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Innovation, endogenous overinvestment, and incentive pay

Roman Inderst*

and

Manuel Klein**

We analyze how two key managerial tasks interact: that of growing the business through creating new investment opportunities and that of providing accurate information about these opportunities in the corporate budgeting process. We show how this interaction endogenously biases managers toward overinvesting in their own projects. This bias is exacerbated if managers compete for limited resources in an internal capital market, which provides us with a novel theory of the boundaries of the firm. Finally, managers of more risky and less profitable divisions should obtain steeper incentives to facilitate efficient investment decisions.

1. Introduction

■ That managers are excessively "hungry for capital" is a common notion found among both practitioners and scholars working on the capital budgeting process. (See, for instance, "Curing Capital Addiction," *The McKinsey Quarterly*, 1993 Number 4.) We show how managers who are expected to generate new growth opportunities will become *endogenously* biased toward overinvesting in their own projects. The source of this distortion is that managers are expected to both generate new projects and to, subsequently, feed information into the corporate budgeting process.

The tension between the two tasks creates a dilemma for corporations. The more managers are incentivized to grow their business, the more they become biased toward overspending. Reducing this bias by dampening incentives may be too costly for businesses that crucially depend on innovation and growth.[1] As illustrated in Jensen (2003), the inefficiencies caused by "lying" in the capital budgeting process may, however, also be substantial. Our analysis shows

* University of Frankfurt; inderst@finance.uni-frankfurt.de.
** INSEAD; manuel.klein@insead.edu.
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[1] A recent study by Accenture, the consulting firm, reports that nearly 60% of firm value in the aggregate U.S. stock market can be attributed to shareholders' expectations of sustained growth (cf. "Future Value: The $7 Trillion Challenge," *Accenture Outlook 2004*, Number 1.).

that the use of high-powered incentives may be key to mitigating this tension—in particular in corporations where multiple divisions must compete for limited resources.

In our model, the role of high-powered incentives is not to tease out incrementally more effort. Instead, their purpose is to reduce corporate overspending. The argument unfolds as follows. The division manager will only work hard at generating new investment opportunities if this increases his expected compensation. Once a new opportunity has been created, however, the "reward" that he was promised for growing the business makes the manager want to undertake even some unprofitable investments. The optimal compensation scheme seeks to minimize this bias. By tying the manager's compensation more closely to the division's profits, the manager has less to gain from convincing headquarters to invest in a relatively unpromising opportunity. As steep incentives also allow the manager to receive a larger share of the profits from a very promising investment, the total reward that he can expect from working on new investment opportunities remains unchanged. Hence, while preserving the manager's incentives to grow the business, steep incentive schemes reduce the potential for (over)investing in negative net present value (NPV) projects.

Some of our predictions link the steepness of managers' compensation to firm characteristics and investment decisions. We find that incentives should be steeper in divisions that require more capital injection, in divisions that look less promising to headquarters, and also in divisions that are *more* risky.[2]

If managers compete for scarce resources, this increases the tension between providing incentives to generate new investment opportunities and providing incentives to reveal accurate information about their profitability. If this is still feasible, the optimal response is then to further tighten the link between managers' pay and divisions' performance. The insight that competition in an internal capital market can lead to more biased information is shared with Ozbas (2005). This complements the analysis of Stein (2002), Brusco and Panunzi (2005), and Inderst and Laux (2005), who show how competition can adversely affect the incentives to generate information, cash flow, or investment opportunities. We also analyze the decision of when to create competition in an internal capital market, including through the integration of previously stand-alone businesses. Here, one of our results is that on average more investment is made in an internal capital market, although some of it may prove to be less profitable than the investment made in comparable stand-alone businesses.

The analysis of competition is also a key difference to a related paper by Levitt and Snyder (1997), which we discuss in more detail below. There, an agent can both increase a project's likelihood of success and provide information that may allow to prematurely cancel unprofitable projects.[3]

The way we endogenize managers' bias toward overinvesting in their own projects may also prove useful in different strands of the literature. That managers derive benefits from building larger empires is a central notion of numerous theories of corporate control and financial contracting that build on Jensen's (1986) free cash flow problem. Here, our approach provides an alternative to the use of nonpecuniary benefits.

The rest of this article is organized as follows. Section 2 introduces the model. Section 3 analyzes the case where divisions do not compete for scarce resources, and Sections 4 and 5 introduce competition. Section 6 concludes.

[2] These are also businesses that, according to our theory, should show more overinvestment. Below we compare these predictions to those arising from other models of capital budgeting along the lines of seminal papers by Harris, Kriebel, and Raviv (1982) or Harris and Raviv (1996), where capital allocations next to incentive schemes serve as screening devices.

[3] Theirs and our articles, as well as Friebel and Raith (2006), which directly builds on Levitt and Snyder (1997), are also related to the literature on "expert advice." In this strand of the literature, Gromb and Martimort (2004) is possibly the closest paper. There, an expert must be incentivated both to produce information and to subsequently advise the principal on which action to take. They focus on optimal organizational responses such as the use of one or two experts. In addition, Bernardo, Cai, and Luo (2006) build on the double-task problem of Levitt and Snyder (1997) to analyze how a manager's total incentive compensation is optimally balanced across different (low- and high-quality) projects.

2. The model

■ **The firm and its investment opportunities.** We consider a firm that is run by headquarters in the interest of its risk-neutral owners. The firm must employ (specialized) division managers to run its individual businesses. There are three time periods: $t = 0$, 1, and 2. In $t = 0$, headquarters hires division managers. Once hired, managers can exert effort to generate new investment opportunities. Although the decision whether to undertake a new project lies with headquarters, when generating the project the respective division manager becomes better informed about its prospects. Hence, a division manager will have to perform the twin tasks of creating new investment opportunities in $t = 0$ and of subsequently guiding headquarters' investment decision in $t = 1$. In the final period, $t = 2$, payoffs are realized. We first analyze the case where divisions do not compete with each other. Section 4 considers the opposite case where only one project can be undertaken at a given time, which may follow as (organizational or financial) resources are scarce or as projects are close substitutes.

Division managers' effort in $t = 0$ involves private disutility $c > 0$. If headquarters wants to realize the generated new investment opportunity, it must invest capital $k > 0$.[4] We normalize the return from alternative investments to zero. If undertaken, the new project realizes positive cash flows of $x > k$ with probability $0 < p \leq 1$ if it is of the "good type" $\theta = g$, which *a priori* is the case with probability $0 < q < 1$. In this case, the expected cash flow equals $\mu := xp > k$. If the project has a "bad type" $\theta = b$, it realizes zero cash flows. After generating the project, in $t = 1$ only the respective manager can observe a noisy signal about the project's type. The signal $s \in S = [\underline{s}, \bar{s}]$ is generated from the distribution functions $F_\theta(s)$, which has no atoms and an everywhere continuous and strictly positive density $f_\theta(s)$. Because $f_g(s)/f_b(s)$ is strictly increasing and satisfies the monotone likelihood ratio property, the posterior belief that the project is of the good type,

$$q(s) := \frac{qf_g(s)}{qf_g(s) + (1-q)f_b(s)},$$

is strictly increasing in s. We denote the conditional success probability by $p(s) := q(s)p$ and the conditional expected cash flow by $\mu(s) := xp(s)$. We assume that $\mu(\underline{s}) < k < \mu(\bar{s})$, implying that there exists a unique cutoff $s_{FB} \in (\underline{s}, \bar{s})$ that satisfies $\mu(s_{FB}) = k$.[5] Hence, it is first-best efficient to undertake the investment only if $s \geq s_{FB}$. Finally, it will prove convenient to work with the *ex ante* distribution over signals, $G(s)$, which is defined by its density $g(s) := qf_g(s) + (1-q)f_b(s)$.

□ **Contracting.** The manager's alternative to working for the firm has value $R > 0$. It turns out that without affecting results, we can suppose that a division's value with a new investment is also equal to R.[6]

Besides satisfying the participation constraint, the contract must incentivize managers to both create new investment opportunities and to assist headquarters in making a more informed investment decision. As we stipulate that the generation of a new project is itself not verifiable, these two tasks cannot be perfectly disentangled.[7] If a division's new project is undertaken and funds k are invested, the manager's pay can, however, be made contingent on the project's success. Precisely, in this case the manager receives a base wage α and, in case of success, a bonus β. We require that $\alpha \geq \underline{\alpha}$, to which we simply refer as the "base-wage constraint." For $\underline{\alpha} = 0$, the

[4] The analysis can be extended to the case where a new opportunity arises only with some probability.

[5] For instance, this holds if the signal is perfectly informative at the boundaries of S, that is, if $f_g(\underline{s}) = f_b(\bar{s}) = 0$ and thus $\mu(\underline{s}) = 0$ and $\mu(\bar{s}) = px$.

[6] If profits were below R, the manager would optimally be fired, in which case he also realizes his reservation value R. If profits were above R, say equal to P, the manager would still be employed. The only difference this would make in the following equations is that without a new project, the firm would then realize $P - R$ instead of zero. This has, however, no qualitative impact on any of our results.

[7] This assumption is also made, for instance, in Rotemberg and Saloner (1994). Arguably, outsiders would find it hard to separate realistic new ideas from either old projects or fake proposals.

latter represents a standard limited-liability constraint. Finally, if no new investment was made, the manager only receives a wage equal to R.

□ **Discussion of contracts.** In the rest of this section, we bring out and discuss two restrictions on the set of feasible contracts.[8]

Assumption 1. In case no new investment opportunity is realized in a given division, the respective manager's wage is equal to R.

Assumption 1 has two parts. The first part stipulates that the manager must not receive *less* than R in case no new investment opportunity is realized. As we show below, this will also imply that the manager's expected compensation is never below R if a new investment is made. This part of Assumption 1 is quite standard and follows if the manager cannot be forced to continue working for the firm ("non-slavery" condition). In our analysis this part of Assumption 1 will, however, not be restrictive.

The second part of Assumption 1 stipulates that the manager must not receive more than his reservation value R if no new investment is made. Also, this assumption is, in different variations, frequently invoked in the financial contracting literature. If a manager was paid more than R, then even those managers who know that they are not even capable of growing the business could earn strictly more than their reservation value. As argued in the financial contracting literature, the firm would then risk being flooded by applications from such "imposters" (or, "fly-by-night" operators).[9] However, we show below that our key insights still hold even if such contracts are feasible.

Assumption 2. Mechanisms where the contract (α, β) is made contingent on some message sent by managers in $t = 1$ are not feasible.

Although Assumption 2 will not be restrictive if divisions do not compete, we show that with competition, such contingent contracts may become optimal. However, they force the firm to trade off between different types of inefficiencies. As we show below, some of our insights will thus be robust to relaxing Assumption 2. Furthermore, Assumption 2 follows some of the recent literature on organization, where communication between managers and their superiors is supposed to be too "soft" to make contracts contingent upon it.

3. The case without competition

■ **The optimal compensation scheme.** In the absence of competition, the manager's expected wage if a project is implemented is $w(s) := \alpha + \beta p(s)$. Although it is straightforward to rule out $\beta < 0$, note that with $\beta = 0$ the manager would either have no incentives to generate a project or, otherwise, he would always want his new project to be undertaken. To ensure both that a project is generated and that the manager does not always want to undertake his project, it is thus necessary that $\beta > 0$. This implies that the conditional expected wage $w(s)$ is strictly increasing in s. If, following the recommendation of the manager, the project is sometimes but not always undertaken, we thus have a cutoff $s^* \in (\underline{s}, \bar{s})$ satisfying

$$w(s^*) = R, \tag{1}$$

such that the project will only be undertaken if $s \geq s^*$.

As shirking only yields R, which coincides with the manager's payoff if a new investment opportunity was generated but not undertaken, the manager will only exert effort in case

[8] Note that we also consider only deterministic mechanisms. As already argued in Levitt and Snyder (1997), stochastic mechanisms, as well as the possibility to arbitrarily scale down projects in our case, would allow to implement the first best without leaving managers with rents.

[9] Formally, if the pool of applicants that is attracted by some rent $z > 0$ has a fraction γ of such "imposters," then holding all else constant, $z = 0$ is uniquely optimal if γ is sufficiently large.

$$\int_{s^*}^{\bar{s}} [w(s) - R]g(s)\,ds \geq c. \tag{2}$$

In order to satisfy the incentive constraint (2), there must be a sufficiently large wedge between the manager's expected compensation if a project is undertaken and his reservation value R. If the manager received a fixed reward $B > R$ for an implemented project, then the manager would *always* recommend that his project be undertaken. By paying him a bonus only if the project succeeds, his incentives become better aligned with those of the firm. Formally, by increasing β and reducing α, the manager's conditional expected compensation $w(s)$ becomes steeper, which reduces his bias toward investment at lower signals.

Headquarters' problem is then to maximize its *ex ante* payoff

$$\int_{s^*}^{\bar{s}} [R + \mu(s) - k - w(s)]g(s)\,ds$$

subject to incentive constraint (2), the constraint that s^* solves (1), and that $\alpha \geq \underline{\alpha}$.[10] By standard arguments, the incentive constraint will be binding such that, after substitution, headquarters' objective function becomes

$$\int_{s^*}^{\bar{s}} [\mu(s) - k]g(s)\,ds - c.$$

Headquarters as the residual claimant thus has the objective to choose a contract (α, β) that makes subsequent investments as efficient as possible. To solve formally for the optimal compensation, note first that from $w(s^*) = R$ and as (2) binds from optimality, we have that

$$\begin{aligned} \beta &= \frac{c}{\int_{s^*}^{\bar{s}} [p(s) - p(s^*)]g(s)\,ds}, \\ \alpha &= R - \beta p(s^*). \end{aligned} \tag{3}$$

If it is possible to achieve the first best, then substituting $s^* = s_{FB}$ into (3) and using that the project's *ex ante* surplus equals

$$\pi_{FB} := \int_{s_{FB}}^{\bar{s}} [xp(s) - k]g(s)\,ds,$$

we have that

$$\begin{aligned} \frac{\beta}{x} &= \frac{c}{\pi_{FB}}, \\ \alpha &= R - k\frac{c}{\pi_{FB}}. \end{aligned} \tag{4}$$

The characterization in (4) is intuitive. Recall first that the manager does not generate a positive rent. To achieve the first-best decision, the manager's own tradeoff between undertaking the project and not must then exactly mirror the respective tradeoff of the firm. This is the case if the ratio of his bonus β to the project's payoff in case of success x is equal to the ratio of his own expected payoff c (over and above his reservation value R) to the project's expected payoff π_{FB}. (Note that at this point the manager's costs of effort are already sunk.)

If α as determined in (4) is not feasible as it would imply that $\alpha < \underline{\alpha}$, then it is optimal to set α as low as possible with $\alpha = \underline{\alpha}$. From the binding incentive constraint (2), we then have that the equilibrium cutoff $s^* < s_{FB}$ now solves

$$\int_{s^*}^{\bar{s}} \left[\frac{p(s)}{p(s^*)} - 1\right] g(s)\,ds = \frac{c}{R - \underline{\alpha}}. \tag{5}$$

[10] Recall that the division's expected payoff equals $R + \mu(s)$ with and just R without a new project.

As long as $c/(R - \underline{\alpha})$ is not too large,[11] (5) has a unique interior solution. (Note that the left-hand side is strictly decreasing and continuous in s^*.) In this case, where the project is implemented too often, the bonus β is then simply obtained from substituting the respective equilibrium cutoff s^* back into (3). We next summarize our results.

Proposition 1. There is a unique optimal compensation contract, which prescribes a bonus $\beta > 0$ and a base wage $\alpha < R$. If the first best is achieved, which from (4) holds if

$$c \leq (R - \underline{\alpha}) \frac{\pi_{FB}}{k}, \tag{6}$$

then the unique optimal contract is characterized by (4). Otherwise, we have $s^* < s_{FB}$, while the base wage is reduced to $\alpha = \underline{\alpha}$.

One of the key insights from Proposition 1 is that overinvestment, which occurs if $s^* < s_{FB}$, can arise endogenously if the manager must also be compensated for generating new investment opportunities in the first place. If this is feasible at all, then the efficient investment rule can only be implemented if the manager is put on a sufficiently steep incentive scheme in exchange for receiving capital k.

□ **Comparative analysis.** In this section, we use Proposition 1 to derive implications for the optimal incentive contract and the efficiency of the capital allocation process.

Investment opportunities requiring more or less capital. As an increase in k reduces the value of the investment opportunity, the first-best cutoff s_{FB} decreases. Unless the firm adjusts the compensation, however, the manager's privately optimal decision rule remains unchanged. To ensure that the manager "internalizes" that the project has become more costly for the firm, headquarters must put him on steeper incentives.

Proposition 2. If a division's investment opportunity requires more funding, the manager is put on a steeper incentive scheme by increasing β and reducing α. If this is not possible as already $\alpha = \underline{\alpha}$, then the decision becomes increasingly distorted as $s_{FB} - s^* > 0$ increases.

Proof. If the first best is feasible before and after the shift, we have from (4) that $d\beta/dk = xc[1 - G(s_{FB})]/(\pi_{FB})^2$ and $d\alpha/dk = -c[\pi_{FB} + k[1 - G(s_{FB})]]/(\pi_{FB})^2$. In case the first best is not feasible before and after the shift, we have from (5) that s^* is not affected, implying from (3) that the same holds for α and β. In the final case, where $s^* = s_{FB}$ holds before and $s^* < s_{FB}$ after the increase in k, we have from the previous arguments that α decreases until $\alpha = \underline{\alpha}$ and that β increases according to (3). *Q.E.D.*

Some models in the capital budgeting literature use incremental adjustments of the budget to screen managers with *ex ante* private information. There, however, managers typically derive some exogenously assumed private benefits from receiving more capital. Similar to Proposition 2, these papers also predict that steeper incentives should go together with more funding (cf Bernardo, Cai, and Luo, 2001). Although there larger investments also have a higher internal rate of return, this is not the case in Proposition 2, where we only consider a variation in k while leaving the project's cash flows unchanged. Finally, Proposition 2 implies that even if managers have no exogenous preference for more capital, overinvestment is more likely the higher the required capital.

Investment opportunities that have higher or lower cash flows. Investment opportunities may have higher expected cash flows as they are either more likely to succeed or as their cash flow in case of success is higher. It turns out that comparing investment opportunities along these two dimensions generates similar implications, albeit the underlying logic is somewhat different.

In analogy to an increase in k, a decrease in the cash flow x raises the first-best cutoff s_{FB}. Headquarters should then optimally shift more of the manager's compensation from the base wage into the bonus and thereby ensure that s^* increases as well.

[11] Formally, we need that $\underline{\alpha} < R - \frac{c}{\int_{\underline{s}}^{\bar{s}} [\frac{p(s)}{p(\underline{S})} - 1] g(s)\, ds}$.

In contrast to an exogenous change in k or x, a reduction in the success probability p directly affects the manager's payoff, as he is less likely to earn a bonus. Although raising either α or β would restore incentive compatibility, doing so without further pushing down s^* requires once more to make the compensation steeper.[12] The same result holds if prior beliefs about the project's possible type, as represented by q, deteriorate.

Proposition 3. Suppose that a division's investment prospects are less promising as the cash flow in case of success, x, is lower. Then the optimal incentive scheme becomes steeper if α can still be adjusted downward, whereas otherwise the investment decision becomes more distorted. Likewise, if it is less likely that the project will succeed as either p or q decreases, then optimally β increases and α decreases as long as this is still feasible.

Proof. See the Appendix.

Under the optimal contract that is set up in $t = 0$, in $t = 1$ headquarters will only grant capital to divisions that were *ex ante* less promising if the respective manager accepts a steeper incentive scheme. In contrast, in models where capital allocation is used as a sorting device, managers with projects having a higher marginal return receive steeper incentives, although there the comparative analysis is with respect to information that is only privately observed by the manager.[13]

Investment opportunities that are more or less risky. We next compare divisions that have more or less risky investment prospects. We model the difference in riskiness by considering a mean-preserving spread such that, while the cash flow x in case of success increases, the probability of success p decreases. Suppose first that the first best is feasible. As the first-best surplus π_{FB} is unaffected, we have directly from (4) that α remains constant while β strictly increases. Likewise, if the first best is not feasible, we have $\alpha = \underline{\alpha}$ while β is chosen just sufficiently large so as to ensure that the incentive constraint still holds.[14] We thus have the following result.

Proposition 4. If a division's investment opportunity is more risky, then the manager is optimally put on a steeper incentive scheme.

Prendergast (2002) surveys a range of studies that show that there is at best a "tenuous" tradeoff between risk and incentives.[15] According to our theory, the purpose of incentive pay is to induce more efficient decision making by better aligning the preferences of the division manager with that of the firm. Intuitively, to ensure such an alignment, managers must accept a higher risk in their own pay as their projects become more risky.[16]

Tendency to overinvest. If the first best cannot be achieved, then there is a strictly positive probability that an investment will be made even though its NPV, conditional on all available information, is negative.[17] As noted in the Introduction, that managers have a propensity to overinvest is a common assumption in the corporate finance literature. In our model,

[12] The difference in the arguments for variations in k or x and variations in p also shows up in the fact that if the first best cannot be obtained, then β only increases strictly if the deterioration is with respect to p.

[13] We are not aware of evidence that relates division managers' incentives to divisions' profitability and growth. To our knowledge, empirical studies along these lines have only been conducted for firms' top management. As Core, Guay, and Larcker (2003) conclude, even at the CEO level there seems, however, to be no consensus on the relationship between incentives and performance.

[14] Incidentally, also in this case s^* does not change, which can be seen formally as all ratios $p(s)/p(s^*)$ remain constant in (5).

[15] According to Prendergast (2002), incentive pay should increase in more volatile environments where direct control of the agent's actions is more difficult. The importance of control is also emphasized in Wulf (2005). Zabojnik (1996) and Marino and Zabojnik (2004) provide alternative explanations.

[16] This observation comes, however, with the caveat that in our model, managers are risk neutral. We would expect that introducing risk aversion should exert a countervailing force to Proposition 4.

[17] A similar implication was derived by Boot, Milbourn, and Thakor (2005) in a model where managers distort information because of career concerns.

overinvestment arises endogenously from compensation schemes that induce managers to grow their business. This finding is also notably different from models where capital allocation, next to incentive contracts, is used as a sorting device. In these models, there will be underinvestment for all but the most profitable projects, in order to reduce informational rents. However, as we show in Section 4, both under- and overinvestment can arise in our model if there is competition between divisions.

□ **Relaxing the contractual assumptions.** By Assumption 1, managers do not earn more than their reservation value R in case no project is either generated or implemented. To analyze how results change if we relax this assumption, recall first that contracts cannot distinguish between whether no project was generated at all or whether a newly generated project was ultimately not funded. Consequently, if in this case the manager realizes a payoff of $R + z$, his incentive constraint becomes

$$\int_{s^*}^{\bar{s}} [w(s) - R - z] g(s)\, ds \geq c. \tag{7}$$

As $z > 0$ represents a rent that is left to the manager, the firm will optimally set $z = 0$ whenever the resulting inefficiency $s^* < s_{FB}$ is not too large. Otherwise, by choosing $z > 0$, the firm can implement a more efficient decision rule. This holds true despite the fact that the manager's compensation must increase so as to still satisfy the incentive constraint with $z > 0$. Intuitively, as only the bonus increases, the difference $w(s) - (R + z)$ increases for high s but decreases for relatively low s, thereby pushing down s^*.

Notwithstanding, we can show that even for $z > 0$, our key insights continue to hold. If the project requires more capital and if already $z > 0$, then the firm will optimally react to the increase in $s_{FB} - s^*$ by choosing a still higher z, which necessitates an increase in β so as to satisfy the incentive constraint. The same argument holds for a reduction in the expected payoff of a good project px, as in Proposition 3, and an increase in risk, as in Proposition 4. Finally, the proof of Proposition 5 also shows that paying less than R, even if this were possible, would not be optimal.

Proposition 5. Choosing $z > 0$ is only optimal if, otherwise, the distortion $s_{FB} - s^* > 0$ is sufficiently large. The optimal contract then still specifies a strictly higher β (next to $\alpha = \underline{\alpha}$) if the investment opportunity requires more funding, if it becomes less profitable as p or x decreases, or if it becomes more risky.

Proof. See the Appendix.

The logic for why paying $z > 0$ can be optimal follows the analysis in Levitt and Snyder (1997). There, an agent can both increase a project's likelihood of success and provide information that may allow to prematurely cancel unprofitable projects. Given that, in the language of our model, the manager's market wage R is equal to $\underline{\alpha}$ in their model, without setting $z > 0$ it is not possible to elicit information.

If it is feasible and also optimal to choose $z > 0$, then following some exogenous change, say in the required funding k, both parts of the contract change, namely the compensation if a new project is implemented, (α, β), and the compensation if no new project is implemented, z. As we know that $\alpha = \underline{\alpha}$ remains unchanged in case we have $z > 0$, the comparison is then restricted to variations in β and z. Proposition 5 extends our previous analysis by looking only at changes in the bonus β. However, as now $R + z$ provides the manager with another floor for his compensation, one could argue that the steepness of the compensation scheme is measured by the difference between β and $R + z$. We can show that our results also hold if we apply this measure.

Corollary 1. Under the conditions of Proposition 5, as β increases so does the difference between β and $R + z$.

Proof. See the Appendix.

We finally consider Assumption 2, which turns out not to be restrictive if divisions do not compete. Any finer partition of information than that where headquarters only knows whether $s \geq s^*$ or $s < s^*$ is of no additional value to headquarters. On the other hand, we can show that eliciting such additional information by way of offering separating contracts to "types" $s \geq s^*$ is costly, as it tends to exacerbate the overinvestment problem (cf also Section 4).

Proposition 6. In the current case, where we can treat each division in isolation as divisions are not in competition with each other, Assumption 2 is not restrictive.

Proof. See the Appendix.

4. The case with competition

■ **Analysis.** We now suppose that in case each of the two divisions generates a new investment opportunity, the firm will only realize one of them. This could be the case as the firm may have only limited organizational or financial resources or as the marginal benefits from undertaking a second project may be too small. We will endogenize this aspect of our model in Section 5.

Optimal compensation schemes for competing divisions. As in the case without competition, it is privately optimal for the manager of division i to propose his project if the observed signal s_i satisfies $w_i(s_i) \geq R$. As we show in the proof of Proposition 8, the optimal contracts will be symmetric, which implies also that the respective cutoffs will be symmetric. To avoid confusion, we denote the cutoff with competition by s_C^*, whereas from now on we refer to the cutoff under *no* competition as s_N^*. If both managers want to pursue their investment opportunity because $s \geq s_C^*$, we stipulate that the firm randomizes with equal probability. Taking this into account, we show in the proof of Proposition 8 that the incentive compatibility constraint becomes

$$\frac{1}{2}\left[1 + G\left(s_C^*\right)\right] \int_{s_C^*}^{\bar{s}} [w(s) - R] g(s)\, ds \geq c. \tag{8}$$

Because competition reduces the likelihood with which an investment opportunity will be realized, which in (8) shows up as $\frac{1}{2}[1 + G(s_C^*)] < 1$, each manager's expected reward must increase, which further biases him toward a lower cutoff. If the firm still wanted to implement the efficient cutoff s_{FB}, then the manager's compensation would have to become steeper under competition. Moreover, this tendency toward steeper incentives under competition is now further exacerbated as the firm's *optimal* cutoff exceeds s_{FB}.

To see why this is the case, we first write out the firm's objective function, which after substituting the two managers' binding incentive constraints (8), becomes

$$\left[1 + G\left(s_C^*\right)\right] \int_{s_C^*}^{\bar{s}} [\mu(s) - k] g(s)\, ds - 2c. \tag{9}$$

Ignoring the first term $1 + G(s_C^*)$, we are back to the case without competition, where the *ex ante* optimal choice was $s_N^* = s_{FB}$ such that $\mu(s_N^*) - k = 0$. With competition, however, a marginal increase of s_C^* at $s_C^* = s_{FB}$ now has two effects.

First, some projects that have positive conditional expected value are no longer undertaken, although at $s_C^* = s_{FB}$ the marginal effect from this is not of first-order importance. Second, as headquarters does not know whether a manager who proposes a new investment has observed some intermediate signal or a truly high signal, choosing one project over the other always runs the risk of actually choosing the less profitable one. Raising s_C^* above s_{FB} reduces this second type of inefficiency. Differentiating (9), the *ex ante* optimal cutoff under competition, which we denote by s_C^{**}, solves

$$\mu\left(s_C^{**}\right) - k = \frac{\int_{s_C^{**}}^{\bar{s}} [\mu(s) - k] g(s)\, ds}{1 + G\left(s_C^{**}\right)}. \tag{10}$$

To avoid confusion, in what follows we also refer to the optimal cutoff with *no* competition by $s_N^{**} = s_{FB}$.

Proposition 7 summarizes our results on the optimal compensation scheme. We relegate a full characterization to the proof in the Appendix.

Proposition 7. With competition, the unique optimal incentive scheme is strictly steeper compared to the case without competition.

Proof. See the Appendix.

Proposition 7 suggests that competition for scarce resources and the provision of potentially steep monetary incentives may be complementary. This result crucially hinges on the role of incentive pay in our model, which is to ensure more efficient decision making. Recent research on internal capital markets suggests that competition and monetary incentives can, however, become substitutes if headquarters is perfectly informed (cf Inderst and Laux, 2005). Intuitively, if managers have (exogenously given) preferences for receiving capital and if headquarters is perfectly informed, then "winner-picking" may already provide high incentives for managers, which in turn may allow to economize on (costly) monetary incentives. It seems an interesting—and ultimately empirical—challenge to determine whether competition and monetary incentives interact more like substitutes or like complements.

Investment policy with competing divisions. By the previous arguments, we know that if the base-wage constraint does not bind under competition, then from $s_C^{**} > s_N^{**}$ the optimal investment threshold is higher. Otherwise, there may be even more overinvestment with $s_C^{*} < s_N^{*} < s_N^{**}$.

Corollary 2. The sets of projects that will be implemented with and without competition, that is, the respective ranges $s \in [s_C^*, \bar{s}]$ and $s \in [s_N^*, \bar{s}]$, compare as follows.

(i) If, without competition, there is overinvestment, then the overinvestment problem is even more severe under competition as $s_C^* < s_N^*$.
(ii) However, if the base-wage constraint is sufficiently slack such that the firm can implement its optimal cutoff under competition, then the opposite result holds with $s_C^* > s_N^*$.

Proof. See the Appendix.

In case (i) of Corollary 2, competition between divisions exacerbates an overinvestment problem, making it harder for headquarters to ensure that funds flow only to projects generating a positive NPV. Corollary 2, although describing the two possible cases, is silent about when, depending on the model's primitives, either one or the other is more likely to arise. Intuitively, we are more likely to be in case (i), where competition exacerbates an overinvestment problem, if the optimal contract requires to make incentives still steeper. To formalize this intuition, we consider a change in c.

Corollary 3. All else equal, investment policies with and without competition compare as follows as the cost of effort c changes. There is a threshold $\bar{c} > 0$ such that for all $c < \bar{c}$ the cutoff is strictly higher under competition, whereas for all $c > \bar{c}$ the cutoff is strictly lower under competition.

Proof. See the Appendix.

□ **Message-contingent incentive pay (Assumption 2).** It is useful to recall first that under competition there are two types of (additional) inefficiencies. First, if the flexibility to provide steeper incentives is exhausted, there will be more overinvestment as $s_C^* < s_N^* \leq s_{FB}$. Second, as a manager's recommendation to undertake his project only reveals that $s \geq s_C^*$, headquarters may end up choosing the less profitable project. By choosing message-contingent contracts and thereby obtaining a finer partition of the information, headquarters may be able to mitigate or even overcome the second type of inefficiency. We explore this issue in the rest of this section.

Our first insight is that unless α can be further reduced, eliciting more information is costly as it increases the first type of inefficiency by further pushing down the cutoff s_C^*. The intuition for this result is the following. To ensure that also intermediate "types" $s \geq s_C^*$ provide a truthful message, the message-contingent contracts (α_s, β_s) must become less attractive at higher s. This shifts some of the expected compensation away from higher s, which is just the opposite of what is required to push down s_C^* while still eliciting effort. As a consequence, pooling through the use of noncontingent pay may still be optimal.

To formalize these arguments, we deviate from our more general model with a continuum of signals, allowing, for the time being, for only three possible signals $s \in S = \{s_1, s_2, s_3\}$.[18] We can now explicitly characterize and compare all feasible contracts, inducing more or less information revelation. We stipulate that $\mu(s_1) < k < \mu(s_2) < \mu(s_3)$, implying that $s_{FB} = s_2$.

Lemma 1. There exists an intermediate range of values c where it is possible to implement $s_C^* = s_2$ under a single pooling contract but not with two separating contracts for s_2 and s_3.

Proof. See the Appendix.

For the comparison in Lemma 1, we have *assumed* that after the mechanism reveals s to headquarters, then headquarters indeed follows the division's advice and undertakes the investment. A common assumption in the theory of capital budgeting is that headquarters can, however, not commit to doing so, in which case we have the following result.[19]

Lemma 2. If the surplus from investing at $s_2, \mu(s_2) - k > 0$, is sufficiently small, then implementing a cutoff $s_C^* = s_2$ while achieving separation between s_2 and s_3 may not be possible if headquarters cannot commit to invest for signal s_2. Formally, in this case, the range of intermediate values c for which $s_C^* = s_2$ is possible under a pooling contract but not under separating contracts increases (compared to Lemma 1).

Proof. See the Appendix.

One of our insights in Section 4 was that in order to reduce the risk of choosing the less profitable project, headquarters wanted to raise s_C^* strictly above the first-best cutoff, provided that this was still feasible. Formally, this argument relied on the fact that the first-order "loss" from a marginal increase in s_C^* at $s_C^* = s_{FB}$ was zero given that $\mu(s_{FB}) - k = 0$. Without a continuum of types, to still obtain overinvestment as an equilibrium outcome we thus clearly need that the surplus $\mu(s_2) - k > 0$ is not too large. The following is the key result of this section.[20]

Proposition 8. Suppose that the surplus from investing at $s_2, \mu(s_2) - k > 0$, is sufficiently small. Then as we increase c, either one of the following two cases applies.

(i) Here, for very low c up to some cutoff $c_1 > 0$, the first-best investment policy is feasible. Then, for $c_1 < c \leq c_2$ we have underinvestment as the optimal contract implements $s_C^* = s_3$. Next, for $c_2 < c \leq c_3$ we have $s_C^* = s_2$ under a single pooling contract, whereas finally we have for all $c > c_3$ overinvestment as $s_C^* = s_1$.

(ii) Here, in contrast to case (i), we have for all $c_1 < c \leq c_2$ underinvestment with $s_C^* = s_3$, whereas for all $c > c_2$ we have overinvestment with $s_C^* = s_1$.

[18] As we now restrict consideration to symmetric mechanisms and thus no longer index observed signals by the division's number i, this (ab)use of our previous notation should not give rise to confusion. With a continuum of signals, the resulting (nonstandard) optimal control problem did not allow us to obtain an explicit characterization of the optimal contracts or an identification of the ranges over which there is pooling or separation of types.

[19] Although the separating mechanism prescribes different contracts *if* the investment is undertaken, the manager cannot force headquarters to undertake an investment by announcing a signal $s \geq s_2$.

[20] Cases (i) and (ii) in Proposition 8 differ only in one aspect, namely whether for an intermediate range of values c we have that $s_C^* = s_2$ when moving from under- to overinvestment. It should be noted also that with a continuum of signals s both cases can arise given that, in contrast to s_N^*, s_C^* need not be continuous in c.

Proof. See the Appendix.

□ **Above-market wages (Assumption 1).** Suppose now that we relax Assumption 1. We now impose symmetry on contracts such that each manager then receives the compensation $R + z$ if his division does not receive new funds.[21] Again, z is then equal to a manager's *ex ante* rent, implying that $z = 0$ is still uniquely optimal either if $s_C^* = s_C^{**}$ or if the inefficiency is not too large. What is, however, less obvious is that once we allow for $z > 0$ both with and without competition, then incentives are still steeper in the former case.

Proposition 9. If we relax Assumption 1 such that the firm can pay a manager whose division obtains no new financing a wage $R + z$, then Proposition 8 continues to hold. That is, also in this case incentives are still steeper with competing divisions.

Proof. See the Appendix.

As we show in the proof of Proposition 9, if we denote the optimal values by β_C and z_C and by β_N and z_N, respectively, then it also holds that $\beta_C - z_C > \beta_N - z_N$. Hence, in analogy to Corollary 1, the compensation also becomes steeper if we look alternatively at the difference between the bonus and the compensation without a realized investment.

It should be noted that provided the other division receives funding, in our model there are no benefits from linking the compensation of the first manager, that is, z, to the cash flow of the other division. Clearly, this could be different if managers' signals were correlated or if their efforts to generate projects were complementary. However, Proposition 9 still ignores one additional degree of flexibility, namely to make z contingent on whether the other division obtained financing or not.[22] Imposing symmetry again, we could then stipulate that a manager who does not receive funding is compensated with $R + z_a$ if the other division does not receive funding either, and with $R + z_b$ if the other division receives funding. We analyze this possibility in the rest of this section.

In this case, if a manager does not request funding, his expected payoff equals

$$R + G\big(s_C^*\big)z_a + \big[1 - G\big(s_C^*\big)\big]z_b, \tag{11}$$

where now s_C^* is the (symmetric) cutoff that is applied by the *other* manager. At $s = s_C^*$, after having generated a project, a manager's expected payoff when requesting funding equals

$$w\big(s_C^*\big)\frac{1 + G\big(s_C^*\big)}{2} + (R + z_b)\frac{1 - G\big(s_C^*\big)}{2}, \tag{12}$$

where we used that the project is only funded with probability one half if both projects request funding. Equating (11) and (12), the new cutoff s_C^* is now determined by

$$w\big(s_C^*\big) = R + \frac{2G\big(s_C^*\big)}{1 + G\big(s_C^*\big)}z_a + \frac{1 - G\big(s_C^*\big)}{1 + G\big(s_C^*\big)}z_b. \tag{13}$$

It follows immediately from our previous arguments that the higher z_a or z_b, the higher the cutoff s_C^* that can be implemented.[23] The drawback of setting $z_a > 0$ or $z_b > 0$ is again that this leaves each manager with a positive rent equal to expression (11). Consequently, the firm's objective function becomes

$$\big[1 + G\big(s_C^*\big)\big]\int_{s_C^*}^{\bar{s}}[\mu(s) - k]g(s)\,ds - 2c - 2\big[G\big(s_C^*\big)z_a + \big[1 - G\big(s_C^*\big)\big]z_b\big]. \tag{14}$$

[21] As before, it is intuitive that paying less than R would not be optimal even if this were feasible (cf the proof of Proposition 8).

[22] We thank one of the referees for drawing our attention to this possibility.

[23] To avoid confusion, we should note, however, that for this conclusion it is not necessary that the right-hand side of (13) is monotonic in s_C^*. See also the proof of Proposition 9.

As we show in the proof of Proposition 10, when comparing the marginal costs of an increase in either z_a and z_b as derived from (14) with the marginal benefits, namely to push up s_C^* according to (13), we find that it is uniquely optimal to set $z_a > 0$ but $z_b = 0$. The intuition for this is straightforward. In order to push up s_C^*, the firm wants to reward the manager for not requesting funds. In contrast, $z_b > 0$ would also be paid to a manager who requested funds but did not obtain them as they were invested instead in the other division.

Importantly, Proposition 9 (and thereby Proposition 7) still holds once we allow for the more flexible choice of $z_a > 0$ and $z_b = 0$. In fact, as this makes it effectively cheaper to push up s_C^*, we find that the difference between s_C^* and s_N^* and thus also between β_C and β_N becomes still larger.[24]

Proposition 10. If we relax Assumption 1 and allow the firm, in addition, to make the payment of z contingent on whether the other division receives financing or not, then the payment is optimally made only if neither of the divisions receives funding. Furthermore, Proposition 8 continues to hold. That is, also in this case, incentives are still steeper with competing divisions.

Proof. See the Appendix.

5. When is competition optimal?

■ **Competition among mutually exclusive projects.** The firm may choose to let more than one manager or division work on a similar business problem, thereby increasing the overall chance of success, albeit at higher costs (namely, to incur c twice). As a benchmark, if effort and the signal were both verifiable, then putting two managers on the same problem would only be profitable if[25]

$$B_1 := \int_{s_{FB}}^{\bar{s}} [\mu(s) - k][2G(s)g(s)]ds - \int_{s_{FB}}^{\bar{s}} [\mu(s) - k]g(s)\,ds \geq c, \tag{15}$$

where we use that in this case always the most profitable project is undertaken by optimality. Without verifiability, however, creating competition is only profitable if

$$B_2 := \left[1 + G\left(s_C^*\right)\right] \int_{s_C^*}^{\bar{s}} [\mu(s) - k]g(s)\,ds - \int_{s_N^*}^{\bar{s}} [\mu(s) - k]g(s)\,ds \geq c, \tag{16}$$

where we now use the respective cutoffs s_N^* and s_C^*. The benefits from competition are now lower for two reasons. First, as headquarters only knows whether the respective signal was above or below the implemented cutoff, if two projects are proposed, it may end up choosing the less profitable one. Second, as we have seen in the previous section, competition may increase an existing overinvestment problem.

In fact, the second problem may now weigh in so strongly that, even when ignoring the additional costs c, creating competition may be inferior. This holds, in particular, in the extreme case where the overinvestment problem is so severe that s_C^* is no longer interior. What makes this more likely under competition is the following "vicious cycle." We know that to implement a cutoff s_C^*, managers need to receive a higher (expected) reward than without competition. Unless headquarters can provide steeper incentives, this leads to more overinvestment. However, if the cutoff drops for one manager, then this reduces the likelihood that the other division's project will be chosen, which requires a further increase in the other manager's reward and so on. If, as a consequence of this, it is no longer possible to achieve $s_C^* > \underline{s}$, then headquarters

[24] Setting $z_a > 0$ and $z_b = 0$ may, however, generate new problems. As is shown in the proof of Proposition 10, if a manager observably deviates and shirks, then the other manager will optimally raise his cutoff, which in turn makes it now more likely that the first manager will receive $z_a > 0$. Consequently, in this case one manager would want to shirk. Sometimes, even without observability, the Pareto-dominant equilibrium may also be that where at least one manager shirks.

[25] We use that $\Pr[\max(s_1, s_2) \leq s] = G^2(s)$.

must choose between two projects that, from its perspective, have the same expected value of $\int_{\underline{s}}^{\bar{s}}[\mu(s)-k]p(s)\,ds-c$. In case of $\underline{s}=s_C^*<s_N^*$ we thus have that $B_2<0$.

We conclude this section with the following intuitive result.[26]

Proposition 11. If in our model it is (weakly) optimal to create competition, then this holds strictly in case both effort and the signal are verifiable. Formally, $B_2\geq c$ implies $B_1>c$.

Proof. See the Appendix.

□ **Integrating two capital-constrained divisions.** If a firm's ability to undertake multiple projects is limited by its financial resources, a slightly different but equally natural question is whether to integrate two previously stand-alone businesses, which also allows pooling of scarce resources.[27] The obvious upside of integration is that if one division fails to have a sufficiently attractive project, then potentially more funds, namely up to $2k$, could now be invested in the other project.[28] To accommodate this possibility in our model, we suppose that with probability ψ a project can be expanded to twice its size, requiring the investment of $2k$, without changing its rate of return.

If headquarters could *commit* to equally distribute funds over the two divisions in case both managers request funds, then integration would leave the probability with which each project is implemented unaffected. Intuitively, in this case, integration would then have no drawback. However, if headquarters can indeed realize the same expected cash flow by investing $2k$ into only one project instead of only k into each of two projects, then it will *strictly* prefer the former option as it must then pay only one manager more than his reservation value.[29] Because this reduces the likelihood with which a given project will be implemented, this can make the overinvestment problem more severe, unless there is still scope for steeper incentives.

For a formalization of these arguments, we consider how the optimality of integration depends on a change in c. In what follows, we suppose that

$$(1-\psi)\int_{\underline{s}}^{\bar{s}}[\mu(s)-k]p(s)\,ds\geq c.$$

This restriction has two implications. First, it ensures that for all considered choices of c it is still optimal to incentivize the manager in the nonintegrated firm, that is, even if the overinvestment problem is so extreme that $s_N^*=\underline{s}$. Second, as we show in the proof of Proposition 12, under this condition it is unprofitable to pool both divisions' resources but to only incentivize one manager. If $R-\underline{\alpha}>0$ is not too large, we have the following result.[30]

Proposition 12. Integration is strictly optimal if the incentive problem is not too severe as c is sufficiently low, whereas it is strictly suboptimal if the incentive problem is sufficiently severe as c is relatively high. Moreover, in the first case, the advantage of integration is larger the higher ψ, that is, the more likely it is that a project can profitably absorb all resources $2k$, whereas in the second case a higher ψ aggravates the adverse effects of integration.

Proof. See the Appendix.

[26] Proposition 11 is not fully obvious because, without verifiability, not all feasible surplus may be realized both with and without competition.

[27] We thank a referee for proposing this application of our model.

[28] As standard in the theory of internal capital markets, we suppose that this transfer of resources is not to the same extent possible via external finance. Essentially, this requires an additional layer of agency problems between insiders, including headquarters, and the providers of outside finance. For instance, in Inderst and Muller (2003), the agency problem originates from the limited ability to pledge future cash flows.

[29] Clearly, this opportunism problem would still persist if the second unit of capital, k, had a somewhat lower, though not too low, marginal return.

[30] It should be noted that Proposition 11 does not assert monotonicity over the whole range of values c, for which we would have to make functional specifications, pinning down, in particular, $p(s)$ and $g(s)$.

Integration has both positive and negative implications for investment efficiency: it may allow allocating more funds to the single (sufficiently profitable) investment opportunity, but it may also lead to more overinvestment as division managers become more biased toward claiming funds for their own projects. This implies that integrated firms should be bigger spenders, but that some of these funds will be less efficiently invested than in comparable stand-alone firms. Whether integration is beneficial or not depends on how severe the underlying agency problem is, as measured in Proposition 12 in terms of the costs of effort c.

Proposition 12 presents, however, at best a preliminary analysis, illustrating how our model could potentially be applied to questions beyond that of the interplay between incentives and investment decisions, which is our primary focus. Whereas Proposition 12 keeps the available funds fixed, for example, as financial frictions make additional external financing always too costly, more generally the availability and costs of external finance should depend on whether businesses are integrated or not (cf Stein, 1997, or Inderst and Muller, 2003).[31]

6. Conclusion

■ This article shows how division managers who are supposed to grow the firm's business become endogenously biased toward overinvesting in their own projects. The reward that is promised for the creation of new investment opportunities biases managers toward communicating overly optimistic information to headquarters. This bias is larger under internal competition, as well as in divisions with riskier and less profitable investment opportunities. The bias can, however, be mitigated if managers are put on steep incentive schemes. Among other results, our theory then implies that managers of less profitable and more risky divisions must accept steeper incentives in return for receiving (fresh) capital from headquarters.

The novel aspect of our model is that we capture both the creation and the realization of new investment opportunities. As noted above, this allows to endogenize managers' tendency to overinvest in their own divisions. Moreover, the fact that the investment opportunity was created by the manager makes it also more plausible that he has better information about its profitability than headquarters. As we argued, much of the extant literature on capital budgeting has focused on managers' responsibility to work on existing projects and on further (incremental) allocation of resources instead. Developing a model that incorporates a broader range of responsibilities, including generating, implementing, and managing new investment opportunities, could possibly provide new insights into budgeting decisions and incentive compensation.

Appendix

■ Proofs of Propositions 3, 5–11, Corollaries 1–2, and Lemmas 1–2 follow.

Proof of Proposition 3. If the first best is feasible, we have from (4) that $d\beta/dx = -ck[1 - G(s_{FB})]/(\pi_{FB})^2$. Likewise, we have that $d\alpha/dx = ck\int_{s_{FB}}^{\bar{s}} p(s)\,ds/(\pi_{FB})^2$. If the first best is not feasible, s^* is not affected by a change in x, implying from (3) that the same holds for α and β. From this the assertion holds as well for the remaining case, where the first best is only feasible for the higher value of x.

We turn next to the comparative statics in p. If the first best is feasible, we have from (4) that $d\beta/dp < 0$ as $d\pi_{FB}/dp = x\int_{s_{FB}}^{\bar{s}} q(s)g(s)\,ds > 0$. For $s^* < s_{FB}$ note first that as $p(s)/p(s^*) = q(s)/q(s^*), s^*$ as defined in (5) is independent of p such that, from $\beta = (R - \underline{\alpha})/p(s^*)$, we have again that β must strictly increase as p decreases. The argument again extends to the case where the first best is only feasible for the higher value of p.

Finally, we consider a decrease in q. As this leads to a strictly lower (maximum) *ex ante* surplus π_{FB}, the assertions follow immediately from (4) if the first best is feasible. Because q also affects the probability distribution over signals $G(s)$, the case where $s^* < s_{FB}$ is slightly more involved. Here, it turns out to be more convenient to take the posterior success probability $\tilde{p} = p(s)$ as the random variable. Denoting $p_l := pq(\underline{s})$ and $p_h := pq(\bar{s})$, $\tilde{p}$ has the support $\tilde{p} \in [p_l, p_h]$ and the distribution function $H(\tilde{p}) := \Pr(q(s)p \leq \tilde{p})$, which has a continuous and strictly positive density $h(\tilde{p})$. The

[31] Moreover, whereas for Proposition 12, headquarters can flexibly redeploy resources, for example, via overhead allocation or transfer pricing, if this were verifiable then making compensation contingent on whether a division received $2k$ or only k could provide some additional commitment power, albeit potentially at the costs of sometimes exacerbating the overinvestment problem.

project will be implemented if $\tilde{p} \geq \tilde{p}^*$, where $\tilde{p}^* = q(s^*)p$. As $\beta = (R - \underline{\alpha})/p(s^*)$ and thus with our new notation also $\beta = (R - \underline{\alpha})/\tilde{p}^*$, we have that β strictly increases if, following a reduction in q, $\tilde{p}^*$ decreases. To show this, we use that, in analogy to (5),

$$\int_{\tilde{p}^*}^{p_h} \left[\frac{\tilde{p}}{\tilde{p}^*} - 1 \right] h(\tilde{p}) d\tilde{p} = \frac{c}{R - \underline{\alpha}}. \tag{A1}$$

Note that a decrease in q only affects (A1) through the distribution (including a shift in p_h). As we show below that a change in q "reduces" $H(\tilde{p})$ in the sense of first-order stochastic dominance (FOSD) and as $\frac{\tilde{p}}{\tilde{p}^*} - 1$ is strictly increasing in $\tilde{p}$, if we hold $\tilde{p}^*$ constant this implies that the left-hand side of (A1) strictly decreases. To restore equality, $\tilde{p}^*$ must thus indeed decrease. To complete the proof, note that we can substitute from $q(s) = qf_g(s)/[qf_g(s) + (1 - q)f_b(s)]$ into $q(s)p \leq \tilde{p}$ to obtain

$$H(\tilde{p}) = \Pr\left(\frac{f_g(s)}{f_b(s)} \leq \frac{\tilde{p}}{p - \tilde{p}} \frac{1 - q}{q} \right),$$

which by monotone likelihood ratio property (MLRP) of $F_\theta(s)$ indeed strictly decreases in q, confirming FOSD. *Q.E.D.*

Proof of Proposition 5. The firm now maximizes

$$\int_{s^*}^{\bar{s}} [R + \mu(s) - k - w(s)] g(s)\, ds - G(s^*) z,$$

where s^* solves $w(s^*) = R + z$. By the argument in the main text, we can focus on the case where $s^* < s_{FB}$ for $z = 0$. Moreover, from the argument in Proposition 1, it is immediate that in this case $\alpha = \underline{\alpha}$ must hold. The binding incentive constraint (7) then becomes

$$\int_{s^*}^{\bar{s}} \left[\frac{p(s)}{p(s^*)} - 1 \right] g(s)\, ds = \frac{c}{R + z - \underline{\alpha}}, \tag{A2}$$

which again pins down a unique value of s^* for given z. Implicit differentiation yields

$$\frac{ds^*}{dz} = \frac{c}{(R + z - \underline{\alpha})^2} \frac{[p(s^*)]^2}{p'(s^*) \int_{s^*}^{\bar{s}} p(s) g(s)\, ds} > 0. \tag{A3}$$

Using (A3), the firm's first-order condition w.r.t. z becomes then

$$[k - \mu(s^*)] g(s^*) \frac{ds^*}{dz} - 1 = 0. \tag{A4}$$

Inspection of (A4) establishes that $s^* < s_{FB}$ holds at the optimal z and that $z = 0$ is uniquely optimal if in this case $s_{FB} - s^*$ remains sufficiently small. (This also uses strict quasiconcavity and that ds^*/dz remains bounded away from zero.) Moreover, we have that $z < 0$ can indeed never be optimal, implying that this part of Assumption 1 always remains slack.

We show next that, provided $z > 0$ is optimal, an increase in k implies a higher optimal z and thus, to still satisfy incentive compatibility, also a higher β. Using strict quasiconcavity of the program, this holds if, holding the previously optimal value of z fixed, the left-hand side of (A4) is strictly positive at a higher k. This follows immediately from the observation that, for given z, both s^* and ds^*/dz do not change. The argument for a reduction in x is analogous.

We turn next to a reduction in p. Note first that for given z, s^* as defined in (A2) is independent of p as $p(s)/p(s^*) = q(s)/q(s^*)$, implying also that ds^*/dz is independent of p for given s^*. As $\mu(s^*)$ is, however, strictly increasing in p, using strict quasiconcavity we have from inspection of (A4) that if implementing some s^* was previously optimal, then after a reduction in p it is optimal to implement a strictly higher cutoff. Substituting $R + z - \underline{\alpha}$ from (A2) into $\beta = (R + z - \alpha)/p(s^*)$, we have that

$$\beta = \frac{c}{p} \frac{1}{\int_{s^*}^{\bar{s}} [q(s) - q(s^*)] g(s)\, ds}. \tag{A5}$$

Hence, β indeed increases, as a reduction of p has by (A5) both a direct (positive) effect and, via the increase in s^*, an additional (positive) effect.

Consider finally a mean-preserving spread. As in this case the ratio $p(s)/p(s^*)$ stays constant, we have again from (A2) and (A3) that for given z both s^* and ds^*/dz are unaffected. From (A4) we thus have that the optimal z does not change, such that $\beta = (R + z - \underline{\alpha})/p(s^*)$ increases, given that $p(s^*)$ decreases following a mean-preserving spread. *Q.E.D.*

Proof of Corollary 1. Denote for a given comparative analysis as conducted in Proposition 5 the respective contractual values by (β, z) and $(\hat{\beta}, \hat{z})$, where $\hat{z} > z$ is associated with a respective cutoff $\hat{s}^* > s^*$. We want to show that

$$\hat{\beta} - \beta > \hat{z} - z. \tag{A6}$$

Consider first changes in k and x. We proceed in several steps. Note first that from the incentive compatibility constraint (7) a lower boundary for $\hat{\beta}$ is obtained if instead of raising s^* to $\hat{s}^*$ we leave the cutoff unchanged. If we denote this lower boundary by $\hat{\beta}' < \hat{\beta}$, we then have, together with the incentive compatibility constraint for the original case, the requirement that

$$\hat{\beta}' - \beta = (\hat{z} - z)\frac{1 - G(s^*)}{\int_{s^*}^{\bar{s}} p(s)g(s)\,ds} > \hat{z} - z, \tag{A7}$$

from which (A6) follows.

Finally, for the case where p changes, the argument needs to be slightly adjusted. Note first from the proof of Proposition 5 that $\hat{s}^* > s^*$ together with $\hat{z} - z$ holds in case the underlying change is to some $\hat{p} < p$. Recall also that this implies $\hat{p}(s) < p(s)$ for all s. We now obtain again a first lower boundary $\hat{\beta}' < \hat{\beta}$ by substituting s^* instead of $\hat{s}^*$ into the binding incentive compatibility constraint (7). Using next that $\hat{p}(s) < p(s)$ holds for all s, we obtain yet another lower boundary $\hat{\beta}'' < \hat{\beta}'$ by now substituting $p(s)$ instead of $\hat{p}(s)$ into the (already modified) incentive compatibility constraint. After these two changes, we then again use (A7) to obtain $\hat{\beta}'' - \beta > \hat{z} - z$ such that (A6) holds. *Q.E.D.*

Proof of Proposition 6. We now consider the possibility that, depending on the message $\hat{s} \in S$ sent by the manager, he receives a contract $(\alpha(\hat{s}), \beta(\hat{s}))$ in case the project is undertaken. Again, we can safely restrict consideration to strictly positive values $\beta(s) > 0$ such that there is again a unique cutoff s^*. If the mechanism is nondegenerate, then it follows immediately from the manager's truth-telling requirement and the fact that $p(s)$ is strictly increasing that $\alpha(s^*) > \underline{\alpha}$. Suppose now that the mechanism is replaced by a simple contract $(\underline{\alpha}, \beta')$, where from setting $\beta' = \beta(s^*) + \frac{\alpha(s^*) - \underline{\alpha}}{p(s^*)}$ the cutoff remains unchanged. As we show below, it holds for this choice of β' that

$$\int_{s^*}^{\bar{s}} [p(s)\beta' + \underline{\alpha}]g(s)\,ds > \int_{s^*}^{\bar{s}} [p(s)\beta(s) + \alpha(s)]g(s)\,ds, \tag{A8}$$

implying that the newly constructed simple contract relaxes the incentive constraint to induce effort. As this allows to further reduce β' until the incentive constraint becomes binding again (which pushes up s^*), and as $s^* < s_{FB}$ holds by assumption, the original mechanism was not optimal.

It thus remains to verify that (A8) indeed holds, which is in turn the case if

$$\underline{\alpha} + p(s)\beta' \geq \alpha(s) + p(s)\beta(s) \tag{A9}$$

holds for all $s \geq s^*$ and strictly for a subset with positive mass. As by the manager's truth-telling requirement the original mechanism must satisfy $\alpha(s^*) + p(s^*)\beta(s^*) \geq \alpha(s) + p(s^*)\beta(s)$ for all $s \geq s^*$, we obtain after substituting for β' that (A9) is always satisfied and holds even strictly whenever $\alpha(s) > \underline{\alpha}$. Unless the mechanism was degenerate and implemented the same contract for almost all $s \geq s^*$, there must finally be a positive mass of s satisfying $\alpha(s) > \underline{\alpha}$. *Q.E.D.*

Proof of Proposition 7. With competition between two symmetric divisions, the probability that manager i's project is implemented is given by $\Pr(s_i \geq s_i^*, s_j < s_j^*) + \frac{1}{2}\Pr(s_i \geq s_i^*, s_j \geq s_j^*)$, which becomes $\frac{1}{2}(1 - G(s_i^*))(1 + G(s_j^*))$. After substitution, we then obtain for manager i's incentive constraint

$$\frac{1}{2}\left[1 + G\left(s_j^*\right)\right]\int_{s_i^*}^{\bar{s}} [w_i(s) - R]g(s)\,ds \geq c. \tag{A10}$$

As the incentive constraints are binding by optimality, the firm's objective function is now

$$\sum_{i=1,2}\frac{1}{2}\left[1 + G\left(s_j^*\right)\right]\int_{s_i^*}^{\bar{s}} [\mu(s) - k]g(s)\,ds - 2c. \tag{A11}$$

Suppose first that headquarters could choose s_1^* and s_2^*. The optimal thresholds are obtained by differentiating (A11), which yields the respective first-order conditions

$$\mu(s_i^*) - k = \frac{\int_{s_j^*}^{\bar{s}}[\mu(s) - k]g(s)\,ds}{1 + G\left(s_j^*\right)}. \tag{A12}$$

Using that a solution to (A12) must satisfy $s_i^* > s_{FB}$ for $i = 1, 2$ and that, given symmetry in (A12), a solution must be symmetric, $s_1^* = s_2^* = s_C^{**}$ must satisfy (10). Note next that from $s_C^{**} > s_N^{**}$ the left-hand side of (10) is strictly increasing in s_C^{**}, whereas the right-hand side is strictly decreasing. As both sides are also continuous and as the left-hand side is strictly larger for $s_C^{**} = \bar{s}$, we have a unique interior solution $s_C^{**} \in (s_N^{**}, \bar{s})$, where $s_N^{**} = s_{FB}$.

We now denote the optimal contract with competition by (α_C, β_C) and refer to the optimal contract with *no* competition by (α_N, β_N). Recall also that we denoted the respective cutoffs by s_N^* and s_C^*. If we can implement $s_C^* = s_C^{**}$, then from (A10) and $w(s_C^{**}) = R$ we have that

$$\begin{aligned} \beta_C &= \frac{c}{\frac{1}{2}\left[1 + G\left(s_C^{**}\right)\right]\int_{s_C^{**}}^{\bar{s}}\left[p(s) - p\left(s_C^{**}\right)\right]g(s)\,ds}, \\ \alpha_C &= R - \beta_C p\left(s_C^{**}\right). \end{aligned} \tag{A13}$$

From (4) and (17), using $s_C^{**} > s_N^{**}$ and $\frac{1}{2}[1 + G(s_C^{**})] < 1$, we thus have that if the base-wage constraint does not bind in either regime, then $\alpha_C < \alpha_N$ and $\beta_C > \beta_N$. If the constraint binds with competition, we have in analogy to (3), (4), and (5) that

$$\beta_C = \frac{c}{\frac{1}{2}\left[1 + G\left(s_C^*\right)\right]\int_{s_C^*}^{\bar{s}}\left[p(s) - p\left(s_C^*\right)\right]g(s)\,ds}, \qquad \alpha_C = R - \beta_C p\left(s_C^*\right), \tag{A14}$$

and that s_C^* must satisfy

$$\int_{s_C^*}^{\bar{s}}\left[\frac{p(s)}{p\left(s_C^*\right)} - 1\right]g(s)\,ds = \frac{2}{1 + G\left(s_C^*\right)}\frac{c}{R - \underline{\alpha}}. \tag{A15}$$

Note that (A15) does not already pin down a unique value of s_C^* and thus, together with (17), a unique optimal contract. As by construction any solution to (A15) satisfies $s_C^* < s_C^{**}$, however, the unique optimal contract is given by substituting the highest solution to (A15) into (17).[32]

To compare contracts when the base-wage constraint binds in either case, note first that from (3) and (17), $\alpha_C \geq \underline{\alpha}$ implies $\alpha_N > \underline{\alpha}$. Suppose first that the base-wage constraint also binds without competition. In this case, we have from (5) with (A15) and $1 + G(s_C^*) < 2$ that $s_C^* < s_N^*$. As $\alpha_C = \alpha_N = \underline{\alpha}$, we then have from $\underline{\alpha} = R - \beta_N p(s_N^*)$ and $\underline{\alpha} = R - \beta_C p(s_C^*)$ that $\beta_C > \beta_N$. If the base-wage constraint only binds with competition and if $s_C^* \geq s_N^{**}$, then direct comparison of (3) with (17) shows that $\beta_C > \beta_N$. If instead $s_C^* < s_N^{**}$, we can use that $\alpha_N > \alpha_C = \underline{\alpha}$ such that $\beta_C > \beta_N$ follows again by comparing $\alpha_N = R - \beta_N\, p(s_N^*)$ and $\alpha_C = R - \beta_C\, p(s_C^*)$. *Q.E.D.*

Proof of Corollary 2. In case (i), where $s_N^* < s_N^{**}$, we have already shown that $s_C^* < s_N^*$. In case (ii), where $s_C^* = s_C^{**}$, the result follows from $s_C^{**} > s_N^{**}$. *Q.E.D.*

Proof of Corollary 3. From (17), we have that $s_C^* = s_C^{**}$ and thus $s_C^* > s_N^*$ whenever

$$c \leq c' := [R - \underline{\alpha}]\left[\frac{1}{2}\left[1 + G\left(s_C^{**}\right)\right]\int_{s_C^{**}}^{\bar{s}}\left[\frac{p(s)}{p\left(s_C^{**}\right)} - 1\right]\right].$$

Recall now from the proof of Proposition 8 that $s_N^* < s_N^{**}$ implies that also $s_C^* < s_N^*$, which from (6) thus holds surely if

$$c > c'' := [R - \underline{\alpha}]\left[\int_{s_N^{**}}^{\bar{s}}\left[\frac{p(s)}{p(s_N^{**})} - 1\right]g(s)\,ds\right].$$

That $c' < c''$ is easily confirmed by noting that $s_C^{**} > s_N^{**}$ and thus also $p(s_C^{**}) > p(s_N^{**})$. As $s_N^* = s_N^{**}$ stays constant over $c \leq c''$, it only remains to show that s_C^* is for $c > c'$ strictly decreasing, which follows by optimality using (A15). *Q.E.D.*

Proof of Lemma 1. With discrete signals, $g(s) > 0$ now denotes the respective probability with which some signal s will be observed. Take first the case with a pooling contract, where we want to find an upper boundary on c up to which $s_C^* = s_2$ is feasible. As the argument proceeds in analogy to the case with a continuum of signals, we can be brief. Setting $\alpha = \underline{\alpha}$, we have that incentive compatibility can still be satisfied as long as $c \leq c_P$, where

$$c_P := \frac{1}{2}[1 + g(s_1)]\sum_{s=s_2,s_3} g(s)\left[\underline{\alpha} + \beta p(s) - R\right]$$

and where we can substitute for β from $\underline{\alpha} + \beta p(s_1) = R$, that is, from the condition that the manager is just indifferent at s_1. Suppose next that two contracts (α_2, β_2) and (α_3, β_3) that induce truth telling are offered. Again, we will find a threshold c_T such that $s_C^* = s_2$ is feasible if and only if $c \leq c_T$. To construct this threshold, note first that to ensure $s_C^* = s_2$ for as high values of c as possible, it must hold again that $\alpha_2 = \underline{\alpha}$. Note next that the incentive constraint so as to elicit effort becomes

$$\begin{aligned} &g(s_2)\frac{1}{2}\left[1 + g(s_1) - g(s_3)\right]\left[\underline{\alpha} + \beta_2 p(s_2) - R\right] \\ &\quad + g(s_3)\frac{1}{2}\left[1 + g(s_1) + g(s_2)\right]\left[\alpha_3 + \beta_3 p(s_3) - R\right] \geq c, \end{aligned} \tag{A16}$$

whereas truth telling with signal s_2 requires that

$$\frac{1}{2}\left[1 + g(s_1) - g(s_3)\right]\left[\underline{\alpha} + \beta_2 p(s_2)\right] \geq \frac{1}{2}\left[1 + g(s_1) + g(s_2)\right]\left[\underline{\alpha} + \beta_3 p(s_2)\right]. \tag{A17}$$

It turns out that if (A17) binds, then we can ignore the truth-telling constraint for the higher signal s_3, while also the contract for s_2 is more attractive to type s_1 than that for s_3. Consequently, to construct c_T we have to use β_2 from $\underline{\alpha} + \beta_2 p(s_1) = R$, while both (17) and (A17) must be satisfied with equality. Next, suppose that we adjust α_3 by $d\alpha_3 < 0$

[32] A sufficient condition for the existence of a nonempty set of solutions $s_C^* > \underline{s}$ to (A15) is given by $\underline{\alpha} < R - 2c/(1 + G(\underline{s}))\int_{\underline{s}}^{\bar{s}}\left[\frac{p(s)}{p(\underline{S})} - 1\right]g(s)\,ds$.

and β_3 by $d\beta_3 = -1/p(s_2)$ such that (A17) is still satisfied with equality. As this increases the left-hand side of (17) by $d\alpha_3[1 - \frac{p(s_3)}{p(s_2)}] > 0$, we thus have obtained that $\alpha_3 = \underline{\alpha}$ must hold for the construction of c_T.

We are now in a position to compare c_T with c_P. Here, we can use that $\beta_2 = \beta$ as both contracts make s_1 just indifferent. As all terms $R - \underline{\alpha}$ cancel out when comparing c_T with c_P, we have, after collecting terms for β, that $c_T < c_P$ holds if

$$\beta_3 p(s_3)[1 + g(s_1) + g(s_2)] < \beta\left[p(s_3)[1 + g(s_1)] + g(s_2)p(s_2)\right]. \tag{A18}$$

As we have from the binding constraint (A17) that

$$\beta_3 = \frac{1 + g(s_1) - g(s_3)}{1 + g(s_1) + g(s_2)}\beta - \frac{g(s_2) + g(s_3)}{1 + g(s_1) + g(s_2)}\frac{\underline{\alpha}}{p(s_2)}, \tag{A19}$$

we know that (A18) surely holds if it still holds after we substitute for β_3 the (for $\underline{\alpha} > 0$ strictly) larger expression $\frac{1+g(s_1)-g(s_3)}{1+g(s_1)+g(s_2)}\beta$. Condition (A18) then finally transforms to $g(s_3)p(s_3) + g(s_2)p(s_2) > 0$. *Q.E.D.*

Proof of Lemma 2. To induce headquarters to undertake the investment also when s_2 is truthfully revealed, it must hold that

$$[\alpha_2 + \beta_2 p(s_2)] - R \leq \mu(s_2) - k. \tag{A20}$$

We now derive in analogy to the proof of Lemma 1 the new threshold on c, which we denote by c_{NC}. The only difference is that β_2, which was previously determined by the requirement that $\underline{\alpha} + \beta_2 p(s_1) = R$, must now also satisfy (A20). Note next that once we substitute for β_3 from (A19), the left-hand side of (17) is strictly increasing in β_2. Consequently, we have $c_{NC} < c_T$ if the additional constraint on β_2 from (A20) becomes binding, which is the case if $\mu(s_2) - k < (R - \underline{\alpha})[p(s_2) - p(s_1)]/p(s_1)$ and if $\mu(s_2) - k$ is sufficiently small. (Note here that from $\mu(s_1) - k < 0, p(s_2) - p(s_1)$ stays bounded away from zero.) *Q.E.D.*

Proof of Proposition 8. Recall first that from Lemmata 1 and 2 we have for all sufficiently low values of $\mu(s_2) - k > 0$ that $0 < c_{NC} < c_P$. We deal next with the underinvestment case where $s_C^* = s_3$. Comparing the firm's payoff to that with $s_C^* = s_2$ under a pooling contract, the underinvestment solution is strictly more profitable if

$$[1 + g(s_1) + g(s_2)]\, g(s_3)\, [\mu(s_3) - k] > [1 + g(s_1)] \sum_{s=s_2,s_3} g(s)[\mu(s) - k],$$

which becomes $g(s_3)[\mu(s_3) - k] > [1 + g(s_1)]\,[\mu(s_2) - k]$ and thus holds surely for all sufficiently low values of $\mu(s_2) - k > 0$. Implementing $s_C^* = s_3$ is next also feasible if $c \leq c_U$, where by applying the arguments from Lemmata 1 and 2 we have

$$c_U := \frac{1}{2}[1 + g(s_1) + g(s_2)]g(s_3)\,[\underline{\alpha} + \beta p(s_3) - R]\,,$$

with β now solving $\underline{\alpha} + \beta p(s_2) = R$. We show that for low values $\mu(s_2) - k > 0$ it holds that $c_U > c_{NC}$. Instead of writing out this condition in generality, we proceed differently and show first that $c_U > c_{NC}$ holds surely if $\mu(s_2) - k = 0$, in which case the respective terms become much simpler. The assertion follows then also for low values of $\mu(s_2) - k > 0$ from continuity, namely as c_U is clearly continuous in $p(s_2)$ and unaffected by x and k, while the constraint (A20) that determines β in case $s_C^* = s_3$ is also continuous in the surplus $\mu(s_2) - k$. Setting thus $\mu(s_2) - k = 0$, we can then use that β_2 for $s_C^* = s_2$ and β for $s_C^* = s_3$ coincide. The requirement that $c_U > c_{NC}$ then simply becomes $\beta_2 > \beta_3$, which holds from (A19). Finally, the two cases in Proposition 9 arise if either $c_P > c_U$ or $c_P \leq c_U$.[33] *Q.E.D.*

Proof of Proposition 9. With competition and $z \geq 0$, the incentive constraint becomes

$$\frac{1}{2}\left[1 + G\left(s_C^*\right)\right]\int_{s_C^*}^{\bar{s}} [w(s) - R - z]g(s)\,ds \geq c. \tag{A21}$$

As the latter binds from optimality, the objective function is then

$$\left[1 + G\left(s_C^*\right)\right]\int_{s_C^*}^{\bar{s}} [\mu(s) - k]g(s)\,ds - 2(c + z).$$

Finally, in analogy to (A15) s_C^* is, for a given z, the highest value solving

$$\int_{s_C^*}^{\bar{s}} \left[\frac{p(s)}{p\left(s_C^*\right)} - 1\right] g(s)\,ds - \frac{2}{1 + G\left(s_C^*\right)}\frac{c}{R + z - \underline{\alpha}} = 0. \tag{A22}$$

Note next that as the left-hand side of (A22) is strictly smaller than zero at all sufficiently high values of s_C^*, we have that at the highest value of s_C^* for which (A22) holds, the derivative with respect to s_C^* must be strictly negative. Moreover,

[33] Proposition 8 makes no claims on how the outcome for $c > \max\{c_P, c_U\}$, where $s_C^* = s_1$, is characterized. However, if $\mu(s_2) - k > 0$ is sufficiently small, then in this case, where it holds by construction that $w(s_1) > R$, it follows already from headquarters' commitment problem that only a pooling contract for all three signals is feasible.

as s_C^* is monotonic in z, the derivative ds_C^*/dz exists almost everywhere. To calculate it at points of differentiability, it is helpful to introduce some additional notation. We denote

$$A(s^*) := \int_{s^*}^{\bar{s}} \left[\frac{p(s)}{p(s^*)} - 1\right] g(s)\, ds,$$
$$B(z) := \frac{c}{R + z - \underset{\sim}{\alpha}}.$$

Hence, we then have at points of differentiability that

$$\frac{ds_C^*}{dz} = \frac{2}{1 + G\left(s_C^*\right)} \frac{B'(z)}{A'\left(s_C^*\right) + B(z)\frac{2g\left(s_C^*\right)}{\left[1+G\left(s_C^*\right)\right]^2}},$$

where from our previous remarks and $B'(z) < 0$ it must hold that

$$A'\left(s_C^*\right) + B(z)\frac{2g\left(s_C^*\right)}{\left[1 + G\left(s_C^*\right)\right]^2} < 0. \tag{A23}$$

To prove Proposition 9, note now that if $z = 0$ is optimal without competition, then we have already from Proposition 7 that $\beta_C > \beta_N$. Precisely, from Proposition 7 this holds if also $z = 0$ is optimal with competition, whereas from (A21) this holds even more so if $z > 0$ is optimal with competition. It thus remains to analyze the case where $z > 0$ is optimal without competition. Define next the surplus (gross of effort costs) with competition by

$$\pi_C := \left[1 + G\left(s_C^*\right)\right] \int_{s_C^*}^{\bar{s}} [\mu(s) - k] g(s)\, ds$$

and likewise

$$\pi_N := \int_{s_N^*}^{\bar{s}} [\mu(s) - k] g(s)\, ds.$$

Claim 1. If $z = z_N > 0$ is optimal without competition, thereby implementing some s_N^*, then with competition it is optimal to implement some $s_C^* > s_N^*$.

Proof of Claim 1. Note first that

$$\frac{d\pi_N}{ds_N^*} = -g\left(s_N^*\right)\left[\mu\left(s_N^*\right) - k\right] \tag{A24}$$

and

$$\frac{d\pi_C}{ds_C^*} = -g\left(s_C^*\right)\left[1 + G\left(s_C^*\right)\right]\left[\mu\left(s_C^*\right) - k\right] + g\left(s_C^*\right)\int_{s_C^*}^{\bar{s}} [\mu(s) - k] g(s)\, ds. \tag{A25}$$

Using the previously introduced expressions, from which we have that $ds_N^*/dz = B'(z)/A'(s_N^*)$, at points of differentiability we obtain

$$\frac{d\pi_N}{dz} = \frac{d\pi_N}{ds_N^*}\frac{ds_N^*}{dz} = -g\left(s_N^*\right)\left[\mu\left(s_N^*\right) - k\right]\frac{B'(z)}{A'\left(s_N^*\right)}$$

and

$$\begin{aligned}\frac{d\pi_C}{dz} = \frac{d\pi_C}{ds_C^*}\frac{ds_C^*}{dz} &= \left[-g\left(s_C^*\right)\left[1 + G\left(s_C^*\right)\right]\left[\mu\left(s_C^*\right) - k\right] + g\left(s_C^*\right)\int_{s_C^*}^{\bar{s}} [\mu(s) - k] g(s)\, ds\right] \\ &\times \left[\frac{2}{1 + G\left(s_C^*\right)} \frac{B'(z)}{A'\left(s_C^*\right) + B(z)\frac{2g\left(s_C^*\right)}{\left[1+G\left(s_C^*\right)\right]^2}}\right].\end{aligned} \tag{A26}$$

To obtain a lower boundary for $\frac{d\pi_C}{dz}$, for the first term in rectangular brackets in (17) we use that $g(s_C^*)\int_{s_C^*}^{\bar{s}}[\mu(s) - k]g(s)\, ds > 0$ together with $\mu(s_C^*) - k < 0$ and for the second term $B'(z) < 0$ together with (A23). We thus have that

$$\begin{aligned}\frac{d\pi_C}{dz} &> \left[-g\left(s_C^*\right)\left[1 + G\left(s_C^*\right)\right]\left[\mu\left(s_C^*\right) - k\right]\right]\left[\frac{2}{1 + G\left(s_C^*\right)}\frac{B'(z)}{A'\left(s_C^*\right)}\right] \\ &> 2\frac{d\pi_N}{dz},\end{aligned} \tag{A27}$$

where we evaluated both derivatives at the same cutoff $s^* = s_N^* = s_C^*$. Note next that the marginal impact of a higher z on the firm's objective function equals $\frac{d\pi_N}{dz} - 1$ without competition and $\frac{d\pi_C}{dz} - 2$ with competition (at points of differentiability).

At z_N we thus have that $\frac{d\pi_N}{dz} = 1$. If we want to implement the same cutoff under competition, then from (17) we have that $\frac{d\pi_C}{dz} - 2 > 0$ holds at the respective value of z. Using once more strict quasiconcavity of the objective function, now for the case with competition, this implies that the optimally implemented cutoff must be strictly higher such that ultimately $s_C^* > s_N^*$. *Q.E.D. (Claim 1)*

We now use Claim 1 to show that $\beta_C > \beta_N$. For this we use for both cases the respective binding incentive compatibility constraint as well as the definitions for the two cutoffs s_N^* and s_C^* to obtain

$$\beta_N = \frac{c}{\int_{s_N^*}^{\bar{s}} \left[p(s) - p\left(s_N^*\right)\right] g(s)\, ds}$$

and

$$\beta_C = \frac{c}{\frac{1}{2}\left[1 + G\left(s_C^*\right)\right] \int_{s_C^*}^{\bar{s}} \left[p(s) - p\left(s_C^*\right)\right] g(s)\, ds}. \tag{A28}$$

With these expressions at hand, it thus remains to show that

$$\frac{1}{2}\left[1 + G\left(s_C^*\right)\right] \int_{s_C^*}^{\bar{s}} \left[p(s) - p\left(s_C^*\right)\right] g(s)\, ds < \int_{s_N^*}^{\bar{s}} [p(s) - p\left(s_N^*\right)] g(s)\, ds$$

which follows immediately from $s_C^* > s_N^*$.

To conclude the proof, we show that, as asserted in the main text after Proposition 9, it also holds that

$$\beta_C - \beta_N > z_C - z_N. \tag{A29}$$

To see this, note first that a lower boundary $\beta_C' < \beta_C$ is obtained by replacing the expression $\frac{1}{2}[1 + G(s_C^*)]$ in the binding incentive compatibility constraint (A21) by one. Next, another lower boundary $\beta_C'' < \beta_C'$ is obtained by replacing, in the already modified binding constraint, the cutoff s_C^* by $s_N^* < s_C^*$. Using now β_C'' together with the modified constraint, subtraction from the binding constraint for the case without competition finally yields

$$\beta_C'' - \beta_N = (z_C - z_N) \frac{1 - G(s_N^*)}{\int_{s_N^*}^{\bar{s}} p(s) g(s)\, ds}. \tag{A30}$$

For $z_C - z_N > 0$ the assertion (A29) follows then immediately from $\beta_C'' < \beta_C$ and (A30). *Q.E.D.*

Proof of Proposition 10. The incentive compatibility constraint becomes

$$\frac{1}{2}\left[1 + G\left(s_C^*\right)\right] \int_{s_C^*}^{\bar{s}} \left[w(s) - z_a \frac{2G\left(s_C^*\right)}{1 + G\left(s_C^*\right)} - z_b \frac{1 - G\left(s_C^*\right)}{1 + G\left(s_C^*\right)}\right] g(s)\, ds \geq c. \tag{A31}$$

Transforming the binding incentive constraint (A31) together with the definition of s_C^* in (13), we have in analogy to Proposition 9 that s_C^* is the highest value satisfying

$$\int_{s_C^*}^{\bar{s}} \left[\frac{p(s)}{p\left(s_C^*\right)} - 1\right] g(s)\, ds = \frac{2}{1 + G\left(s_C^*\right)} \frac{c}{R - \underline{\alpha} + z_a \frac{2G\left(s_C^*\right)}{1+G\left(s_C^*\right)} + z_b \frac{1-G\left(s_C^*\right)}{1+G\left(s_C^*\right)}}. \tag{A32}$$

It proves now, in a slight deviation from the proof of Proposition 9, more helpful to rearrange (A32) and to introduce some additional notation such that

$$R - \underline{\alpha} + z_a \frac{2G\left(s_C^*\right)}{1 + G\left(s_C^*\right)} + z_b \frac{1 - G\left(s_C^*\right)}{1 + G\left(s_C^*\right)} - y\left(s_C^*\right) = 0 \tag{A33}$$

with

$$y\left(s_C^*\right) = \frac{2c}{\left[1 + G\left(s_C^*\right)\right] \int_{s_C^*}^{\bar{s}} \left[\frac{p(s)}{p\left(s_C^*\right)} - 1\right] g(s)\, ds}.$$

By an argument as in the proof of Proposition 9, we have that s_C^* is strictly increasing in both z_a and z_b. At points of differentiability, we have from (A33) that

$$\frac{ds_C^*}{dz_a} = \frac{2G\left(s_C^*\right)}{1 + G\left(s_C^*\right)} Z_1,$$

$$\frac{ds_C^*}{dz_b} = \frac{1 - G\left(s_C^*\right)}{1 + G\left(s_C^*\right)} Z_1,$$

where

$$Z_1 = \frac{d}{ds_C^*}\left[z_a \frac{2G\left(s_C^*\right)}{1 + G\left(s_C^*\right)} + z_b \frac{1 - G\left(s_C^*\right)}{1 + G\left(s_C^*\right)} - y\left(s_C^*\right)\right] > 0.$$

For the sake of brevity, we now suppose in the remainder of the proof that s_C^* is everywhere continuously differentiable over the considered range of values z_a and z_b. Denoting now the firm's payoff (14) by Ω, we have that

$$\frac{d\Omega}{dz_a} = 2G\left(s_C^*\right)\left[\frac{Z_1}{1+G\left(s_C^*\right)}\frac{d\pi_C}{ds_C^*} - 1\right] \tag{A34}$$

and

$$\frac{d\Omega}{dz_b} = \left[1 - G\left(s_C^*\right)\right]\left[\frac{Z_1}{1+G\left(s_C^*\right)}\frac{d\pi_C}{ds_C^*} - 2\right], \tag{A35}$$

where $d\pi_C/ds_C^*$ is given by (A25).

We now argue to a contradiction and suppose first that both $z_a > 0$ and $z_b > 0$ are jointly optimal, in which case both (A34) and (A35) would have to be equal to zero, which is not possible. Next, if $z_a = 0$ but $z_b > 0$, then as (A35) must be equal to zero, it follows that (A35) is strictly positive, contradicting optimality of $z_a = 0$.

Next, from the binding incentive constraint (A31) together with the definition of s_C^* in (13), we obtain again

$$\beta_C = \frac{c}{\frac{1}{2}\left[1 + G\left(s_C^*\right)\right]\int_{s_C^*}^{\bar{s}}\left[p(s) - p\left(s_C^*\right)\right]g(s)\,ds},$$

which is identical to expression (A28) in the proof of Proposition 10. To show that incentives are still steeper under competition, it is thus sufficient to show that s_C^* is optimally still higher with contingent payments. Using our previously introduced notation, we have that s_C^* changes in z and in z_a, respectively, according to

$$\begin{aligned} \frac{ds_C^*}{dz} &= \frac{1}{y'(s^*)}, \\ \frac{ds_C^*}{dz_a} &= \frac{2G\left(s_C^*\right)\left[1+G\left(s_C^*\right)\right]}{y'(s^*)\left[1+G\left(s_C^*\right)\right]^2 - 2g\left(s_C^*\right)z_a}. \end{aligned} \tag{A36}$$

To avoid confusion, we now denote the respective firm profits by Ω_z and Ω_a such that

$$\frac{d\Omega_a}{dz_a} = \frac{d\pi_C}{ds_C^*}\frac{ds_C^*}{dz} - 2G\left(s_C^*\right) \tag{A37}$$

and

$$\frac{d\Omega_z}{dz} = \frac{d\pi_C}{ds_C^*}\frac{ds_C^*}{dz} - 2. \tag{A38}$$

Consider now the cutoff s_C^* at which Ω_z is maximized such that (A38) is equal to zero.[34] The assertion follows if, when evaluated at this value of s_C^*, expression (A37) is strictly positive. After substitution from (A38) this holds in turn if $\frac{ds_C^*}{dz_a} > \frac{ds_C^*}{dz}G(s_C^*)$. Substituting from (17), this transforms to $2g(s_C^*)z_a > -y'(s^*)[1 - G(s_C^*)]^2$, which is true.

We finally analyze when, under the optimal contract, the nonshirking equilibrium is unique. For this we now allow for different cutoffs, which we denote by s_{1C}^* and s_{2C}^*. Using this to rewrite (13), we then have for manager i's "best-response" function in $t = 1$

$$\frac{ds_{iC}^*}{ds_{jC}^*} = \frac{2g(s_{jC}^*)}{\left[1+G(s_{jC}^*)\right]^2}\frac{z_a - z_b}{\beta_C p'(s_{iC}^*)}. \tag{A39}$$

From the perspective of manager i the case with $s_{jC}^* = \bar{s}$ is equivalent to the one where manager j shirks. From (A39) this induces manager i to raise his cutoff. Denote now the respective optimal cutoff of manager i by $s_{Cno}^* > s_C^*$. Consequently, under the optimal contract an equilibrium where both managers shirk in $t = 0$ can be ruled out if and only if[35]

$$\int_{s_{Cno}^*}^{\bar{s}}\left[w(s) - R - z_a\right]g(s)\,ds > \frac{1}{2}\left[1+G\left(s_C^*\right)\right]\int_{s_C^*}^{\bar{s}}\left[w(s) - R - z_a\frac{2G\left(s_C^*\right)}{1+G\left(s_C^*\right)}\right]g(s)\,ds. \qquad Q.E.D$$

[34] Again, for brevity we invoke strict quasiconcavity of the firm's objective function as well as differentiability at the optimal choice of s_C^*.

[35] Note that provided the choices at $t = 0$ are not observable, which is what we assume here, it follows immediately from $s_{Cno}^* > s_C^*$ that there will not be an asymmetric equilibrium. Formally, if manager j is expected to choose the cutoff s_{Cno}^*, then manager i, provided that he deviates and thus does *not* shirk, will choose a cutoff $s_{CDno}^* < s_C^*$. Together with $s_{Cno}^* > s_C^*$, the incentive compatibility constraint for manager i is then indeed surely slack.

Proof of Proposition 11. The proof of Proposition 11 is not obvious, as we have that, at least for high enough c, both π_N and π_C are decreasing in c. (Recall the definitions from the proof of Proposition 10.) We now argue to a contradiction, implying that there exists some $\hat{c}$ where $B_1 \leq B_2$. As at $c = 0$ we have that $B_1 > B_2$ and as B_1 does not change in c, this requires that[36]

$$\int_0^{\hat{c}} \frac{d\pi_C}{dc} dc > \int_0^{\hat{c}} \frac{d\pi_N}{dc} dc. \tag{A40}$$

Recall next that from the proof of Corollary 3 we have $d\pi_N/dc = 0$ for all $c \leq c''$, where $s_N^* = s_N^{**}$, which implies that $\hat{c} > c''$. From this and Corollary 2, we also know that at $c = \hat{c}$ we have $\hat{s}_C^* < \hat{s}_N^* < s_N^{**}$. Note now that each c induces a respective cutoff s_N^* and s_C^*. At $c = 0$, these are given by $s_N^* = s_N^{**} < s_C^* = s_C^{**}$. For (A40) to hold, it must thus be true that, after a change of variables, we have

$$\int_{\hat{s}_N^*}^{s_N^{**}} \frac{d\pi_N}{ds^*} ds^* > \int_{\hat{s}_C^*}^{s_C^{**}} \frac{d\pi_C}{ds^*} ds^*. \tag{A41}$$

As $s_N^{**} < s_C^{**}$ and $\hat{s}_C^* < \hat{s}_N^*$, (A41) can only hold if $\int_{\hat{s}_N^*}^{s_N^{**}} (\frac{d\pi_N}{ds^*} - \frac{d\pi_C}{ds^*}) ds^* > 0$. We finally obtain a contradiction as it holds for all $s_C^* = s_N^* = s^*$ satisfying $\hat{s}_N^* \leq s^* \leq s_N^{**}$ that $\frac{d\pi_N}{ds^*} < \frac{d\pi_C}{ds^*}$. Using (A24) and (A25), this is immediate as $\mu(s^*) - k \leq 0$ for $s^* \leq s_N^{**} = s_{FB}$. *Q.E.D.*

Proof of Proposition 12. Without integration, the total gross payoff from both businesses is $2\pi_N$, where π_N was defined in Proposition 9. Note next that the case with integration does not fully coincide with that where two divisions compete with mutually exclusive projects. The probability with which a given project is implemented depends now on whether any of the two projects can be scaled up to allow the investment of $2k$. For either project, this is in turn the case with probability ψ. Taking this into account and using that the conditional expected compensation under a realized project is $[\int_{s_I^*}^{\bar{s}} w(s) g(s)\, ds]/[1 - G(s_I^*)]$, the incentive constraint becomes[37]

$$\frac{2 - \psi(2-\psi)[1 - G(s_I^*)]}{2} \int_{s_I^*}^{\bar{s}} [w(s) - R] g(s)\, ds \geq c.$$

From the firm's perspective, it will now be able to invest $2k$ with probability $[1 - G(s_I^*)]^2 + 2G(s_I^*)[1 - G(s_I^*)]\,\psi$, whereas with probability $2G(s_I^*)[1 - G(s_I^*)]\,(1 - \psi)$ only k will be invested. Denoting the expected gross payoff by π_I, we have that

$$\pi_I := 2[1 + \psi G(s_I^*)] \int_{s_I^*}^{\bar{s}} [\mu(s) - k] g(s)\, ds.$$

Consequently, integration is optimal if and only if[38]

$$\pi_I \geq 2\pi_N.$$

Before deriving conditions for when this holds, note first that a third alternative is to integrate but to only incentivize a single manager. As in the latter case the cutoff is s_N^*, while we save c, it is immediate that the firm's profits are now $(1 + \psi)\pi_N - c$. Given our assumption that $(1 - \psi) \int_{\underline{s}}^{\bar{s}} [\mu(s) - k] p(s)\, ds \geq c$, this is strictly lower than the firm's profits without integration (i.e., $2(\pi_N - c)$).

Note next that in analogy to (10), the optimal cutoff under integration, s_I^{**}, is defined by

$$\mu(s_I^{**}) - k = \psi \frac{\left[\int_{s_I^*}^{\bar{s}} [\mu(s) - k] g(s)\, ds\right]}{1 + \psi G(s_I^*)}.$$

The following argument is now analogous to that in Corollary 4. First, note that for $s_I^* = s_I^{**}$ it is immediate that $\pi_I > 2\pi_N$. Next, this case applies whenever c is sufficiently small. Precisely proceeding as in Corollary 4, we obtain from the requirement that $\alpha \geq \underline{\alpha}$ the threshold

$$c \leq (R - \underline{\alpha}) \left(\frac{2 - \psi(2-\psi)\left[1 - G(s_I^{**})\right]}{2} \right) \int_{s_I^{**}}^{\bar{s}} \left[\frac{p(s)}{p(s_I^{**})} - 1 \right] g(s)\, ds.$$

Finally, by construction of s_I^{**} it also follows immediately from the envelope theorem that

[36] We use here that π_N is continuous in c and that π_C is nondecreasing, while both are also almost everywhere differentiable. Hence, if π_C is not everywhere continuous over $0, \hat{c}]$, then (A40) is still necessary.

[37] Intuitively, for $\psi = 0$ the incentive constraint coincides with that under nonintegration, whereas for $\psi = 1$ the incentive constraint coincides with that under competition.

[38] We use here that in both cases the respective incentive constraint binds such that the firm's profits are $2(\pi_N - c)$ without integration and $\pi_I - 2c$ with integration.

$$\frac{d\pi_I}{d\psi} = 2G\left(s_I^*\right)\int_{s_I^*}^{\bar{s}} [\mu(s) - k] g(s)\, ds > 0,$$

implying that over this range of values c an increase in ψ also increases the difference $2\pi_N - \pi_I$.

Take now the case for high c, where we have in analogy to (A22) that s_I^* is the highest value satisfying

$$\int_{s_I^*}^{\bar{s}} \left[\frac{p(s)}{p\left(s_I^*\right)} - 1\right] g(s)\, ds = \frac{2}{2 - \psi(2-\psi)\left[1 - G\left(s_I^*\right)\right]} \frac{c}{R - \underline{\alpha}}.$$

Also, in analogy to the comparison between s_N^* and s_C^*, we have a threshold $\tilde{c}$ such that $s_I^* > \underline{s}$ if and only if $c < \tilde{c}'$ and a threshold $\tilde{c}' > \tilde{c}$ such that $s_N^* > \underline{s}$ if and only if $c < \tilde{c}''$. Consequently, $\pi_I = \int_{\underline{s}}^{\bar{s}} [\mu(s) - k] g(s)\, ds < \pi_N$ holds for all $c \in (\tilde{c}, \tilde{c}')$.

Finally, we show that for all c sufficiently close to $\tilde{c}'$ it holds that $d\pi_I / d\psi < 0$. This follows as, again at points of differentiability, we can write $\frac{d\pi_I}{d\psi} = \frac{d\pi_I}{ds_I^*}\frac{ds_I^*}{d\psi} + \frac{\partial \pi_I}{\partial \psi}$, where it is straightforward to show that $\frac{d\pi_I}{ds_I^*}\frac{ds_I^*}{d\psi} < 0$ remains bounded away from zero while $\frac{\partial \pi_I}{\partial \psi} = 2G\left(s_I^*\right)\int_{s_I^*}^{\bar{s}} [\mu(s) - k] g(s)\, ds$ converges to zero as $s_I^* \to \underline{s}$. *Q.E.D.*

References

BERNARDO, A., CAI, H., AND LUO, J. "Capital Budgeting and Compensation with Asymmetric Information and Moral Hazard." *Journal of Financial Economics*, Vol. 61 (2001), pp. 311–344.

———. "Motivating Entrepreneurial Activity in a Firm." Working Paper, Department of Economics, UCLA, 2006.

BOOT, A., MILBOURN, T., AND THAKOR, A. "Sunflower Management and Capital Budgeting." *Journal of Business*, Vol. 78 (2005), pp. 501–527.

BRUSCO, S. AND PANUNZI, F. "Reallocation of Corporate Resources and Managerial Incentives in Internal Capital Markets." *European Economic Review*, Vol. 49 (2005), pp. 659–681.

CORE, J., GUAY, R., AND LARCKER, D. "Executive Equity Compensation and Incentives: A Survey." *Economic Policy Review*, Federal Reserve Bank of New York, 2003, pp. 27–50.

FRIEBEL, G. AND RAITH, M. "Resource Allocation and Firm Scope." CEPR Discussion Paper no. 5763, 2006.

GROMB, D. AND MARTIMORT, D. "The Organization of Delegated Expertise." Working Paper, London Business School, 2004.

HARRIS, M. AND RAVIV, A., "The Capital Budgeting Process: Incentives and Information." *Journal of Finance*, Vol. 51 (1996), pp. 1139–1174.

———, KRIEBEL, C., AND RAVIV, A. "Asymmetric Information, Incentives, and Intrafirm Resource Allocation." *Management Science*, Vol. 28 (1982), pp. 604–620.

INDERST, R. AND LAUX, C. "Incentives in Internal Capital Markets: Capital Constraints, Competition, and Investment Opportunities." *RAND Journal of Economics*, Vol. 36 (2005), pp. 215–228.

——— AND MULLER, H. "Internal versus External Financing: An Optimal Contracting Approach." *Journal of Finance*, Vol. 58 (2003), pp. 1033–1062.

JENSEN, M. "Agency Costs of Free Cash Flow, Corporate Finance, and Takeovers." *American Economic Review*, Vol. 76 (1986), pp. 323–329.

———. "Paying People to Lie: The Truth about the Budgeting Process." *European Financial Management*, Vol. 9 (2003), pp. 379–406.

LEVITT, S.D. AND SNYDER, C.M. "Is No News Bad News? Information Transmission and the Role of Early Warning in the Principal-Agent Model." *RAND Journal of Economics*, Vol. 28 (1997), pp. 641–661.

MARINO, A.M. AND ZABOJNIK, J. "Internal Competition for Corporate Resources and Incentives in Teams." *RAND Journal of Economics*, Vol. 35 (2004), pp. 710–725.

OZBAS, O. "Integration, Organizational Processes, and Allocation of Resources." *Journal of Financial Economics*, Vol. 75 (2005), pp. 201–242.

PRENDERGAST, C. "The Tenuous Trade-Off between Risk and Incentives." *Journal of Political Economy*, Vol. 110 (2002), pp. 1071–1102.

ROTEMBERG, J. AND SALONER, G. "Benefits of Narrow Business Strategies." *American Economic Review*, Vol. 84 (1994), pp. 1330–1349.

STEIN, J. "Internal Capital Markets and the Competition for Corporate Resources." *Journal of Finance*, Vol. 52 (1997), pp. 111–133.

———. "Information Production and Capital Allocation: Decentralized versus Hierarchical Firms." *Journal of Finance*, Vol. 57 (2002), pp. 1891–1921.

WULF, J. "How Tenuous Is the Trade-Off between Risk and Incentives? Evidence from Divisional Manager Positions." Working Paper, University of Pennsylvania, 2005.

ZABOJNIK, J. "Pay-Performance Sensitivity and Production Uncertainty." *Economics Letters*, Vol. 53 (1996), pp. 291–296.