect measure of performance, which exposes the manager to a compensation risk and he requires a risk premium for taking this risk.¹ If hedging reduces the variance of output, the agent’s exposure to risk as well as the required risk premium are reduced. However, output is a signal not only of the manager’s performance. It contains information about the firm’s abilities, its prospects or the business environment it operates in. Moreover, information provided to investors or owners of the firm is available to other parties as well, namely to a potential competitor. Providing more precise information about output (due to hedging) to the competitor may encourage market entry and in turn harm the firm. Given this trade off, I find that four different strategies might be optimal for the incumbent
firm. (i) It might be optimal not to hedge at all to prevent entry of the competitor. (ii) The principal may choose to separate w.r.t. hedging and to allow entry whenever nature is good. (iii) It might be optimal to pool with hedging and to bear the expected cost of entry. (iv) It might be optimal to hedge and to reduce the precision of the signal via appropriate contracting with the agent to avoid entry.

The remainder of the paper is organized as follows. The next section reviews related literature. Section 3 presents the details of the model. Section 4 and 5 view the moral hazard problem and the market entry problem separately. Section 6 combines the two and 7 gives some numerical examples. Section 8 summarizes the results.

2. RELATED LITERATURE

Starting with the well known Modigliani-Miller (1958) irrelevance result, there seems to be no need for a company to engage in derivative markets. With perfect markets and no transaction costs every strategy adopted by the firm could equally well be adopted by its shareholders.

Building on that ground several contributions to the literature discuss possible motives and effects of derivative trading and hedging on a firm level, allowing for different kinds of market imperfections. E.g. it has been shown by Smith and Stulz (1985) that hedging might increase shareholders’ expected welfare given convexity of the corporate tax code or bankruptcy costs to be incurred by shareholders. Froot et al (1993) assume higher costs of external compared to internal financing in combination with decreasing investment returns to give a rationale for hedging.

Other contributions presume market imperfections arising from asymmetric information. In DeMarzo and Duffie (1991) shareholders are assumed to be risk averse with firms having proprietary information with respect to their risk exposure. They show that it might be
optimal in such a setting if the firm hedges on behalf of its shareholders. Breeden and Viswanathan (1998) focus on asymmetric information w.r.t. management ability. Managers in their model care about reputation. Hedging incentives are present for high ability managers. Hedging allows these managers to reduce noise in performance measurement and to identify themselves as high ability managers. A somewhat related paper by DeMarzo and Duffie (1995), however, shows the opposite result. Contrary to Breeden and Viswanathan in their model neither the agent nor the principal is aware of the agent’s ability or type at the start of the game. First period outcome serves as a signal about the agent’s ability and affects contracting in period two. Hedging increases the precision of the signal and at the same time its relevance for the second contract. The result is an increase in the variance of the agent’s exposure to risk in period two. In such a setting it turns out be optimal for the agent to garble output rather than to hedge.

Further work that analyses hedging within a principal agent setting has been provided by Smith and Stulz (1985), Campbell and Kracaw (1987), Meth (1996), and Fischer (1999). Smith and Stulz (1985) find that hedging reduces the risk exposure of the agent and in turn the agency costs to be borne by the principal. A similar result is obtained by Campbell and Kracaw (1987) given hedging is anticipated when the contract is signed. Otherwise the manager’s opportunity to hedge might reduce effort and hurt shareholders. Additional distortions occur in their model if the extent of hedging is assumed to depend on the manager’s effort. Meth (1996) uses a two task model in which the agent’s effort either increases the mean of output or reduces output variance. He shows that variance reduction is favorable if risk aversion is high even if it is costly. Fischer (1999) allows for hedging on the individual level as opposed to the firm level only. He identifies conditions under which private hedging of the agent cannot make up for risk management on the firm level.
Another channel of contributions focuses on the effects of different accounting standards on the companies’ optimal hedging strategies. It is emphasized by Melumad et al (1999) that without hedge accounting, companies hedging choice is distorted. This economically non optimal behavior might well be avoided using appropriate hedge accounting methods. Barnes (2001) employs a signaling model with good and bad firms in the market. The hedging opportunity is confined to the good ones. He finds that mark to market accounting might motivate bad firms to speculate rather than to hedge to make themselves indistinguishable from the good firms and to increase intermediate market valuation. Hughes et al (2002) focus on the effect of additional disclosure requirements on forward contracting. They use a duopoly model in which one firm has private information and can exploit this informational advantage by taking an appropriate position in the forward market. If the forward position is publicly observed, two opposing effects occur: The informed firm gains a first mover advantage and the private information is revealed, which is detrimental for the informed firm. Hughes et al (2002) show that it is very likely that the second effect dominates the first one which implies that the informed party would prefer to take its forward position secretly.

This paper analyzes hedging within a principal agent setting that is closest to the ones used in Smith and Stulz (1985) and Campbell and Kracaw (1987). Hedging is assumed to be possible on the firm level only, it reduces noise and in turn mitigates the moral hazard problem. Given this simple setting I add a market entry problem. The hedging decision affects not only the principal’s moral hazard problem but also the strategy of a potential competitor. The problem of an adverse use of information has been mentioned in Hughes et al (2002). However, their framework differs considerably from the one employed in this paper. Even though accounting standards are not explicitly modeled in this paper, the analysis contains some implications for standard setting.
3. THE MODEL

To analyze possible implications of hedging I assume that a company faces a moral hazard problem and, at the same time, the threat of a market entry from a potential competitor. The company may or may not choose to hedge output.

The company’s owner, also called the principal in what follows, wishes to employ a manager, the agent, to run the business. The principal aims at maximizing expected output net of the manager’s expected compensation. If the potential competitor enters the market this will decrease the company’s future output.

The sequence of events is given in figure 1 below.

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Figure 1: Timeline

At the beginning of the game the principal and the agent agree upon a labor contract. This contract aims at providing the agent with appropriate incentives to work hard. However, the cost of effort $K_i$ is an important factor for contracting but is unknown to every outsider to the market. It is publicly known, however, that $K_i = k_i a^2$, $k_i$ is binary with $i = L, H$ and $0 < k_L < k_H$. The ex ante probability for $i = L$ is perceived to be $p$. Which cost function pops up depends on the conditions for doing business in the specific market. It is determined by the environment the company is acting in rather than by any specific characteristics of the agent. Favorable conditions like substantial demand, good quality of materials supplied, efficient distribution channels etc might be explanations for $i = L$. To discover what the working
conditions are like, it is necessary to enter the market in the first place and to become part of it. As the principal as well as the agent know that the information is about to come once they start the business, they agree upon a contract conditional on \( K_i \), fixing a compensation function for the agent and the hedging strategy to be carried out in both states of nature.

Having learned \( K_i \) the hedging decision is made and the agent privately performs his effort. The potential entrant does observe the hedging decision as well as the conditional contract but does not learn \( K_i \). The hedging decision is assumed to be publicly observable to reflect the comprehensive documentation required by accounting standard setters w.r.t. the firms’ hedging activities. With regard to management compensation contracts, firms are typically required to disclose the type and nature of the contract but not necessarily all details on which part of a contract becomes effective during the contracting period. In the model we limit observability to the contingent contract on that ground. Finally, the model structure allows for several information levels that are likely to occur in reality. While the manager is closest to the production process and has the most detailed information, the potential competitor, as an outsider, knows only what is publicly known. The owner/principal in some sense is in between and holds some private information.

A potential entrant needs to decide whether it is worthwhile for him to prepare for a market entry. I assume that it is necessary for him to invest an amount \( I \) beforehand to allow himself a market entry later on. This investment might e.g. include costs associated with market studies, a search for an appropriate production plant, efforts to discover possible distribution channels but also for legal fees to be paid in order to get permission for a start up.

At the end of the period both, the principal and the potential entrant, observe the gross output. The agent receives his payment. At the beginning of period two the competitor decides whether to enter the market according to the output observed, given he has invested \( I \) in the first place. The course of events repeats itself with respect to the principal-agent relationship
from that point on in the second period. However, I assume a two period model and therefore no threat of entry exists in period two. As there are very little insights to be gained from the events in period two it is not explicitly modeled.

The solution concept used is Perfect Bayesian Equilibrium (PBE). This implies that the principal chooses the contracting and hedging strategy with regard to the possible costs of effort for the agent and taking into account the inferences drawn by the potential entrant. The competitor chooses his strategy according to the contracting and hedging decision he observes as well as to the outcome and updates his beliefs about the company’s type according to Bayes rule.\(^5\)

4. THE MORAL HAZARD PROBLEM

As a benchmark I assume in a first step that there is no threat of market entry from a potential competitor and all the principal has to deal with is the moral hazard problem to be solved in the presence of a hedging opportunity.\(^6\)

The principal is assumed to be risk neutral and the manager is risk and effort averse with an exponential utility function of the following form:\(^7\)

\[
U(S, a) = - \exp[-r(S - K(a))]
\]

\(S\) denotes the agent’s compensation, \(a\) is the agent’s effort and \(K(a)\) the above-mentioned cost of effort or, equivalently, his disutility from working hard. \(r\) is the parameter of constant absolute risk aversion for the agent.

The effort performed by the agent is unobservable for the principal. However, the principal observes the output \(x\) that is given by

\[
x = a + \theta, \quad \theta \sim N(0, \sigma^j) \text{ with } j = H, NH.
\]

The index \(j\) refers to the hedging strategy chosen with \(j = H\) for hedging and \(j = NH\) for no hedging.
The principal offers a contract to the agent containing two candidate compensation functions. Which one of the two becomes relevant for both parties depends on the cost of effort level learned after they have signed the agreement. Clearly, both compensation functions depend on \( x \). I assume linear contracts:

\[
S = \begin{cases} 
    S_L(x) = S_L + s_L x & \text{if } K_L(a) \\
    S_H(x) = S_H + s_H x & \text{if } K_H(a)
\end{cases}
\]

The principal maximizes his expected net profit subject to two types of constraints.

\[
\max_{S_L, a_L, S_H, a_H} \quad pE[x(a_L, \theta) - S_L(x)] + (1 - p)E[x(a_H, \theta) - S_H(x)]
\]

s.t.

\[
\begin{align*}
E[U(S_L(x), a_L)] & \geq U(\underline{U}) \\
E[U(S_H(x), a_H)] & \geq U(\underline{U}) \\
\alpha_L & \in \arg\max_{a_L} E[U(S_L(x), a'_L)] \quad \text{for all } a'_L \\
\alpha_H & \in \arg\max_{a_H} E[U(S_H(x), a'_H)] \quad \text{for all } a'_H
\end{align*}
\]

According to the individual rationality constraints (IRC\(_i\)) the agent receives an expected utility that equals at least the utility he would get from working elsewhere. \( \underline{U} \) determines the compensation from an alternative employment. The constraints ensure that the agent is willing to sign the contract and to stay with the firm in each state of nature. The incentive compatibility constraints (ICC\(_i\)) take into account that the agent aims at maximizing his own welfare and chooses effort accordingly.

The agent’s expected utility can be expressed in terms of his certainty equivalent that is characterized by the following expression:

\[
E[U(S_i(x), a_i)] = U[S_i + s_i E(x) - K_i(a_i) - \frac{r}{2}s^2\sigma^2]
\]

Applying the first order approach to the ICCs and noting that \( E(x_i) = a_i \) the optimization problem takes the following form:

8
\[
\max_{s_L,s_H,s_L^*,s_H^*,a_L,a_H} p[a_L - (S_L + s_L a_L)] + (1-p)[a_H - (S_H + s_H a_H)]
\]

s.t.
\[
S_L + s_L a_L - K_L(a_L) - \frac{r}{2} s_L^2 \sigma^2 \geq U \quad \text{(IRC}_L')
\]
\[
S_H + s_H a_H - K_H(a_H) - \frac{r}{2} s_H^2 \sigma^2 \geq U \quad \text{(IRC}_H')
\]
\[
s_L - K'_L(a_L) = 0 \quad \text{(ICC}_L')
\]
\[
s_H - K'_H(a_H) = 0 \quad \text{(ICC}_H')
\]

As mentioned above, \( K_i(a) = k_i a^2 \) is learned by the principal and the agent before hedging takes place and before the agent performs his effort.

Independently of the business environment the company faces a hedging opportunity. The hedging instrument causes zero costs and allows to reduce the standard deviation of \( \theta \), and in turn of \( x \) from \( \sigma^{NH} \) to \( \sigma^H \) with \( \sigma^{NH} > \sigma^H \). The hedging activity is publicly observable which allows the principal to force the agent to behave according to the contract agreed upon.

The solutions to the principal’s optimization problems given a state of nature \( K_i(a_i) \) and a hedging strategy chosen are summarized in table 1 below.\(^{10}\) \( E(V^j | K_i(a_i) ) \) determines the expected profit for the principal given \( K_i(a_i) \), net of the agent’s compensation.

| \( a_i \) | \( E(V^j | K_i(a_i) ) \) |
|---|---|
| \( \frac{1}{2k_i(1 + 2r k_i (\sigma^j)^2)} \) | \( \frac{1}{4k_i(1 + 2r k_i (\sigma^j)^2)} U \) |

Table 1: Second best solution for the principal’s optimization problem.

Comparing the expressions for profit \( E(V^j | K_i(a_i) ) \) in the scenario with hedging to the one without, shows that \( E(V^H | ) \) is higher than \( E(V^{NH} | ) \) given either \( k_L \) or \( k_H \) as \( \sigma^H < \sigma^{NH} \). The
premise for this result is the assumption of a risk averse agent. The agent is exposed to a compensation risk and requires a risk premium to be paid by the principal. The hedging instrument results in a decrease of the variance of $x$. $x$ therefore becomes a more accurate signal for the agent’s effort $a$ and the risk exposure is reduced. The risk premium c.p. shrinks, a higher effort is motivated at the optimum, and the expected profit increases. This leads to proposition 1.

**Proposition 1:**

If the only problem at hand is a moral hazard problem and hedging is costless and commonly observed and the agent is risk averse, the principal strictly prefers to hedge the company’s output $x$ regardless of $K_i(a_i^j)$.

5. **THE MARKET ENTRY PROBLEM**

The potential competitor has to make two decisions in the game. First of all he has to decide whether to invest $I$ to allow himself a market entry later on. Secondly he chooses whether to enter the market given the investment has been made. I assume that a market entry results in a gain of $G > 0$, if the competitor enters the market and the market conditions are favorable, that is costs are low. If market conditions are poor, the entrant faces a loss of $-L < 0$. As $k_i$ itself is not observable for the potential entrant, he has to decide according to what he learns about nature throughout the game. If the incumbent firm separates w.r.t. hedging it is possible for the competitor to infer $K_i(a_i^j)$ from the hedging decision he observes and to invest whenever low costs, $i=L$, are present. His ex ante expected profit in a separating setting is given by

$$E(P^S) = p(-I + G).$$

Given a pooling strategy, however, he is unable to make any such inferences. His decisions have to be based on his ex ante beliefs, his observation of the contingent contract as well as
on the realization of \( x \). Holding the common ex ante beliefs about \( K_L(a^L_j), K_H(a^H_j), p \), and \((1-p)\), the expected profit from the market entry can be described as follows:

\[
E(P^j) = -I + G \cdot p \cdot \pi(x > g^j|K_L(a^L_j)) - L \cdot (1 - p) \cdot \pi(x > g^j|K_H(a^H_j)) \quad j = H, NH
\]

\(\pi(x > g^j|K_j(a^j))\) denotes the conditional probability that the competitor chooses to enter the market given \( K_L(a^L_j) \) or \( K_H(a^H_j) \) is the true cost. Whether he does so, however, depends on the value of \( x \) he observes. \( g^j \) denotes the critical value that leaves the competitor indifferent between entering the market and to choose not to. The index \( j \), again, refers to whether the output has been hedged or not: \( j = H \) or \( j = NH \).

Assuming that the company pools w.r.t. hedging, that is it either hedges in both states of nature or does never hedge, \( g^j \) is determined in Lemma 1. All proofs are in the appendix.

**Lemma 1:**

In a pooling equilibrium w.r.t. hedging it is optimal for the potential entrant to enter the market whenever

\[
x > g^j = \frac{\ln\left[\frac{L(1-p)}{Gp}\right](\sigma^j)^2}{(a^L_j - a^H_j)} + \frac{a^L_j + a^H_j}{2}.
\]

The second part of the expression above determines the intersection of the probability density functions of the output \( x \) given high and low costs, respectively. The first part can be interpreted as the distance of \( g^j \) from this intersection point. It becomes zero if \( \frac{L(1-p)}{Gp} = 1 \) and is positive (negative) if \( \frac{L(1-p)}{Gp} > 1 \) (\( < 1 \)). In what follows I restrict

\[
\frac{L(1-p)}{Gp} \in \left\{e^{\frac{-(a^L_j-a^H_j)^2}{2(\sigma^j)^2}}, e^{\frac{(a^L_j-a^H_j)^2}{2(\sigma^j)^2}}\right\} \text{ which implies } g^j \in (a^H_j, a^L_j).^{11}
\]
To give an intuition for the result from Lemma 1 it is useful to assume $p = (1-p) = 0.5$ and $L = G$ for the moment. In this setting $g^j = \frac{a_I^j + a_H^j}{2}$ which is depicted in figure 2.

Figure 2: Determination of the critical value $g$ for the potential entrant.

Figure 2 clearly shows that it is optimal for the competitor to enter whenever the $x$ observed is larger than $g^j$. Would he decide to enter somewhere to the left of $g^j$, the probability of doing the wrong thing is the dotted area plus the striped area to the left of $g^j$.

The probability of being right is equal to the dotted area, only. Assuming that ex ante expected gain from entry equals expected loss, entering to the left of $g^j$ reduces expected profits. If the competitor enters to the right of $g^j$, however, the probability of not entering though costs are low is characterized by the horizontally striped plus the dotted area. The probability to enter even though costs are high is the horizontally striped area, only. Again such behavior reduces expected profits.

If $L(1-p) \neq Gp$, the optimal $g^j$ ends up either to the left or to the right of the intersection point. If $L(1-p) > Gp$ the first part of the expression in Lemma 1 becomes positive. As the ex ante expected loss from entering the market exceeds the expected gain, c.p. a higher $x$ has to be observed to make the competitor enter the market. On the other hand, if $L(1-p) < Gp$ the
competitor is willing to enter to the left of the point, where the probability density functions equate.

Whether the agent chooses to hedge or not to hedge in a pooling situation is relevant for the competitor’s decision whether to invest $I$. This is shown in Proposition 2.

Proposition 2:

I assume for the moment that second best contracts as shown in table 1 are implemented within a pooling strategy. If the agent hedges output, the expected profit of the potential entrant increases compared to a situation with no hedging. In other words $E(P^H) > E(P^{NH})$.

The intuition for this result is as follows: Hedging c.p. reduces the standard deviation of output and at the same time increases the difference between expected outputs given low cost, $i=\text{L}$, and high costs, $i=\text{H}$, respectively. The probabilities for the potential entrant to enter, if costs are actually low and to abstain from entry if costs are high do increase. This obviously goes along with a reduced probability for “errors”, namely not to enter even though the costs are low and to enter even though costs are high. The result is an increase in expected profit from entry if the company hedges.

From the entrant’s perspective the investment is worthwhile, if and only if its expected profit is positive. In what follows I assume that in a pooling situation

$$E(P^{NH}) = -I + G \cdot p \cdot \pi(x > g^{NH} \mid K_L(a^{NH}_L)) - L \cdot (1 - p) \cdot \pi(x > g^{NH} \mid K_H(a^{NH}_H)) = 0.$$ 

If the agent does not hedge in either situation, the potential entrant abstains from investing $I$ and therefore does not enter the market. However, any minor increase of $E(P^I)$ motivates an investment of $I$. As hedging increases $E(P^I)$ this implies that, given a pooling strategy with hedging, the competitor optimally chooses to invest $I$ and to enter the market with probability

$$p\pi(x > g^H \mid K_L(a^H_L)) + (1 - p)\pi(x > g^H \mid K_H(a^H_H)) > 0.$$
Moreover, as $E(P^S) > E(P^H) > E(P^{NH})$ the competitor enters with ex ante probability $p$ given a separating strategy. The principal incurs a cost $C$ if the competitor enters.

6. COMBINING THE MORAL HAZARD AND MARKET ENTRY PROBLEM

So far the analysis has shown that hedging reduces the risk premium to be paid by a company facing a moral hazard situation. It has also shown that hedging might encourage a potential competitor to enter the market. In a separating setting hedging allows the potential entrant to infer $K_t(a)$. With pooling he is able to draw better inferences from the observation of $x$.

The first effect is welcome from the perspective of the principal while the second one harms the principal and calls for strategies to minimize a potential loss.

Two strategies are available to entirely prevent entry of the competitor: The first one is not to hedge. According to the assumption made above this will prevent entry for sure if second best contracts are offered to the agent. The second one is to hedge but to offer a menu of contracts that differs from the second best contracts assumed in Proposition 2. As shown above the competitor will enter with positive probability if and only if his expected profit does exceed $E(P^{NH})$. This result can be avoided by shifting the expected values of output. If expected outputs of the low cost and the high cost type move closer together, this weakens the effect of hedging by increasing the probability for the potential entrant to enter if costs of effort are high and reducing the probability to enter if costs of effort are low. A shift in expected outputs to be closer to one another occurs if either the low cost type reduces effort from the second best level to a lower third best level or the high cost type increases effort from the second best level to a higher third best level. Both strategies, as well as one in which both types shift expected output, allow for a sufficient reduction in expected profit to ensure that $E(P^H) \leq E(P^{NH})$. The shift in expected output, of course, is obtained by a change in the agent’s compensation contract, motivating the appropriate level of $a_i$. As the potential entrant
observes the menu of contracts offered by the principal at the beginning of the game he will optimally choose not to invest if his expected return will be less or equal to zero.\textsuperscript{12}

However, whether it is optimal at all to prevent entry of the competitor depends on the cost \( C \) to be borne by the principal if entry actually occurs. If \( C \) is sufficiently low it might be optimal for the principal to hedge and to allow entry of the competitor with positive probability. If this is the case, it might be either optimal to separate and in turn to allow entry of the competitor if the state of nature is good or to pool with hedging and to risk entry if the realized output \( x \) is sufficiently high.

The discussion above suggests that four different strategies might be favorable for the principal. To analyze the conditions for each of them to be optimal, it is convenient to introduce some additional notation.

\( E(V^{NH}) \) is defined as the principal’s expected net output in the optimum if second best contracts are offered and the agent does not hedge (NH - no hedging). The terms below have already been presented in table 1:

\[
E(V^{NH}) = p \frac{1}{4k_{l}(1+2rk_{l}(\sigma^{NH})^2)} + (1-p) \frac{1}{4k_{H}(1+2rk_{H}(\sigma^{NH})^2)} - U.
\]

\( E(V^{S}) \) defines expected profit if a separating strategy w.r.t. hedging is implemented. The separating strategy can either establish hedging in the good or in the bad state of nature. As this strategy is part of the publicly known contract with the agent, the potential entrant will be able to interpret the hedging decision correctly and enters whenever nature is good. Expected profit for the principal will be either

\[
\begin{align*}
(i) \quad E(V^{SL}) &= p \frac{1}{4k_{l}(1+2rk_{l}(\sigma^{H})^2)} + (1-p) \frac{1}{4k_{H}(1+2rk_{H}(\sigma^{NH})^2)} - U - pC \quad \text{or} \\
(ii) \quad E(V^{SH}) &= p \frac{1}{4k_{l}(1+2rk_{l}(\sigma^{NH})^2)} + (1-p) \frac{1}{4k_{H}(1+2rk_{H}(\sigma^{H})^2)} - U - pC
\end{align*}
\]
With $E(V^{SL})$ and $E(V^{SH})$ referring to expected profit ($SL$ – hedging with low costs $k_L$ and $SH$ – hedging with high costs $k_H$).

The principal will choose the separating strategy to maximize expected profit which is analyzed in Lemma 2.

**Lemma 2:**

Whether $E(V^{SL})$ or $E(V^{SH})$ is higher depends on $k_H - k_L$ and on probability $p$. We define $k_H = k_L + \Delta_2$. For every $\Delta_2$ exists a critical probability $p^c$ for which the principal is indifferent between both strategies. If $p < (> p^c$ it is favorable to hedge if nature is bad (good). The higher $\Delta_2$ the lower $p^c$. As $\Delta_2 > 0$ we always get $p^c < 0.5$.

Note that with separating it is always optimal for the principal to offer second best contracts to the agent. As the potential entrant decides about entry according to the hedging decision observed, it is impossible for the principal to affect the ex ante probability of entry via contracting. It is therefore optimal to stick to second best contracts inducing the optimal effort choice of the agent.

If the principal pools with hedging and allows for entry with positive probability, I denote his expected profit $E(V^{H-E})$. If he ensures via appropriate contracting that there is no incentive for the competitor to invest, expected profit is $E(V^{H-NE})$. For both strategies, however, it is impossible to obtain closed form solutions to the respective optimization problems. To make up for this shortcoming I present the optimization problem and analyze the effects of its specific properties on optimal contracting. Second best contracts serve as a benchmark.

If the principal maximizes $E(V^{H-E})$ he faces the following problem:
\[
\max_{s_L, s_H, t_L, t_H, a_L, a_H} p[a_L - (s_L + s_L a_L)] + (1 - p)[a_H - (s_H + s_H a_H)] \\
-C(p(x > g^H | K_L(a_L))) + (1 - p)\pi(x > g^H | K_H(a_H))
\]

s.t.
\[
\begin{align*}
S_L + s_L a_L - K_L(a_L) - \frac{r}{2} s_L^2 (\sigma^H)^2 & \geq U & \text{(IRC}_L') \\
S_H + s_H a_H - K_H(a_H) - \frac{r}{2} s_H^2 (\sigma^H)^2 & \geq U & \text{(IRC}_H') \\
s_L - K'_L(a_L) & = 0 & \text{(ICCL}_L') \\
s_H - K'_H(a_H) & = 0 & \text{(ICCH}_H')
\end{align*}
\]

Note that \(g^H\) as determined in Lemma 1 is a function of \(a_L\) and \(a_H\). The principal pursues two goals when choosing the parameters of the compensation contract. On the one hand he aims at motivating appropriate effort, on the other hand he wishes to keep the ex ante probability of the competitor to enter low. The effect on optimal contracting, in other words on the effort \(a_i\) motivated, however, can be determined only for some special cases as presented in Lemma 3.

**Lemma 3:**

(i) If \(\frac{L(1-p)}{Gp} \neq 1\) it is ambiguous whether the ex ante probability for entry increases or decreases when \(\Delta_1 = a_L - a_H\) increases or decreases, respectively.

(ii) If \(\frac{L(1-p)}{Gp} = 1\) and \(p < (>) 0.5\) the ex ante probability for entry decreases if \(\Delta_1\) increases (decreases). At the optimum \(\Delta_1\) will be increased (decreased) compared to the second best solution without a threat of competition.

(iii) If \(\frac{L(1-p)}{Gp} = 1\) and \(p = (1-p) = 0.5\) the ex ante probability for entry is a constant of 0.5. As the principal is unable to influence the expected loss from entry via contracting it is optimal to offer second best contracts.
Finally, if the principal wishes to avoid entry of the competitor for sure even though he hedges output, that is he maximizes $E(V^{H,NE})$, he faces the following optimization problem:

$$\max_{s_L, s_H, a_L, a_H} p[a_L - (S_L + s_L a_L)] + (1 - p)[a_H - (S_H + s_H a_H)]$$

s.t.

$$S_L + s_L a_L - K_L(a_L) - \frac{r}{2} s_L^2 (\sigma^H)^2 \geq U$$  \hspace{1cm} (IRC$_L'$)

$$S_H + s_H a_H - K_H(a_H) - \frac{r}{2} s_H^2 (\sigma^H)^2 \geq U$$  \hspace{1cm} (IRC$_H'$)

$$s_L - K^*_L(a_L) = 0$$  \hspace{1cm} (ICC$_L'$)

$$s_H - K^*_H(a_H) = 0$$  \hspace{1cm} (ICC$_H'$)

$$pG\pi(x > g^{NH} | K_L(a_L^{NH})) - (1 - p)L\pi(x > g^{NH} | K_H(a_H^{NH})) \geq 0$$  \hspace{1cm} (NEC)

Compared to the optimization problem without a threat of competition an additional constraint needs to be added that I call the no-entry-condition NEC. This condition ensures that expected profit for the potential entrant in a hedging situation does not exceed the one obtained without hedging. As we have assumed that it is optimal for the competitor not to enter without hedging, this constraint ensures that he stays out of the market for sure in this setting as well. Adding the condition results in a reduced value for $\Lambda_1 = a_L - a_H$. If expected values of output move closer together the probability for the potential entrant to enter if nature is good is reduced and at the same time the risk to enter if nature is bad is increased given $g^H$ is chosen optimally. Both effects lead to a reduction in expected profit and will avoid entry if the threshold is reached. For the principal this comes at the cost of motivating effort levels which are non optimal w.r.t. the moral hazard problem.
**Proposition 3:**

Given the agent as well as the potential entrant behave as utility maximizers each of the following strategies of the principal might be optimal:

(i) The principal offers second best contracts and the agent does not hedge. Optimal if: \( E(V^{NH}) \geq \max\{E(V^{H-E}), E(V^{H-NE}), E(V^{S})\} \)

(ii) The principal offers second best contracts and the agent separates w.r.t. hedging. Optimal if: \( E(V^{S}) \geq \max\{E(V^{NH}), E(V^{H-E}), E(V^{H-NE})\} \)

(iii) The principal offers third best contracts leading to a market entry with positive probability and the agent pools with hedging. Optimal if: \( E(V^{H-E}) \geq \max\{E(V^{H-NE}), E(V^{S}), E(V^{H-E})\} \)

(iv) The principal offers third best contracts avoiding a market entry for sure and the agent does hedge. Optimal if: \( E(V^{H-NE}) \geq \max\{E(V^{NH}), E(V^{S}), E(V^{H-E})\} \)

For some special cases it can be shown that pooling with hedging dominates separating. Sufficient conditions are stated in Lemma 4.

**Lemma 4:**

If \( p = 0.5 \) and \( L \geq G \) strategy (iii) dominates strategy (ii) and the principal always prefers to pool and to risk a market entry with positive probability rather than to separate.

The intuition for this result is as follows. As described above the principal aims at paying a low risk premium to the agent and at keeping the ex ante probability for market entry low. With respect to the first aspect, pooling is beneficial compared to separating as hedging takes place in both states of nature. For the second aspect it can be shown that the ex ante probability of entry with pooling is lower than with separating if \( p = 0.5 \) and if and only if \( L \geq \ldots \)
G. In that case pooling is favorable w.r.t. both aspects and dominates separating. If \( L < G \), however, the ex ante probability for entry with pooling exceeds the one with separating and it is ambiguous which strategy is favorable.

7. NUMERICAL ANALYSIS

In what follows an example is given for each of the strategies identified above. The examples point out the effects of hedging on the agent’s effort and confirm the results stated above.

For all four numerical examples I do assume that

\[
E(P^{NH}) = 0,
\]

\[ k_L = \frac{1}{2} \text{ and } k_H = 1, \quad p = 0.15, \quad G = 12,000, \quad L = 1,000, \quad \sigma^{NH} = 4,000 \text{ and } \sigma^H = 2,000. \]

The functional form of the output has been changed to \( x = 100a + \theta \) rather than \( x = a + \theta \). This has been done to obtain more friendly numbers and does not affect the structure of the results.

\( U \) is set to zero. The examples differ from each other with respect to the assumption of the agent’s risk aversion and with respect to \( C \).

The results from the calculations are shown in tables 2-5.

<table>
<thead>
<tr>
<th>( r = 0.0000005; \ C = 40 )</th>
<th>( NH )</th>
<th>( S )</th>
<th>( H-E )</th>
<th>( H-NE )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E(V) )</td>
<td>2,871.01</td>
<td>2,867.55</td>
<td>2,862.65</td>
<td>2,830.92</td>
</tr>
<tr>
<td>( a_L )</td>
<td>99.92</td>
<td>99.92</td>
<td>100.40</td>
<td>77.01</td>
</tr>
<tr>
<td>( a_H )</td>
<td>49.92</td>
<td>49.98</td>
<td>49.94</td>
<td>52.01</td>
</tr>
<tr>
<td>( \pi(x &gt; g; K_L(a)) )</td>
<td>0.8898</td>
<td>-</td>
<td>0.9405</td>
<td>0.8898</td>
</tr>
<tr>
<td>( \pi(x &gt; g; K_H(a)) )</td>
<td>0.4901</td>
<td>-</td>
<td>0.1675</td>
<td>0.4901</td>
</tr>
</tbody>
</table>

Table 2: Results for example 1.

Given a relatively low risk aversion for the agent of \( r = 0.0000005 \) and a cost to the principal if the competitor enters if \( C = 40 \), the expected profit for the principal \( E(V) \) is maximized if no
hedging takes place in either state of nature. Optimal efforts are given with roughly 100 in the
good and 50 in the bad state of nature. As the parameter $k_i$ doubles in the bad state the optimal
effort to be motivated is considerably lower than in the good state.

$$r = 0.0000005; \ C = 10$$

<table>
<thead>
<tr>
<th></th>
<th>$NH$</th>
<th>$S$</th>
<th>$H-E$</th>
<th>$H-NE$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E(V)$</td>
<td>2,871.01</td>
<td><strong>2,872.05</strong></td>
<td>2,871.15</td>
<td>2,830.92</td>
</tr>
<tr>
<td>$a_L$</td>
<td>99.92</td>
<td>99.92</td>
<td>100.38</td>
<td>77.01</td>
</tr>
<tr>
<td>$a_H$</td>
<td>49.92</td>
<td>49.98</td>
<td>49.94</td>
<td>52.01</td>
</tr>
<tr>
<td>$\pi(x &gt; g</td>
<td>K_L(a))$</td>
<td>0.8898</td>
<td>-</td>
<td>0.9404</td>
</tr>
<tr>
<td>$\pi(x &gt; g</td>
<td>K_H(a))$</td>
<td>0.4901</td>
<td>-</td>
<td>0.1676</td>
</tr>
</tbody>
</table>

Table 3: Results for example 2.

Compared to example 1 the only number that has been changed is $C$, which is 10 by now.
While this reduction does not affect the results from strategies that avoid entry of the
competitor for sure ($NH$ and $H-NE$), a reduction in $C$ increases expected profit with separating
as well as with hedging and entry. In this setting separating with hedging in the bad state of
nature turns out to be the optimal strategy. The competitor enters whenever the state of nature
is good. The ex ante probability for entry is $p = 0.15$. Compared to pooling with hedging this
is considerably low as we get an ex ante probability for entry of

$$0.15 \cdot 0.9404 + 0.85 \cdot 0.1676 = 0.2835$$

The reduced risk of entry makes up for the additional
risk premium to be paid if nature is good and no hedging takes place. Compared to $NH$ the
risk premium is reduced in the bad state of nature which occurs with $(1-p) = 0.85$. The
reduction in risk premium is higher than the expected cost to be born due to market entry of
the competitor and separating is favorable.
Table 4: Results for example 3.

In example 3 the assumed degree of risk aversity has been increased compared to the examples above. As a result hedging becomes more worthwhile as it reduces the compensation risk of the agent. Given the low costs of entry of \( C = 10 \) it turns out to be optimal from the principal’s perspective to pool with hedging and to allow entry of the competitor with positive probability.

Table 5: Results for example 4.

If the costs of entry are increased, however, as in example 4, the best strategy turns out to be \( H-NE \). Reducing \( a_L \) and increasing \( a_H \) beyond second best levels in this setting ensures that it becomes detrimental for the potential entrant to invest \( I \). This is obvious from comparing the conditional probability with \( NH \) to \( H-NE \). Apparently both are identical which ensures that \( E(P^{NH}) = E(P^{H-NE}) \).
8. CONCLUSIONS

This paper analyzes the effects of hedging in a principal agent setting with a potential competitor. Hedging turns out to alleviate the moral hazard problem faced by the principal but at the same time aggravates the market entry problem.

Whether it is optimal for the principal to hedge depends on whether the benefits from hedging exceed the costs. Benefits occur from a reduction in the agent’s risk premium due to hedging and a higher effort motivated at the optimum. Costs occur either from market entry or from offering third best contracts to avoid entry. Ceteris paribus hedging is more beneficial for the principal the higher the agent’s degree of risk aversion. Whether a company chooses to prevent or to accept entry with hedging depends on the entry costs \( C \). Trading off benefits and costs, it might be optimal to pool with or without hedging or to separate w.r.t. hedging.

Given these results it turns out that for companies it is most important to consider their own position in the market when fixing a hedging strategy. From an outside observers view it should be clear that there is a rationale for corporate decisions to hedge as well as not to hedge, for separating as well as pooling. Finally, standard setters may be aware of the fact that comprehensive disclosure requirements w.r.t. hedging may not only increase competition but also distort production decisions.
Proof of Lemma 1:
The competitor chooses \( g' \) as to maximize his expected profit from market entry:
\[
\max_{g'} E(P^j) = -I + G \cdot p \cdot \pi(x > g')|K_L(a_L)) - L \cdot (1 - p) \cdot \pi(x > g')|K_H(a_H))
\]
The optimization problems with hedging and without hedging, are structurally identical.
Therefore a general solution is derived for \( \sigma^j \).
\[
\pi(x > g'|K_L(a)) = \int_{g'}^{\infty} \frac{1}{\sqrt{2\pi\sigma^j}} \cdot e^{-\frac{(u-a_j)^2}{2\sigma^j}} du = \int_{g'}^{\infty} f(u)du
\]
\[
\pi(x > g'|K_H(a)) = \int_{g'}^{\infty} \frac{1}{\sqrt{2\pi\sigma^j}} \cdot e^{-\frac{(u-a_j)^2}{2\sigma^j}} du = \int_{g'}^{\infty} h(u)du
\]
\[
E(P^j) = -I + G \cdot p \cdot \int_{g'}^{\infty} f(u)du - L \cdot (1 - p) \cdot \int_{g'}^{\infty} h(u)du
\]
\[
= -I + G \cdot p \cdot [1 - F(g^j)] - L \cdot (1 - p) \cdot [1 - H(g^j)]
\]
\[
= -I + G \cdot p - G \cdot p F(g^j) - L \cdot (1 - p) + L \cdot (1 - p) \cdot H(g^j)
\]
\[
\frac{\delta E(P^j)}{\delta g^j} = -G \cdot p \cdot \frac{1}{\sqrt{2\pi\sigma^j}} \cdot e^{-\frac{(g^j-a_j)^2}{2\sigma^j}} + L \cdot (1 - p) \cdot \frac{1}{\sqrt{2\pi\sigma^j}} \cdot e^{-\frac{(g^j-a_j)^2}{2\sigma^j}} = 0
\]
\[
\Leftrightarrow L \cdot (1 - p) \cdot \frac{1}{\sqrt{2\pi\sigma^j}} \cdot e^{-\frac{(g^j-a_j)^2}{2\sigma^j}} = G \cdot p \cdot \frac{1}{\sqrt{2\pi\sigma^j}} \cdot e^{-\frac{(g^j-a_j)^2}{2\sigma^j}}
\]
\[
\Leftrightarrow \frac{L \cdot (1 - p)}{G \cdot p} = e^{-\frac{(g^j-a_j)^2}{2\sigma^j}}
\]
\[
\Leftrightarrow \frac{L \cdot (1 - p)}{G \cdot p} = e^{\frac{-a_j^2 + 2g^j(a_j^j - a_L^j) + a_L^j}{2\sigma^j}}
\]
\[
\Leftrightarrow g^j = \frac{\ln[L \cdot (1 - p)] \cdot \sigma^j}{G \cdot p} + \frac{a_L^j + a_H^j}{2}
\]
Proof of Proposition 2:

It needs to be shown that \( E(P^H) > E(P^{NH}) \) is true given

\[
\frac{L(1-p)}{Gp} \in (e^{-\frac{(a^H_l-a^H_H)^2}{2(\sigma')^2}}, e^{-\frac{(a_l^L-a_H^L)^2}{2(\sigma')^2}}).
\]

Writing down the complete expression we get:

\[
- I + G \cdot p \cdot \pi(x > g^H \mid K_l(a^H_l)) - L \cdot (1-p) \cdot \pi(x > g^H \mid K_H(a^H_H)) > \\
> - I + G \cdot p \cdot \pi(x > g^{NH} \mid K_l(a^{NH}_l)) - L \cdot (1-p) \cdot \pi(x > g^{NH} \mid K_H(a^{NH}_H))
\]

From the proof of Lemma 1 we know that this is equivalent to:

\[
G \cdot p \cdot [1 - F(g^H)] - L \cdot (1-p) \cdot [1 - H(g^H)] > G \cdot p \cdot [1 - F(g^{NH})] - L \cdot (1-p) \cdot [1 - H(g^{NH})] \quad (A1)
\]

To prove A1 we need to show that

\[
F(g^{NH}) > F(g^H) \quad \text{and} \quad H(g^{NH}) < H(g^H) \quad (A2)
\]

are true statements.

I proceed in three steps

(i) I show that \( a^L - a^H \) increases as \( \sigma \) decreases.

(ii) I show that A2 is fulfilled if \( \bar{g} \) is chosen rather than the optimal \( g^H \).

(iii) I argue that given (ii) A2 has to be true for \( g^H \) as well.

(i) In section IV I obtained the following optimal values for \( a^L_l \) and \( a^H_H \):

\[
a^L_l = \frac{1}{2k_L (1 + 2r_k L \sigma'^2)} \quad \text{and} \quad a^H_H = \frac{1}{2k_H (1 + 2r_k H \sigma'^2)}
\]

Define \( \Delta_l = a^H_l - a^L_l \)

\[
\Delta_l = \frac{1}{2k_L (1 + 2r_k L \sigma'^2)} - \frac{1}{2k_H (1 + 2r_k H \sigma'^2)}
\]

\[
\frac{\delta \Delta_l}{\delta \sigma'} = -\frac{8(k_H - k_L)r^2 \sigma'^3 (1 + k_H r \sigma'^2 + k_L r \sigma'^2)}{(1 + 2k_H r \sigma'^2)^2 (1 + 2k_L r \sigma'^2)^2} < 0 \quad (A3)
\]

As \( \sigma'^H < \sigma'^{NH} \) it follows that \( a^H_l - a^H_H > a^L_l - a^H_H \). The expected output difference increases with hedging and c.p. the overlapping area of the density functions becomes smaller.
(ii) Let us define 
\[
\bar{g} = \frac{\ln\left[ \frac{L(1-p)}{Gp} \right] (\sigma_{NH}^2)}{a_{L}^{NH} - a_{H}^{NH}} + \frac{a_{L}^{H} + a_{H}^{H}}{2}.
\]
\(\bar{g}\) determines a threshold value to enter in a hedging setting and is characterized by the same distance to the intersection point as \(g^{NH}\).

Combined with (i) \(F(g^{NH}) > F(\bar{g})\) and \(H(g^{NH}) < H(\bar{g})\) follows from the following general properties of normal distributions:

If \(X \sim N(\mu_x, \sigma_x)\) and \(Y \sim N(\mu_y, \sigma_y)\), for \(\mu_x - \mu_y \geq \sigma_x - \sigma_y\) and \(\mu_x > \mu_y\) and \(\sigma_x < \sigma_y\) then \(F(x) < F(y)\).

If \(X \sim N(\mu_x, \sigma_x)\) and \(Y \sim N(\mu_y, \sigma_y)\), for \(x - \mu_x \geq y - \mu_y\) and \(x > \mu_x\) and \(y > \mu_y\) and \(\sigma_x < \sigma_y\) then \(F(x) > F(y)\).

As \(a_{L}^{H} - a_{H}^{H}\) increases with hedging and the distance of \(\bar{g}\) to the intersection point equals the one of \(g^{NH}\), we get \((a_{L}^{H} - \bar{g}) > (a_{L}^{NH} - g^{NH})\) and \((\bar{g} - a_{H}^{H}) > (g^{NH} - a_{H}^{NH})\).

It follows that \(1-F(\bar{g}) > 1-F(g^{NH})\) and \(1-H(\bar{g}) < 1-H(g^{NH})\). Therefore A1 is fulfilled for a threshold value \(\bar{g}\) rather than \(g^{H}\).

(iii) However, as \(g^{H}\) is the result of an optimization process it has to be true that 
\[
E(P^H | g^{H}) \geq E(P^H | \bar{g})
\]
and therefore A2 must be fulfilled as well.

This completes the proof. \(\Box\)

Proof of Lemma 2:

For separating to be more favorable with hedging in the good state of nature than in the bad state of nature we need \(E(V^{SL}) > E(V^{SH})\)

\[
\Leftrightarrow p \left( \frac{1}{4k_L(1 + 2r k_L(\sigma^H)^2)} + (1-p) \frac{1}{4k_H(1 + 2r k_H(\sigma^NH)^2)} \right) > \frac{1}{4k_L(1 + 2r k_L(\sigma^H)^2)} + (1-p) \frac{1}{4k_H(1 + 2r k_H(\sigma^H)^2)}
\]

calculating a critical value by equating the left and right hand side and solving for \(p\) I get:

\[
p^c = \frac{(1 + 2k_L r(\sigma^H)^2)(1 + 2k_L r(\sigma^NH)^2)}{2[1 + r(\sigma^H)^2(k_H + k_L)] + r(\sigma^NH)^2(k_H + k_L) + 2r^2(\sigma^NH)^2(\sigma^H)^2(k_H^2 + k_L^2)]}
\]

(A4)

Defining \(k_H = k_L + \Delta_2\) A4 can be rewritten:
\[ p^c = \frac{(1 + 2k_L r(\sigma^H)^2)(1 + 2k_L r(\sigma^{NH})^2)}{2[(1 + 2k_L r(\sigma^H)^2)(1 + 2k_L r(\sigma^{NH})^2) + \Delta_2 r((\sigma^{NH})^2 + (\sigma^H)^2)(1 + 2(\Delta_2 + k_L) r(\sigma^{NH}))]} \]

The first terms of the denominator are equal to those in the numerator. If \( \Delta_2 = 0 \) the latter part in the denominator vanishes and \( p^c = 0.5 \). Whenever \( \Delta_2 > 0 \), \( p^c < 0.5 \) and decreases in \( \Delta_2 \).

Proof of Lemma 3:

To analyze how the threat of competition affects \( a_L^H \) and \( a_H^H \) compared to second best, it is sufficient to focus solely on the (new) last term of the objective function in the H-E-setting (p.14):

Define \( \eta \equiv p\pi(x > g^H|K_L(a_L^H)) + (1 - p)\pi(x > g^H|K_H(a_H^H)) \)

From Lemma 1 we know this is equal to: \( \eta \equiv p(1 - F(g^H)) + (1 - p)(1 - H(g^H)) \) \hspace{1cm} (A5)

Defining \( F(g^H) \equiv \phi\left(\frac{g^H - a_L^H}{\sigma^H}\right) \) and \( H(g^H) \equiv \phi\left(\frac{g^H - a_H^H}{\sigma^H}\right) \)

and inserting the expressions obtained for \( g^H \) in Lemma 1 we get for A5:

\[ \eta = p(1 - \phi\left(\frac{Gp}{a_L^H - a_H^H} + \frac{a_H^H - a_L^H}{2\sigma^H}\right)) + (1 - p)(1 - \phi\left(\frac{Gp}{a_H^H - a_L^H} + \frac{a_L^H - a_H^H}{2\sigma^H}\right)) \] \hspace{1cm} (A6)

As \( \phi(\cdot) \) is a strictly monotonic increasing function some inferences about the direction of change of \( \phi(\cdot) \) can be drawn from analyzing the arguments of \( \phi(\cdot) \).

\[ \eta \equiv p(1 - \phi(\kappa)) + (1 - p)(1 - \phi(\nu)) \]

As in Proposition 2 I use \( \Delta_1 = a_L^H - a_H^H \) and get

\[ \kappa(\Delta_1) = \frac{\ln\left(\frac{L(1 - p)}{Gp}\right)\sigma^H}{\Delta_1} - \frac{\Delta_1}{2\sigma^H} \quad \text{and} \quad \nu(\Delta_1) = \frac{\ln\left(\frac{L(1 - p)}{Gp}\right)\sigma^H}{\Delta_1} + \frac{\Delta_1}{2\sigma^H} \]

Taking the first derivatives for both expressions above gives

\[ \frac{\delta\kappa(\Delta_1)}{\delta\Delta_1} = -\frac{\ln\left(\frac{L(1 - p)}{Gp}\right)\sigma^H}{\Delta_1^2} - \frac{1}{2\sigma^H} \quad \text{and} \quad \frac{\delta\nu(\Delta_1)}{\delta\Delta_1} = -\frac{\ln\left(\frac{L(1 - p)}{Gp}\right)\sigma^H}{\Delta_1^2} + \frac{1}{2\sigma^H} \] \hspace{1cm} (A7)

(i) \( \frac{L(1 - p)}{Gp} \neq 1 \)
(a) If \( \frac{L(1-p)}{Gp} > 1 \): 
\[ \frac{\delta \kappa(\Delta_1)}{\delta \Delta_1} < 0 \] and \( \frac{\delta \nu(\Delta_1)}{\delta \Delta_1} > 0 \)

To show that the latter inequality is true note that we assumed earlier that \( \frac{L(1-p)}{Gp} < \exp(\frac{(a^H - a^H)^2}{2(\sigma^H)^2}) \). \( \frac{\delta \nu(\Delta_1)}{\delta \Delta_1} \) takes on the lowest value if \( \frac{L(1-p)}{Gp} \) is maximized.

Inserting \( \exp(\frac{(a^H - a^H)^2}{2(\sigma^H)^2}) \) for \( \frac{L(1-p)}{Gp} \) we get:

\[ \frac{\delta \nu(\Delta_1)}{\delta \Delta_1} = -\frac{1}{2\sigma} + \frac{1}{2\sigma} = 0. \] Inserting a number smaller than \( \exp(\frac{(a^H - a^H)^2}{2(\sigma^H)^2}) \) obviously leads to \( \frac{\delta \nu(\Delta_1)}{\delta \Delta_1} > 0. \)

It follows that if \( (a^H - a^H) \) increases the probability for entry if nature is good increases and the probability for entry decreases if nature is bad. The overall effect is ambiguous.

(b) If: \( \frac{L(1-p)}{Gp} < 1 \) 
\[ \frac{\delta \kappa(\Delta_1)}{\delta \Delta_1} < 0 \] and \( \frac{\delta \nu(\Delta_1)}{\delta \Delta_1} > 0 \)

the first inequality follows directly from (A7). The second one can be shown analogously to (a). It follows that if \( (a^H - a^H) \) increases the probability for entry if nature is good increases and the probability for entry decreases if nature is bad. The overall effect again is ambiguous.

(ii) If \( \frac{L(1-p)}{Gp} = 1 \) A6 reduces to

\[ \eta' = p(1 - \phi(\frac{a^H - a^H}{2\sigma^H})) + (1 - p)(1 - \phi(\frac{a^H - a^H}{2\sigma^H})) \]

rearranging terms and inserting \( \Delta_1 \) for \( a^H - a^H \) we obtain

\[ \eta' = \phi(\frac{\Delta_1}{2\sigma})(2p - 1) + (1 - p) \] \hspace{1cm} (A7)

If \( p > ( <) \) 0.5 the second term in brackets in A7 becomes positive (negative) and \( \eta' \) decreases as \( \Delta_1 \) decreases (increases).

(iii) If \( \frac{L(1-p)}{Gp} = 1 \) and \( p = (1-p) = 0.5 \) inserting into A7 leads to a constant value of \( \eta' = 0.5 \).
Proof of Lemma 4:

If $p = 0.5$ the ex ante probability for market entry of the competitor given strategy (iii) is as follows:

$$\eta'' = 0.5(1 - \phi\left(\frac{\ln\left(\frac{L}{G}\right)\sigma^H}{(a^H_L - a^H_H)}\right) - \frac{\Delta_l}{2\sigma^H}) + 0.5(1 - \phi\left(\frac{\ln\left(\frac{L}{G}\right)\sigma^H}{(a^H_L - a^H_H)}\right) + \frac{\Delta_l}{2\sigma^H})$$

From Lemma 3 (iii) we know that for $L = G$ $\eta' = \eta'' = 0.5$

As $\phi(\cdot)$ is a increasing monotonic function it follows that

$\eta'' < 0.5$ if $L > G$ and $\eta'' > 0.5$ if $L < G$.

(i) If the principal chooses a separating strategy, the ex ante probability for the competitor to enter the market equals $p = 0.5$. Therefore if $L > G$ the ex ante probability for entry to occur is lower with pooling than with separating. Moreover, with pooling a lower expected risk premium has to be paid than with separating. As both effects are in favor of pooling, pooling dominates separating.

(ii) If $L < G$ the ex ante probability of entry with pooling is higher than with separating. As the risk premium remains lower with pooling either separating or pooling may be beneficial in this setting.

$\square$
NOTES

1 This assumption (implicitly) implies that the manager cannot diversify his compensation risk e.g. via private hedging. In other words the hedging instrument available to the firm is not available to the manager as a single individual. One can think of several reasons for such a situation to occur in imperfect markets. One might be that the hedging instrument is not standardized and therefore is not traded in a regular stock exchange.

2 The contract is assumed to be binding for the principal. The agent, however, is assumed to be free to leave the company at any time sacrificing his compensation.

3 Crucially to the model, we assume that the information on the effort function \( K_f \) is contractible, that is verifiable by a third party like a court, but at the same time is not publicly observable. An example for such an information could be an order book that provides proof regarding demand and that can be handed over to a court but is not accessible for the public.

4 See e.g. IAS 32.43A and SFAS 133.44-45.

5 For a formal definition of PBE see Fudenburg/Tirole (1992), pp. 325, 326.

6 A comprehensive disquisition on the principal-agent model provides Laffont/Martimort (2002).

7 The model type employed here is well known in the literature as the LEN-Model. For a detailed description see e.g. Spremann (1987) or Holmström/Milgrom (1991).

8 At this point the optimization problem could equally well be treated as two separate problems each containing a single IRC and ICC. However, this is no longer feasible in latter sections. To keep comparisons easy I start with the above representation.

9 This is a simplifying assumption. It is obvious that hedging will never be beneficial if transaction costs are extremely high. However, results that identify hedging as detrimental only due to transaction costs appear to provide very limited insights and are therefore not considered.

10 Solutions for \( S_i \) and \( S_f \) are omitted as they are of no relevance for the forthcoming analysis.

11 This assumption increases mathematical tractability without affecting the results qualitatively.

12 Note that the principal-agent relationship is crucial for this result. The principal signs a publicly observed contract that induces the agent to perform an ex post sub-optimal effort. Appropriate contracting ensures that the agent’s action becomes credible. In other words, delegating the job to the agent allows the principal to commit to a certain behavior. If, in contrast, the effort were performed by the principal himself, there is no way to make credible a third best effort. Moreover, in equilibrium the potential entrant would optimally invest whenever he observes hedging.

13 An example for either strategy (i)-(iv) being optimal is given in the following section so a formal proof is omitted.
REFERENCES


