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Managerial Compensation, Bonus Banks, and Long-Term Orientation

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ABSTRACT

Bonus banks are multiyear performance plans for deferring bonus payments and enhancing pay-for-performance by facilitating downward corrections of bonuses. These compensation schemes have become widely accepted among practitioners and regulators in recent years with the aim to reduce managerial short-termism. This paper examines the incentive properties of bonus bank schemes based on performance measures as proposed in the literature. To attain efficient investment decisions, such a scheme depends on managers' reports about value creation, but managers have incentives to misreport. We study how the bonus bank can be used to elicit truthful reporting and hence efficient investment in multiyear settings. For situations in which equity market values are not applicable, for example, when managers have private information, we find that an internal market for the bonus bank between the leaving manager and the successor can induce truthful reporting under restrictive conditions only. In particular, negotiations under asymmetric information require the successor to have significantly superior capabilities to compensate for the uncertainty inherent in valuing the bonus bank.

1 | Introduction

This paper formally analyzes the investment incentives of bonus banks. Bonus banks are multiyear accounting-based performance plans in which a portion of variable remuneration is not paid out immediately but collected in internal accounts, deferred and paid out subject to prespecified conditions. Bonus banks are considered an effective way to integrate negative bonuses in compensation schemes in order to deter managers from short-termism (Murphy and Jensen 2011). Short-termism includes any actions that increase short-term returns at the expense of long-term performance, such as taking on negative NPV projects or engaging in accounting earnings management or fraud (Edmans et al. 2012).

Bonus banks have become popular in the aftermath of the financial crisis, to which defective remuneration was found to be a contributory factor (Ibrahim and Lloyd 2011). Europe and Australia have introduced regulatory requirements for such schemes and the U.S. follow a similar approach.[1] Consulting firms have promoted bonus banks to attain managerial long-term orientation for a long time, but how this objective is achieved is left unexplained (Stewart 1991; Young and O'Byrne 2001). Despite their increasing prevalence, it is yet unclear whether they are effective in aligning managerial behavior with firm interest. The aim of this study is to examine the incentive properties of bonus banks as they are proposed in the literature (e.g., Bischof et al. 2010; O'Hanlon and Peasnell 2002).

With few exceptions (e.g., Hartmann and Slapnicar, 2015; O'Hanlon and Peasnell, 1998, 2002), bonus banks have received little attention in the literature. O'Hanlon and Peasnell (2002) propose that bonus banks can mitigate short-termism if they are based on an accounting performance measure called "Excess Value Created" (EVC), but do not analyze the incentive properties of such a bonus scheme. EVC is identical to the net present value (NPV) of a project at its initiation. In later periods, EVC measures additional value creation and managers' success in the realization of initial plans, based on actual performance and current knowledge. However, EVC depends on managers' reports about value creation and managers have incentives to misreport. As a result, the incentive problem is shifted from investment decision-making to determining value creation.

Edmans et al. (2012) assume that value creation can be determined based on observable market prices in an efficient capital market and find that bonus structures similar to bonus banks mitigate the problem of top-level managers' myopia in listed firms. However, stock market values may not always be available (Baker 1992) or may not be a sufficient performance metric to measure managerial effort or skill (Indjejikian 1999; Ittner et al. 1997; Sloan 1993). In particular, stock prices may not fully reflect valuable contracting information, because managers have private information about how their effort or skill translates into firm value (Bushman et al. 1996). Even if market prices include all available information on managerial actions, the relative weights placed on these signals will not be the same as the weights that would be given to them in the incentive contract (Gjesdal 1981; Paul 1992; Feltham and Xie 1994).[2] Moreover, stock market values are subject to fluctuations that are beyond managers' control and the use of accounting-based performance measures in compensation contracts helps shield executives from these fluctuations (Sloan 1993).

This incremental usefulness of accounting measures of performance over stock prices derives from their stewardship value as opposed to their valuation usefulness for investors (Bushman et al. 2006). Bonus banks focus on the stewardship function and measure performance by contrasting expectations with realizations of value creation in each period. Because investment decisions are delegated to managers because they have better (private) information on investment prospects, the information aggregated in market prices will in many cases be insufficient to measure performance for the bonus bank. Consequently, we study the incentive properties of bonus banks based on accounting measures rather than stock market values.

We examine an analytical model in which investment decision-making is delegated to the better-informed manager and compensation is determined based on accounting information. When managers are myopic, that is, are planning to leave or retire before all the benefits of the investment are realized, they may underinvest relative to the efficient level. We follow Baker (1992) and Bushman et al. (2000) and assume that the principal's objective (firm value) is not contractible because it is not observable. Managers are better informed about an investment opportunity and the firm relies on managerial reports about investment profitability based on generally accepted accounting principles (GAAP). Because accounting-based performance measures provide the opportunity for managers to misreport (Burgstahler and Dichev 1997), managers may inflate reported performance in an attempt to maximize their payoffs. Consequently, we study whether the bonus bank can be used to induce truthful reporting and mitigate underinvestment problems in situations where the firm depends on managerial reports and managers can misreport.

We use the result developed by Rogerson (1997) as the benchmark solution. He shows that a special cost-allocation procedure to determine residual income (RI) for managerial performance evaluation can solve the problem of myopic underinvestment. However, this solution relies on information about an investment's relative productivity profile over time, which is frequently not available to the firm. In particular, Rogerson (1997) does not address how truthful information can be obtained to implement the proposed cost-allocation procedure, which is considered here.

We analyze bonus banks based on EVC as proposed by O'Hanlon and Peasnell (2002), and find that an optimal bonus pay-out-scheme can be developed that reproduces the Rogerson-solution. However, this scheme requires that the principal knows EVC ex ante. Consequently, inducing the manager to truthfully report about value creation becomes the main problem when the manager has private information about project profitability. Similar to Edmans et al. (2012), who use stock prices determined in an efficient capital market to capture the consequences of managers' actions, we rely on an internal market, because a price mechanism is considered the most efficient way to aggregate asymmetric information (Hayek 1945; Grossman 1976). We examine a situation where the leaving manager is allowed to sell the bonus bank to a successor when leaving the firm before the project is completed. Such a scenario is often found in firms without publicly traded shares. For example, partnerships and private firms frequently rely on negotiations to determine the value of firm shares (Scholes et al. 2007, Scholes et al., 2008). Similarly, legal acts on limited liability companies often rely on arms-length transactions to determine the payment a partner receives when withdrawing from the partnership (Donn 1998; Saulsbury 2011). Internal markets that allow firms to elicit dispersed asymmetric information are also used to determine the value of phantom shares (e.g., Matzler et al. 2016). Phantom shares allow firms to tie compensation to firm value even when the stock is not publicly traded (e.g., Ellig 2014; Whittlesey 1994; England 1992). Bonus banks differ from phantom shares in that their value, like goodwill, is a residual value (O'Hanlon and Peasnell 2002; Ohlson 2002; Schultze and Weiler 2010) and depends on a comparison of projected and realized performance.

We assume that the successor is better informed than the firm and serves to verify investment prospects. This assumption is legitimate, considering that the successor who is chosen to replace the leaving manager needs to have similar capabilities, including personal traits, skill, characteristics and knowledge that affect the project's profitability. We analyze the conditions under which bonus banks can provide efficient investment incentives if trade occurs under (i) symmetric or (ii) asymmetric information between the trading parties. Under symmetric information, the successor is as well informed about the investment as the leaving manager and both managers directly observe each other's capabilities. Under asymmetric information, managers have incomplete knowledge of each other's capabilities and estimate the value of the project.

Under symmetric information between the managers, we find that the internal market creates incentives for efficient investment decisions if the leaving manager can expect the successor to have at least equal capabilities. As the successor can directly determine project value and reveal misreporting, the leaving manager has no incentive to lie. The purchase price reflects all information on both managers' capabilities.

Under asymmetric information, we find that efficient investments and truthful reports are induced as long as the successor has higher capabilities. When both managers have incomplete information about each other's capabilities and bargain under two-sided information asymmetry, the successor is willing to trade only if the value surplus he can generate compensates for potential overstatements of the bonus bank by the leaving manager. When the successor can estimate the leaving manager's capabilities, the managers bargain under one-sided information asymmetry. In both cases of (one- and two-sided) information asymmetry, the bonus bank creates efficient investment incentives as the leaving manager receives a share of the value surplus created by the successor's higher capabilities. Trade is more likely to occur when the uncertainty about managerial capabilities is lower. The resulting purchase price contains information about the managers' capabilities which are not observable by the firm or the capital market.

Our study contributes to the literature analyzing the effectiveness of performance metrics and incentive systems used in practice, such as Economic Value Added (EVA) (e.g., Biddle et al., 1997; Ittner and Larcker, 2001; O'Hanlon and Peasnell, 1998, 2002), by highlighting that bonus banks as proposed in the literature mitigate myopic investment decisions only under restrictive conditions. In particular, their use requires a mechanism to induce truthful reporting about value creation. We show that under asymmetric information between the managers, an internal market can provide such incentives only if the successor can create a value surplus. When these conditions for the managers' capabilities are not met, the bonus bank will fail to provide efficient investment incentives. We also show that transparency about the leaving managers' capabilities increases the likelihood of trade and hence improves efficient investment decision-making.

We also contribute to the literature on dynamic incentives. We extend Edmans et al. (2012) and Zhu (2018) to situations where firms use accounting performance measures because stock market-based performance measures are not available or applicable for use in incentive contracts (Indejejikian and Nanda 1999; Bernardo et al. 2004). We identify the conditions under which an internal market can be used to reveal managers' private information that is not available to the firm or its owners. Prices observed in the internal market under asymmetric information aggregate managers' private information on their capabilities and their effect on project value. As a result, the internal market price differs from a price obtained in a less than strong-form efficient capital market that cannot observe managers' private information. A bonus bank based on such external market prices would not provide efficient incentives.

The following Section 2 discusses the related literature. Section 3 describes the model framework, formalizes the bonus bank based on EVC, and presents the benchmark solution. Section 4 examines the incentive properties of the bonus bank and Section 5 provides a critical discussion and conclusion.

2 | Related Literature

2.1 | The Problem of the Impatient Manager and Goal Congruence

There is a large literature on the problem of the "impatient manager". If the manager's compensation contract is based on accounting performance measures, he can affect both future cash flows and his compensation by adapting investment levels. Investment levels thus depend on the manager's private incentives. If the manager's time horizon is shorter than the firm's because he plans to leave or retire, or the manager's attitude towards risk is different than the firm's, he may have incentives to underinvest.

Three different concepts of efficient investment incentives are used in the literature: goal congruence, strong goal congruence and robust goal congruence. Goal congruence is the general incentive compatibility constraint. It creates incentives for the manager to accept all projects with a positive *NPV* by ensuring that the present value of the gain from accepting a project is proportional to the project's *NPV* (Reichelstein 1997). When the manager's and the project's time horizons are not conflicting, compensation contracts based on residual income *RI* induce efficient investment decisions. The reason for this result is the conservation property (Preinreich 1937). However, this result does not hold when managers are impatient. Goal congruence is not sufficient to induce efficient investment decisions when the manager is impatient (e.g., Dutta and Reichelstein 2005).

For the case when the manager's and the project's time horizons are conflicting, Rogerson (1997) shows that the problem of the impatient manager can be solved by applying specific accounting rules when the incentive contract is based on *RI*. Such strong goal congruence creates incentives for the manager to accept all projects with a positive *NPV* (Rogerson 1997). Under strong goal congruence, the gain from accepting a project has the same sign as the project's *NPV* in each period. Dutta and Reichelstein (2002) extend the analysis of Rogerson (1997) with respect to an adverse selection problem and show that the Rogerson-solution can also be applied when the manager has precontract information about the absolute profitability of a project. In this case, informational rents that must be paid to the manager can be captured by a hurdle rate strictly exceeding the firm's cost of capital. Again, the problem of the impatient manager can be solved by using *RI* as a performance measure in combination with specifically designed accounting rules. Rajan and Reichelstein (2009) find that any depreciation schedule, which is accelerated relative to the allocation rule proposed by Rogerson (1997), results in underinvestment if the manager is impatient.

In the special case of capital constraints, when the manager has to decide about a portfolio of projects, strong goal congruence is not a sufficient criterion. Mohnen and Bareket (2007) develop accounting rules leading to an annuity-*RI* that induce an impatient manager to choose the investment levels that maximize the

NPV of the investment portfolio. This concept is termed robust goal congruence. We use these concepts of goal congruence as benchmark solution.

However, these solutions to the problem of the impatient manager rely on the investment's relative productivity profile over time which is used to determine goal congruent performance measures. Yet, this information is frequently not available to the firm, and it is often considered impractical to alter the accounting and adjust performance measures used in incentive contracts. We consequently examine the use of the bonus bank to generate incentives for better-informed managers to reveal this information. We extend this literature by addressing the question how truthful information can be obtained to implement goal congruent incentive payments. Rather than implementing goal congruent performance measures as a basis for linear bonus schemes, the bonus bank solution considered here implements strong goal congruent bonus payments based on generally accepted accounting principles (GAAP).

2.2 | Bonus Banks Based on Residual Income (Practitioners' Approach)

The practitioners' literature claims that bonus banks (i) encourage long-term decision-making by managers, (ii) smooth bonus payments to the manager, and (iii) provide a potentially unlimited reward for success and a genuine penalty for failure (Ehrbar 1998; Stewart 1991). Bonus banks are internal accounts which accumulate and transfer bonuses to later periods when they are paid out subject to meeting predetermined performance targets. Essentially, bonus banks have four key elements (Stewart 1991): (i) rules for out- and inflows of bonuses from and to the bonus bank, (ii) the interest rate used to compound the balance of the bonus bank, (iii) an arbitrary amount which is credited to the bonus bank at the starting point (i.e., "opening balance"), and (iv) rules concerning the final settlement of the bonus bank account.

Rules for out- and inflows of bonuses are designed to provide incentives for managers to act in the owners' best interest. The literature generally assumes that the bonus bank is based on *RI* calculated based on GAAP (Ehrbar 1998; Stewart 1991). Fractions of positive (negative) *RI* are credited (debited) to the bonus bank, retained and accumulated at an interest rate r. Fractions of the resulting balance are paid out later. Bonus payouts from the bonus bank consequently depend on current and past performance. This is considered a way of creating liability on the downside and holding the manager accountable for unfavorable outcomes in any given period. Recouping compensation would be difficult if the bonus had been paid out earlier. The remaining bonus bank balance is retained and accumulated at an interest rate r. The practitioners' literature does not explicitly discuss the interest rate r used to compute the balance of the bonus bank.

The third element of a bonus bank contract is the opening balance. According to Stewart (1991), it can be the result of the following cases: (i) the opening balance constitutes a loan to the manager which is amortized, (ii) it is contributed by the manager himself, or (iii) the opening balance may come "from nowhere at all" (p. 237). A positive opening balance is intended to allow for possible negative bonuses to be deducted from the bonus bank and avoid negative bonus payments (Bischof et al. 2010).

The fourth element of a bonus bank is its final settlement. Proposed rules for the case when the manager leaves the firm before project completion include paying out the entire positive balance or forfeiting some or even all of the leaving manager's bonus bank balance (Bischof et al. 2010; Stewart 1991). The former may create incentives for managers to leave in case of negative performance expectations, whereas managers will be more inclined to stay if job termination results in forfeiture of the bonus bank balance (Bischof et al. 2010). Regardless of the settlement rule, managers who cannot expect to receive any positive bonus payments in the near future due to accumulations of negative bonuses do not have incentives to stay. Firms may thus encourage outperformers to stay and underperformers to quit (Stewart 1991). The resulting ex ante investment incentives of both settlement rules are not considered in the practitioners' literature.

2.3 | Bonus Banks Based on Excess Value Created

O'Hanlon and Peasnell (2002) discuss the bonus bank and find that the practitioners' arguments are solely based on the "conservation property" of residual income (*RI*). If the manager is rewarded proportionately to *RI* and has the same time preferences as the firm, he will choose the investment level that maximizes *NPV*. If, however, his time horizon is different, the conservation property is insufficient because there is no immediate link between *RI* observed in one particular period and a manager's success in achieving long-term value creation.

In view of this deficit, O'Hanlon and Peasnell (2002) develop a measure of long-term value creation termed "excess value created" (*EVC*) which captures both value creation and value realization in one period (Ohlson 2002). Value creation means that the manager initiates projects that increase shareholder wealth. It is the result of an infinite series of excess returns (Johnson and Petrone 1998) and is equivalent to the present value of the expected future *RI*. In contrast, value realization describes the success in realizing the planned figures. Realized value is identical to all *RI* earned and accumulated to date t, accrued at the interest rate r. *EVC* thus segregates the past and the future part of value creation (Ohlson 2002) and provides the "missing link" between goodwill accounting, capital budgeting and performance measurement (O'Hanlon and Peasnell 2002). While O'Hanlon and Peasnell (2002) suggest that bonus banks be based on periodic changes of *EVC* rather than *RI*, they provide no analysis of the incentive properties of this mechanism. This paper fills this gap and finds that such bonus banks only create efficient investment incentives under restrictive conditions.

2.4 | Incentive Properties of Bonus Banks

To the best of our knowledge, only Edmans et al. (2012) and Zhu (2018) provide formal analyses of the incentive properties of bonus banks. In particular, Edmans et al. (2012) study a "dynamic incentive account" similar to a bonus bank. In their model, myopic behavior inflates firm value in the short-term but is detrimental in the long-term. The proposed solution consists of three key components: The present value of all future compensation is (i) credited to an internal account in the period when the manager is appointed, (ii) invested in firm stock, and (iii) paid out over a period of time exceeding the manager's appointment. The value of the internal account depends on firm value and is determined in an efficient capital market. By assumption, managers' actions directly translate into firm market value. Deferring payout of bonuses over time until all consequences of myopic behavior are realized ensures that managers participate in the long-term consequences of their actions.

Consequently, the results in Edmans et al. (2012) largely depend on the observability of managers' actions in an efficient capital market. In contrast, we assume that managers have private information about how their capabilities affect firm value. Moreover, in their model, managers receive bonus payments after they have left the firm. Doing so rewards managers based on the performance of others, not their own, which contradicts the controllability principle (Antle and Demski 1988). If managers were rewarded based on the bonus bank after they have left the firm, their expectations about future performance would affect their reports about EVC and would hence bias their investment decisions. While the literature (e.g., Bischof et al. 2010; Stewart 1991) considers paying out some or all of the remaining bonus bank balance, continuing the bonus bank account after the manager has left is not considered feasible. In addition, literature finds that the number of clawbacks that are enforced in practice is limited indicating that bonus adjustments after managers' employment are problematic (Fried and Shilon 2011; Glater 2005; Addy et al. 2014).[3] Consequently, we study a setting where no bonus payments are made after the manager leaves the firm. When managers have private information on how their capabilities affect firm value and the firm cannot rely on efficient market prices to reveal the consequences of managers' actions on firm value, the firm depends on managerial reports until value creation is revealed at the end of the project. Obviously, unconditional payout of the remaining bonuses to leaving managers would not induce efficient investment when myopic managers can inflate these bonuses by misreporting. Our model hence examines whether an internal market allows the firm to induce truthful reporting.

We further extend prior results by Zhu (2018) to investment decisions with continuous effects on performance in multiple periods. Zhu (2018) examines a model with consecutive one-period investments and dichotomous (high vs. low) performance outcomes. At the beginning of each period, managers can choose an investment that leads to high performance at the end of the period only if the investment is successful. Alternatively, they can choose a myopic action that surely leads to high performance at the end of the period, but low performance in the following period. In the bonus bank contract, variable remuneration is earned in prior periods and paid out in subsequent periods only if performance is high. Consequently, managers have no incentive to choose the myopic action because they would not receive the bonuses earned. By continuity, this result translates to future periods and managers will choose the long-term investment only.

In the model used in Zhu (2018), the firm observes "output" as a signal of high or low performance at the end of each period, which is possible because investment projects only span one period. However, Zhu (2018) is not concerned with performance measurement and does not consider investments that span multiple periods. In general, the performance of a multiperiod investment will only be observable upon termination of the project. During the course of the project, cash flows provide no clear signal of project performance and the firm cannot determine high or low performance based upon these (Dechow 1994). For this reason, Rogerson (1997) has developed a cost-allocation procedure to determine a performance measure that annuitizes this problem: the resulting RI is positive in each period if, and only if, the NPV of the project is positive. This performance measure provides a period-by period indication of high or low performance, but it makes a bonus bank redundant, as bonuses can directly be based on this measure to provide strong goal congruent investment incentives. However, this solution of adjusted accounting performance measures relies on the investment's relative productivity profile over time, which is frequently not available to the firm. We consequently examine the use of the bonus bank to generate incentives for better-informed managers to reveal this information. Zhu (2018) does not consider how accounting performance measures can be used to induce efficient investment decisions on multiperiod investments regardless of the manager's time horizon by means of a bonus bank. Our analysis closes this gap and shows that bonus banks can reproduce the stream of bonus payments as in Rogerson (1997) and induce efficient investment decisions in multiperiod investments. We also extend Zhu (2018) to a setting with multiple investment opportunities and find that under certain conditions managers will maximize firm value even for a portfolio of investment projects.

3 | The Model

3.1 | Model Assumptions

We consider a model in which the risk-neutral principal delegates an investment decision to the better informed, risk-neutral manager.[4] Consider $T+1$ periods indexed by $t \in \{0, \ldots, T\}$. The principal hires a manager at the beginning of $t=0$ to choose the efficient investment level in period 0 and to realize cash flows in each of the periods $1, \ldots, T$. Investment decisions are delegated to managers because they are better informed about project profitability.

A project has the cash flow structure $(-I, CF_1, \ldots, CF_T)$, where I denotes the level of investment in $t=0$ and CF_t is the cash flow at date t associated with the project. The accounting system directly measures I and realized CF_t. Assume that the manager is better informed about her own time horizon $T^A \leq T$.[5] Further assume that the manager has private information on θ, which reflects the manager's capabilities including personal traits, skill, characteristics and knowledge that determine the marginal productivity of the investment. θ is drawn from a set Θ before the principal offers the manager a contract. Whereas the manager directly observes θ, the firm can only form expectations of θ during the hiring process, that is, $E_0(\theta)$. Further assume that the manager's and the principal's cost of capital r are equivalent. The period t cash flow is affected by θ and the investment level I. Formally, the period t cash flow is determined by

$$CF_t = \rho_t \delta(I, \theta) + \varepsilon_t \quad (1)$$

where $\delta(I,\theta) = \theta\delta(I)$ is an increasing function of I for every θ and ε_t is a normally distributed random variable $\varepsilon_t \sim N(0, \sigma^2)$. ρ is the time pattern of the investment's relative productivity profile, that is only known to the manager. As a result, expected future cash flows are only known to the manager. Further assume that ε_t is not correlated over time. As the productivity parameters ρ and $\delta(I,\theta)$ are linked in a multiplicatively separable way, the relative marginal productivity of investments across periods is not affected by the level of investment. Note that the optimal level of investment cannot be computed based on ρ without knowledge of θ. Further note that due to the shocks to cash flows, θ cannot be inferred from individual cash flow realizations.

The efficient investment level that maximizes expected discounted cash flows as a function of the manager's capabilities θ is the level that maximizes:

$$NPV_0 = \sum_{t=1}^{T} \frac{\rho_t \delta(I,\theta)}{(1+r)^t} - I \quad (2)$$

To guarantee that for every θ there is a unique value of I that maximizes the NPV of future cash flows, assume that for every θ, $\delta(I,\theta)$ is continuously differentiable, strictly increasing, and strictly concave in I. We denote the optimal investment level $\hat{I}(\theta)$.

$B(I) = (B_1(I), \ldots, B_T(I))$ represents the bonuses the manager receives from the project at the end of periods $1, \ldots, T$.[6] We abstract from operative effort incentives and assume zero private cost of value creation. Consequently, the manager's objective is to maximize the present value of expected bonuses during T^A $\sum_{t=1}^{T^A} \frac{E_0(B_t(I))}{(1+r)^t}$. We follow Rogerson (1997) and assume that bonus payments are restricted to the manager's employment with the firm.[7]

The manager chooses the investment level I^m to maximize the present value of expected bonus payments:

$$I^m \in \arg\max_I \sum_{t=1}^{T^A} \frac{E_0(B_t(I))}{(1+r)^t} \quad (3)$$

A bonus contract B induces efficient investment if, for every possible θ, managers maximize their expected utility by choosing the efficient investment level $I^m(\theta) = \hat{I}(\theta)$ which maximizes the NPV of the project.

The timeline and information structure is as follows: θ is randomly determined by nature before the manager and the principal first interact. Only the manager knows θ and T^A, the firm only observes $E_0(\theta)$. The firm offers the manager a bonus contract which specifies the bonus payments B_t from a bonus bank based on realized accounting performance.[8] If the manager accepts the contract, she then chooses an investment level in period 0. Otherwise, the relationship is over and she receives her reservation utility. In each of the following periods $t \in \{1, \ldots, T\}$, a cash flow is realized according to (1). The manager receives a bonus payment as specified by the bonus contract at the end of each period $t \in \{1, \ldots, T^A\}$.

3.2 | Formalization of Bonus Banks Based on Excess Value Created

O'Hanlon and Peasnell (2002) find that the bonus bank based on RI cannot provide long-term incentives, develop the performance measure EVC which captures both value creation and value realization in one period (Ohlson 2002), and suggest to use EVC to feed a bonus bank. EVC is formally defined as

$$EVC_t = \sum_{i=1}^{t} RI_i (1+r)^{t-i} + \sum_{i=1}^{\infty} E_t(RI_{t+i})(1+r)^{-i} \quad (4)$$

where RI is calculated based on generally accepted accounting principles (GAAP) in each period and $E_t(\cdot)$ denotes expected values in period t based on the information available in t. Formally, RI is defined as the difference between current period's net income NI^{GAAP} and the cost of capital r on the capital employed in the previous period CE_{t-1}:

$$RI_t = NI_t^{GAAP} - rCE_{t-1} \quad (5)$$

When performance evaluation is based on EVC, a constant portion ξ of Residual Economic Value Created ($REVC_t$) is credited to the bonus bank in any period t. REVC is the periodic change in EVC (ΔEVC) less the cost of capital on the previous period's EVC:

$$\begin{aligned} REVC_t &= \Delta EVC_t - rEVC_{t-1} \\ &= RI_t + \Delta NPV_t - rNPV_{t-1} \end{aligned} \quad (6)$$

where $NPV_t = \sum_{i=t+1}^{T} \frac{E_t(RI_i)}{(1+r)^{i-t}}$ denotes value creation until the end of the planning horizon in $t = T$ and $\Delta NPV_t = NPV_t - NPV_{t-1}$ denotes the periodic change in NPV. Consequently, in each period, REVC reflects deviations from original projections of value creation and value realization.

Payouts $B_t(\cdot)$ to the manager reduce the balance of the bonus bank. The opening balance K_0 of the bonus bank is given by $K_0 = \xi REVC_0 = \xi NPV_0$.[9] The bonus bank balance is compounded at the cost of capital r. As a result, the bonus payment B_t and the balance of the bonus bank K_t at date t are formally given by

$$B_t = \upsilon_t \xi REVC_t + \upsilon_t K_{t-1}(1+r) \quad (7)$$

$$\begin{aligned} K_t &= \xi REVC_t + (1+r)K_{t-1} - B_t \\ &= \xi \sum_{i=0}^{t} (1+r)^{t-i} REVC_i - \sum_{i=1}^{t} (1+r)^{t-i} B_i \end{aligned} \quad (8)$$

where υ_t is the payout ratio in period t in the REVC-based bonus bank.

In the period of initiating a new investment project, REVC equals the NPV of the project. In subsequent periods, a zero value for REVC indicates that original projections were exactly met and an adequate return was earned. From the perspective of date 0, $REVC_t,\ t = 1, \ldots, T$ are expected to be zero. As a result, the expected bonus payment B_t and the balance of the bonus bank K_t at date t can be rewritten as

$$\mathrm{E}_0(B_t) = \omega_t \xi REVC_0 (1+r)^t \tag{9}$$

$$\mathrm{E}_0(K_t) = \xi REVC_0(1+r)^t - \sum_{i=1}^{t} (1+r)^{t-i} B_i(I)(\cdot)\ \forall\ t \in \{0, \ldots, T\} \tag{10}$$

where $\omega_t = \upsilon_t \prod_{i=0}^{t-1} (1-\upsilon_i)$ reflects the payout ratio of $REVC_0$ in period t.

REVC reflects past and future performance that is not directly observable. The principal depends on managers' reports about forward-looking information at any date $t < T$ to determine REVC. The principal can only detect previous misreporting upon project completion; as a result, the manager may misreport at any date $t < T$ and REVC may be overstated. Let $l_t \geq 0$ be real-valued, where $l_t > 0$ denotes managers' overstatement for period t.[10] Let $REVC_t$ denote true REVC at date t and $REVC_t^l$ reported REVC with

$$REVC_t^l = REVC_t + l_t \tag{11}$$

Within this formulation, differences between reported forecasted values and later realized values are due to (i) an untruthful report by the manager ($l_t > 0$ for any t), and (ii) deviations from expected values. In this setting, a mechanism is needed to induce managers to truthfully report about value creation.

3.3 | Benchmark Solution

The structure of our model is equivalent to the model in Rogerson (1997) except for the assumptions on the incentive contract and the availability of cash flow information. We use the bonus structure resulting from the solution in Rogerson (1997) as our benchmark and examine whether a bonus bank based on REVC as defined in (9) and (10) can generate a bonus structure that induces efficient investment. When managers' time horizon is shorter than the firm's, strong goal congruence creates incentives for efficient investment decisions. It requires that managers' gain from accepting a project in each period has the same sign as the project's NPV and ensures that investment decisions are independent of managers' time horizon (Rogerson 1997).

Formally, a bonus contract B is strong goal congruent if expected bonus payments conditional on the investment level I satisfy the following conditions:

$$\begin{aligned} E_0(B_t(I)) &\geq 0\ \forall\ t \in \{1, \ldots, T\} \Leftrightarrow NPV_0(I) \geq 0 \\ E_0(B_t(I)) &< 0\ \forall\ t \in \{1, \ldots, T\} \Leftrightarrow NPV_0(I) < 0. \end{aligned} \tag{12}$$

A bonus contract B is robust goal congruent, if expected bonus payments during managers' time horizon T^A conditional on the investment levels I_s in S possible project portfolios indexed by $s \in \{1, \ldots, S\}$ satisfy the following condition:

$$\sum_{t=1}^{T^A} \frac{\mathrm{E}_0(B_t(I_s))}{(1+r)^t} = kNPV_{0,s}\ \forall\ s \in \{1, \ldots, S\} \tag{13}$$

for an arbitrary, nonnegative constant k. A contract that satisfies (12) and (13) solves the problem of managerial myopia under capital constraints. Similar definitions of strong and robust goal congruence are used in Ross (1973), Reichelstein (1997), Dutta and Reichelstein (2005), and Mohnen and Bareket (2007).

Rogerson (1997) shows that specific accounting rules achieve efficient investment decisions in a linear contract when managers receive a portion ξ of RI_t in each period. When RI_t is calculated according to the relative marginal benefits allocation rule (MBAR), that matches revenues and costs, bonuses are strictly positive in every period if and only if project NPV is positive. Let $a = (a_1, \ldots, a_T)$ be a vector of real numbers, where a_t denotes the investment cost allocated to period t for every monetary unit invested. These allocation costs comprise depreciation and interest charges on the remaining book value of the investment. Rogerson (1997) shows that MBAR, denoted by $a_t^{\rho,r}$, is the unique allocation rule that induces efficient investment decisions in a linear bonus contract. MBAR is given by

$$a_t^{\rho,r} = \frac{\rho_t}{\sum_{i=1}^{T} \frac{\rho_i}{(1+r)^i}} \tag{14}$$

When RI_t is calculated based on MBAR, bonus payments have the following structure:

$$B_t^{\rho,r}(I) = \xi \frac{\rho_t}{\sum_{i=1}^{T} \frac{\rho_i}{(1+r)^i}} \left(\sum_{t=1}^{T} \frac{\rho_t \delta(I,\theta)}{(1+r)^t} - I \right) \tag{15}$$

This solution can be extended to adverse selection problems when managers have precontract information about the absolute profitability of projects (Dutta and Reichelstein 2002). Any contract that replicates the stream of bonus payments $B_t^{\rho,r}$ according to (15) creates efficient investment incentives regardless of the manager's time horizon. We use (15) and (13) as the benchmark solution to the problem of managerial myopia to study the incentive properties of the bonus bank and examine whether bonus bank contracts based on REVC as defined in (9) and (10) achieve strong and robust goal congruence.

4 | Incentive Properties of Bonus Banks Based on Excess Value Created

4.1 | Bonus Banks Based on Excess Value Created Given Truthful Reporting

To analyze whether bonus banks can provide incentives for managers to report their private information truthfully, we first analyze a situation in which truthful reports about project NPV are available. In the next section, we analyze how such truthful reports can be attained.

Lemma 1. *Suppose that the manager is compensated according to the REVC-based bonus bank concept as defined in* (9) *and* (10). *Investment incentives are*

(i) strong goal congruent if bonus payments are as follows:

$$E_0\left(B_t(I)\right) = \omega_t \xi REVC_0(1+r)^t, \ \omega_t = \frac{\rho_t}{\sum_{i=1}^{T} \frac{\rho_i}{(1+r)^{(i-t)}}} \tag{16}$$

(ii) strong goal congruent and robust goal congruent if bonus payments are as follows:

$$E_0(B_t(I)) = \omega_t \xi REVC_0(1+r)^t, \ \omega_t \geq 0 \ \forall t \in \{0, \ldots, T\} \text{ and } \sum_{t=0}^{T} \omega_t = 1 \tag{17}$$

(iii) strong goal congruent and robust goal congruent, and reports will be truthful ($l_t = 0, \ \forall t \in \{0, \ldots, T\}$) *for a manager with* $T^A = T$ *if bonus payments are as follows:*

$$E_0(B_t(I)) = \omega_t \xi REVC_0(1+r)^t, \ \omega_t = 0 \ \forall t \in \{0, \ldots, T-1\} \text{ and } \omega_T = 1 \tag{18}$$

Lemma 1(i) shows that the Rogerson-solution can be reproduced by a specific pay-out-scheme ω_t when managers receive bonus payments from a bonus bank based on periodic changes of EVC. Because bonus payments are positive if and only if the NPV of the project is positive, the principal induces efficient investment decisions regardless of managers' time horizon or utility function. This solution requires knowledge of ρ.

While the MBAR-allocation rule is unique in inducing the efficient investment level (Rogerson 1997), Lemma 1(ii) shows that when truthful reports have been elicited, a large set of pay-out-schemes $(\omega_0, \ldots, \omega_T)$ induces efficient investment incentives according to (12) and (13) because $REVC_0$ reflects the economic value of a project. For any set of nonnegative pay-out ratios $(\omega_0, \ldots, \omega_T)$ that add up to 1 the bonus payment has the same sign as the project's NPV (measured by $REVC_0$) in each period and the present value of bonus payments from a specific project is linear in the project's NPV.[11] Managers maximize their bonus payments by choosing the efficient investment level regardless of their time preferences and choose the investment levels that maximize the value of a project portfolio under capital constraints. The REVC-based bonus bank attains strong and robust goal congruence. No adjustments to the measurement basis and accounting rules are necessary. In particular, this solution does not require the principal to have knowledge of ρ (but requires truthful reports about REVC).

One form of Lemma 1(ii) is a pay-out-scheme in which the entire bonus bank balance is paid out at one point in time $t = s$ and the manager receives a bonus $B_s(I) = \xi(1+r)^s REVC_0$ equal to the time value of a portion of project NPV.[12] If managers could sell the bonus bank in an arm's length transaction at its fair value, they could expect to receive this amount. When misreporting is possible, negotiations in an internal market can verify the value of the bonus bank. This is analyzed in detail in the following section 4.2, where we make use of this result as well as Lemma 1(iii).

Lemma 1(iii) shows that the REVC-based bonus bank and the bonus structure $\omega = (0, \ldots, 0, 1)$ induces strong and robust goal congruence as well as truthful reporting ($REVC_t^l = REVC_t, \ \forall t \in \{0, \ldots, T\}$) when managers plan to stay until project completion. Following (6), bonus payments can be made at the end of period T for each project based on the ex post realized value:[13]

$$\begin{aligned} B_T &= \xi \sum_{t=0}^{T} REVC_t(1+r)^{T-t} \\ &= \xi \sum_{t=0}^{T} \left(RI_t + NPV_t - (1+r)NPV_{t-1}\right)(1+r)^{T-t} \\ &= \xi \sum_{t=0}^{T} RI_t(1+r)^{T-t} \end{aligned} \tag{19}$$

Because bonus payments are based on realized, directly observable values, untruthful reports about forward-looking information do not affect bonus payments and misreporting is prevented.[14] However, when the manager plans to leave before project completion ($T^A < T$) and terminal bonus payments are not feasible, a mechanism is needed to induce truthful reporting. In the next section, we use Lemma 1(iii) to examine whether bonus banks provide incentives for managers to reveal their private information.

4.2 | Internal Market for the Bonus Bank

4.2.1 | The Internal Market Model

In this section, we analyze how an internal market for the bonus bank can be used as a device to provide incentives for managers to report their private information truthfully and thus ultimately to correctly value the bonus bank for providing efficient investment incentives. In the internal market, the leaving manager (manager 1) negotiates with a potential buyer (manager 2) in period j. A successful transaction leads to a purchase price P for the bonus bank. The intuition behind this analysis is as follows: If the leaving manager can expect to receive a price for the bonus bank which is equivalent to the present value of the bonus payments he would receive if he stayed with the firm, his initial investment decision will be unbiased by his later departure from the project as he can expect to receive his expected share of project cash flows even in case of his leaving. However, the succeeding manager will need to be able to manage the project in a way that realizes at least the same returns as the leaving manager would have realized if he had continued with the project to afford such a price. For the leaving manager to be contented with the sale of the bonus bank, a satisfactory purchase price for the bonus bank will hence depend on the capabilities of the successor relative to the leaving manager.

We focus our attention to situations in which the successor remains with the firm until project completion, that is, their time horizon T^S exceeds the remaining duration of the project ($T^S > T - T^A$).[15] Both managers are risk neutral and discount future bonus payments at the cost of capital r. We assume that the managers have capabilities θ_i, $i = 1, 2$, that will affect the project's absolute profitability $\delta(I, \theta_i) = \theta_i \delta(I)$, $i = 1, 2$, after the transaction. The random variables θ_i, $i = 1, 2$ are independently distributed. We assume that in the period of the investment ($t = 0$), only manager 1 has information about manager 2's expected capabilities. The capabilities of the leaving manager and the potential buyer are equal in expectation ($\mathrm{E}_0(\theta_1) = \mathrm{E}_0(\theta_2) = \theta_c$). We further assume that both managers know the project's relative productivity profile ρ, I and realized CF_t. We make no assumption about the hiring policies of the firm in which the successor is identified (Levin and Tadelis 2005). Bonus payments follow the REVC-based bonus bank concept as defined in (18).

In the bargaining process, each manager has two choices in period $j \in \{0, \ldots, T-1\}$: Manager 1 can sell the bonus bank for a price P, or continue with the project. In the latter case, manager 1 receives a bonus payment at date T according to (19). The reservation utility of manager 1 $U_j^1(\cdot)$ at date j is:

$$U_j^1(\cdot) = \xi\left(\sum_{i=1}^{j} RI_i(\theta_1)(1+r)^{j-i} + \sum_{i=j+1}^{T} \mathrm{E}_j(RI_i(\theta_1))(1+r)^{j-i}\right) \tag{20}$$

Manager 2 can buy the bonus bank for a price P or invest in risk-equivalent financial assets on the capital market. The value of the bonus bank for manager 2 ($U_j^2(\cdot)$) at date j is given by

$$U_j^2(\cdot) = \xi\left(\sum_{i=1}^{j} RI_i(\theta_1)(1+r)^{j-i} + \sum_{i=j+1}^{T} \mathrm{E}_j(RI_i(\theta_2))(1+r)^{j-i}\right) \tag{21}$$

The difference between both utilities depends on the managers' capabilities to generate future cash flows.

Deviations of the time line and information structure from the basic model are as follows: In period 0, nature has already randomly and independently determined θ_i, $i = 1, 2$. Only manager i knows his capabilities θ_i. The firm observes $\mathrm{E}_0(\theta_1)$ during the hiring process and offers manager 1 a bonus bank contract with bonus payments as defined in (18). Manager 1 chooses an investment level I in period 0 if she accepts the contract. In period $j \in \{0, \ldots, T-1\}$, manager 1 negotiates the purchase price of the bonus bank ($B_j(\cdot) = P$) with manager 2. If no trade takes place, manager 1 stays with the firm and receives a bonus payment according to (19) at date T, while manager 2 invests in risk-equivalent financial assets on the capital market. If trade takes place, manager 2 pays manager 1 a price P to buy the bonus bank. Manager 2 receives a bonus payment according to (19) at date T. The bonus payment in T according to (19) is based on observable value creation and independent from l_t. As a result, reporting will be unbiased whether or not trade takes place as shown in Lemma 1.

4.2.2 | The Bargaining Solution Under Symmetric Information About Project Profitability

We begin our analyses of the incentive properties of an REVC-based bonus bank for a situation when the leaving manager and the successor are both able to observe the other manager's capabilities.[16] We assume here that in the period of trade, manager 1 and 2 symmetrically observe each others' capabilities θ_1 and θ_2 and update their beliefs about future performances. Figure 1 depicts the sequence of events for this situation and illustrates directly observable flows of funds. It also represents the leaving manager's and the successor's information regarding the project's future profitability.

To attain a purchase price between symmetrically informed managers, we exploit the Nash bargaining solution (Nash 1950). The upper bound for a possible purchase price P is the value of the bonus bank for manager 2. He will not pay a price P that exceeds his expectations in the project. The lower bound for a possible purchase price P is the value of the bonus bank for manager 1. She will only trade the bonus bank for a price P exceeding her value of the bonus bank. The boundaries of the purchase price are given by

$$U_j^1(\cdot) \leq P \leq U_j^2(\cdot) \tag{22}$$

Solving the Nash-bargaining solution yields the optimal price P for the bonus bank in $t = j$:

$$P = \xi\left(EVC_j + \frac{1}{2}\left(\sum_{i=j+1}^{T} \left(\mathrm{E}_j(RI_i(\theta_2)) - \mathrm{E}_j(RI_i(\theta_1))\right)(1+r)^{j-i}\right)\right) \tag{23}$$

Trade occurs if and only if the investment's marginal productivity under manager 2 is at least as high as the marginal productivity under manager 1, that is, if manager 2 has at least the same capabilities as manager 1 ($\theta_1 \leq \theta_2$).

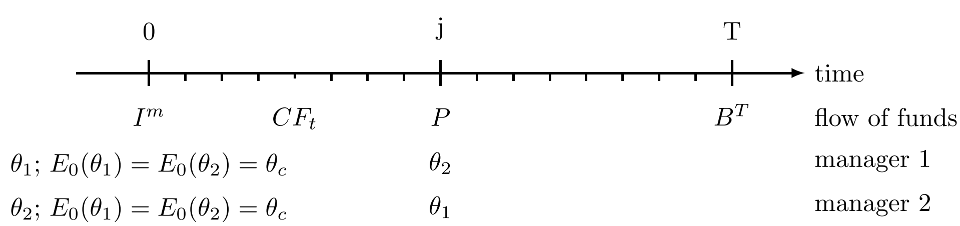

FIGURE 1 | Sequence of events - Bargaining under symmetric information.

To examine the incentive properties of the Nash-bargaining solution, we calculate the expected purchase price for the leaving manager.

Proposition 1. *Suppose that the capabilities of the leaving manager and the potential buyer are equal in expectation*($\mathrm{E}_0(\theta_1) = \mathrm{E}_0(\theta_2) = \theta_c$)*. The state parameter* θ_c *is the best estimate of the project's profitability in* $t = 0$*. The expected purchase price* $\mathrm{E}_0(P)$ *at date* $t = 0$ *under a Nash-bargaining solution is*

$$\mathrm{E}_0(P) = \xi(1+r)^j NPV_0(I, \theta_1, \rho, T) \tag{24}$$

for an arbitrary $j \in \{0, \ldots, T-1\}$*. Manager 1 is rewarded based on the project's NPV. She has no incentive to lie and will choose the efficient investment level, that is,* $I^m(\theta_1) = \hat{I}(\theta_1)$ *and* $l_t^i = 0, \forall t \in \{0, \cdots, T\}$.

Proposition 1 shows that manager 1 will choose the efficient investment level regardless of his time horizon T^A, when manager 1 expects manager 2 to have equal capabilities ($\mathrm{E}_0(\theta_1) = \mathrm{E}_0(\theta_2) = \theta_c$), that is, when the distribution function of the managers' capabilities is identical. The intuition is that when the succeeding manager 2 has at least equal capabilities, the value of the bonus bank will be at least as high as if the leaving manager 1 decided to stay. The leaving manager 1 will hence receive a bonus of at least the same amount as if he had stayed. Moreover, when manager 2 has superior capabilities, symmetric information about project profitability in $t = j$ leads to a purchase price for the bonus bank that is equal to the overall project value as reflected by EVC and half of the additional value created by the successor's superior capabilities. The added value of the transaction is shared evenly between manager 1 and manager 2. Both benefit from higher future cash flows if manager 2's capabilities are superior ($\theta_1 < \theta_2$) and have strong incentives to trade. Because manager 2 can directly observe the true value of the bonus bank, manager 1 has no incentives to provide untruthful reports. If manager 1 anticipated manager 2 to have superior capabilities ($\mathrm{E}_0(\theta_1) < \mathrm{E}_0(\theta_2)$), she would still make efficient investments, because these superior capabilities of manager 2 will only generate additional project value that manager 1 participates in. As a result, the leaving manager's objective is to maximize expected project value given the successor's expected capabilities and investment decisions will be efficient in expectation.

This cooperation between the managers is also beneficial from the perspective of the firm, because it creates additional value, that the managers participate in. Consider REVC in the period of trade ($t = j$) under the assumption that differences in the economic performance are solely due to the sale of the bonus bank ($\mathrm{E}_j(RI_j) = RI_j$):

$$\begin{aligned} REVC_j &= RI_j - r\left(\sum_{i=j}^{T} \mathrm{E}_j(RI_i(\theta_1))(1+r)^{j-i-1}\right) \\ &\quad + \sum_{i=j+1}^{T} \mathrm{E}_j(RI_i(\theta_2))(1+r)^{j-i} - \sum_{i=j}^{T} \mathrm{E}_j(RI_i(\theta_1))(1+r)^{j-i-1} \\ &= \sum_{i=j}^{T} \mathrm{E}_j\big(RI_i(\theta_2) - RI_i(\theta_1)\big)(1+r)^{j-i}. \end{aligned} \tag{25}$$

This implies that $REVC_j > 0$ if $\theta_1 < \theta_2$. If the successor can increase project NPV, the successor has incentives to take over the project because his payoff is proportional to the additional value created.

4.2.3 | The Bargaining Solution Under Asymmetric Information About Project Profitability

In many real world situations, the managers will not have the same information about the other manager's capabilities. This section hence relaxes the assumption of symmetric information between the two managers and considers a setting where the managers bargain under incomplete information about their capabilities θ_i. In addition to the model assumptions in Section 4.2.1, in this section we assume that in the period of trade manager 1 and manager 2 observe the cumulative distribution function $F_i(\theta_i), i = 1, 2$ of each other's capabilities. The event sequence for this situation is displayed in Figure 2, as well as the leaving manager's and the successor's information concerning the project's future profitability.

The random variables $\theta_i,\ i = 1, 2$ are independently distributed with cumulative distribution functions $F_1(\theta_1)$ and $F_2(\theta_2)$ that have strictly positive densities $f_1(\theta_1)$ and $f_2(\theta_2)$ in the respective range $\Theta_i = [\underline{\theta_i}, \overline{\theta_i}]$. We follow Chatterjee and Samuelson (1983) in restricting attention to uniform type distributions. To avoid different case distinctions, we assume

$$\max\left\{\underline{\theta_1}, \underline{\theta_2}\right\} < \theta_1, \theta_2 < \min\left\{\overline{\theta_1}, \overline{\theta_2}\right\} \tag{26}$$

This condition can only be satisfied for all values of θ_1 and θ_2 if the upper and lower limits of $F_1(\theta_1)$ and $F_2(\theta_2)$ coincide, that is, if $\Theta_i = [\underline{\theta}, \overline{\theta}],\ i = 1, 2$. The conditional trading probability is strictly positive but less than one. The corner solutions are discussed in Baldenius (2000).

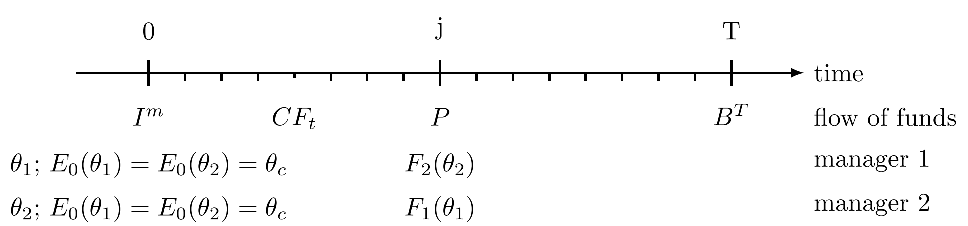

FIGURE 2 | Sequence of events - Bargaining under asymmetric information.

Following Chatterjee and Samuelson (1983), we model the bargaining process as an equal-split sealed-bid mechanism. In period j, both managers submit sealed bids, and trade occurs if and only if the successor's bid b exceeds the leaving manager's bid s. In this case, the surplus is split equally; $P = \frac{1}{2}(b + s)$. While an increase of s by one dollar increases the price by fifty cents, the probability that b exceeds s decreases, that is, a transaction becomes less likely (Baldenius 2008). The optimal linear bidding strategies where both effects just balance each other out represent the Bayesian–Nash equilibrium. In order to determine incentives for truthful reporting, we examine the purchase price in an equal-split sealed-bid mechanisms. Details are provided in the Appendix.

Lemma 2. *Suppose uniformly distributed state parameters θ_i and a trade decision at date $j \in \{0, \dots, T-1\}$ under asymmetric information about capabilities. Trade takes place if $\theta_2 - \theta_1 \geq \frac{\overline{\theta} - \underline{\theta}}{4}$. It holds that $l_t^i = 0, \ \forall \ t \in \{0, \cdots, j\}$, as the purchase price*

$$\begin{aligned} P \ &= \xi\left(\sum_{i=1}^{j} CF_i(1+r)^{j-i} - I(1+r)^j\right) \\ &+ \xi\frac{1}{6}\sum_{i=j+1}^{T} \rho_i \delta(I)(1+r)^{j-i}\left(\overline{\theta} + \underline{\theta} + 2\theta_1 + 2\theta_2\right). \end{aligned} \tag{27}$$

is independent from l_t^i.

Lemma 2 provides the result that truthful reporting about value creation is induced by the sale of the bonus bank. As in the previous section, the leaving manager will receive a price for the bonus bank that compensates him for the future bonus payments he foregoes by leaving. However, trade only occurs if the successor's capabilities differ significantly from his, that is, are at least in a higher quartile than the leaving manager's, that is, $\theta_2 - \theta_1 \geq \frac{\overline{\theta} - \underline{\theta}}{4}$. This requirement derives from the risk imposed by incomplete information, which results in a lower estimated value of the bonus bank. In this situation, the leaving manager has no incentive to lie about value creation in prior periods. The purchase price for the bonus bank depends on both managers' true capabilities (θ_1 and θ_2) and the upper ($\overline{\theta}$) and lower limit ($\underline{\theta}$) of their capabilities. The following proposition analyzes the resulting investment incentives by examining the expected purchase price.

Proposition 2. *Suppose that the capabilities of the leaving manager and the potential buyer are equal in expectation $(\mathrm{E}_0(\theta_1) = \mathrm{E}_0(\theta_2) = \theta_c)$. The leaving manager and the potential buyer bargain under incomplete information for the purchase price of the bonus bank at date $j \in \{0, \dots, T-1\}$. The random variables $\theta_i, \ i = 1, 2$ are independently and uniformly distributed in the respective range $\Theta_i = [\underline{\theta_i}, \overline{\theta_i}]$. Suppose $\theta_2 - \theta_1 \geq \frac{\overline{\theta} - \underline{\theta}}{4}$, then the following relation holds*

$$I^m(\mathrm{E}_0(\theta_1)) = \hat{I}(\theta_c) \Leftrightarrow \Theta_i = [\underline{\theta}, \overline{\theta}], \ i = 1, 2 \tag{28}$$

The bonus bank creates incentives to choose the efficient investment level.

Proposition 2 provides the result that efficient investment decision-making is induced if the managers' capabilities are distributed in an identical range, that is, the successor's estimation of the minimum (maximum) project value attainable by manager 1 is identical to the leaving manager's estimation of the minimum (maximum) project value possible if manager 2 takes over. The reason for this result is that manager 1 takes probability considerations of the successor's action into account. The intuition is that the overlap of estimates of each other's capabilities needs to be large enough for both managers to be able to consider their impact on future cash flows.

When the managers are not symmetrically informed about their capabilities θ_i, manager 2 can use observations of past performance to estimate the leaving manager's type θ_1. We therefore assume in the following that θ_1 is observable in equilibrium based on realized cash flows, which manager 2 can use to estimate manager 1's capabilities. Formally, this leads to a situation, where information asymmetry rests only on one side of the two bargaining parties (one-sided information asymmetry), which is formally characterized by $\theta_1 \sim F_1[\theta_1, \theta_1 + \Delta]$ where $\Delta \to 0$, and $\Theta_2 = [\underline{\theta_2}, \overline{\theta_2}]$. In order to determine the investment incentives when the managers bargain under marginal uncertainty about θ_1, we examine the impact of untruthful reports on the purchase price in an equal-split sealed-bid trading mechanism.

Lemma 3. *Suppose uniformly distributed state parameters θ_i, a trade decision at date $j \in \{0, \dots, T-1\}$, and one-sided information asymmetry characterized by $\theta_1 \sim F_1[\theta_1, \theta_1 + \Delta]$ where $\Delta \to 0$, and $\Theta_2 = [\underline{\theta_2}, \overline{\theta_2}]$. The optimal linear bidding strategies $\hat{s}^\star(\theta_1, I)$ and $\hat{b}^\star(\theta_2, I)$ in an equal-split sealed-bid trading mechanism are:*

$$\hat{s}^\star(\theta_1, I) \to \gamma(I) + \frac{1}{4}\phi(I)\left(\overline{\theta}_2 + 3\theta_1\right) \tag{29}$$

$$\hat{b}^\star(\theta_2, I) = min\{U^2(\theta_2, I), \hat{s}^\star(\theta_1, I)\} \tag{30}$$

with

$$\gamma(I) = \xi\left(\sum_{i=1}^{j} CF_i(1+r)^{j-i} - I(1+r)^j\right) \tag{31}$$

and

$$\phi(I) = \xi\sum_{i=j+1}^{T} \rho_i \delta(I)(1+r)^{j-i} \tag{32}$$

Trade takes place if $\theta_2 \geq \frac{1}{4}\left(\overline{\theta}_2 + 3\theta_1\right)$ and the purchase price for the bonus bank is:

$$P^\star = \gamma(I) + \frac{1}{4}\phi(I)\left(\overline{\theta}_2 + 3\theta_1\right) \tag{33}$$

It holds that $l_t^i = 0 \ \forall \ t \in \{0, \cdots, j\}$, because manager 2 can perfectly estimate θ_1.

Lemma 3 provides the result that when manager 2 derives a perfect estimate of θ_1 in equilibrium, trade under one-sided information asymmetry when manager 2 has superior capabilities leads to a purchase price that is greater than the value manager 1 would obtain if she continued with the project, that is, $P^{\star} > \gamma(I) + \phi(I)\theta_1$. Because superior capabilities of manager 2 will generate additional project value that manager 1 participates in, manager 1 benefits from manager 2's superior capabilities and will continue to invest in any project that she would have invested in if trade occurred under symmetric information about project profitability. Investments will be efficient and manager 1 will report truthfully.

As the cash flow profile of the project ρ is common knowledge among the two managers, investments with positive realized cash flows in the period of trade but pending negative consequences will not inflate the buying manager's estimate of the leaving manager's capabilities. Consequently, the leaving manager does not have incentives to invest inefficiently to obfuscate her true capabilities. When sufficient cash flows have been realized and manager 2 can estimate the leaving manager's capabilities, Lemma 3 thus provides the result that inefficient investments do not increase the purchase price. Consequently, manager 1 will invest efficiently.

To conclude, when managers bargain under two-sided or one-sided information asymmetry, trade occurs if the successor's capabilities are superior. The two cases differ in the distribution of the surplus created by the successor. Under two-sided information asymmetry, the successor ceteris paribus receives a larger share of the value surplus as his capabilities increase. Under one-sided information asymmetry, he receives a share of the value surplus regardless of his capabilities. However, in both cases, the leaving manager can ex ante expect to participate in the additional value created by the successor and hence optimizes the expected purchase price by investing efficiently.

4.2.4 | Summary and Implications

In summarizing, the preceding sections highlight the conditions under which efficient investment decisions may be attained under symmetric and asymmetric information. Within the Nash-bargaining solution analyzed in Proposition 1, both managers observe the private information of the other manager symmetrically in the period of trade and incentives for efficient investment decisions are provided when manager 1 expects manager 2 to have at least equal capabilities. When manager 2 has at least the same capabilities as manager 1, trade occurs and both managers receive equivalent shares of the additional value created by manager 2. Manager 1 has no incentives to provide untruthful reports as manager 2 can directly observe the true profitability of the project in the bargaining process. Consequently, the bonus bank creates strong goal congruent investment incentives. From the perspective of the firm, the transaction between the managers is beneficial because additional value is created if the bonus bank is sold to a more knowledgeable and capable successor.

To analyze the case when the two managers are not equally informed, we allow for asymmetric information in an equal-split sealed bid setting. Uncertainty about the other manager's capabilities reduces the probability that trade occurs because the optimal bidding strategies of the leaving manager and the successor are interdependent. The leaving manager's ask price depends on her estimation of the successor's bid price and vice versa. Within the Bayesian–Nash equilibrium, as a result of the uncertainty inherent in the bargaining process, trade only occurs when the successor has superior capabilities that can compensate for potential misreporting by the leaving manager. Then, truthful reporting is attained because misreporting does not affect the purchase price. When the successor can estimate the leaving manager's capabilities and only the successor's capabilities are unknown, the managers bargain under one-sided information asymmetry. In this case, only the successor's capabilities are unknown, the successor can directly verify value creation and the leaving manager has no incentives to misreport and invests efficiently. Trade only occurs when the successor has superior capabilities and the leaving manager receives a share of the additional value created by the successor. In both cases, the bonus bank induces efficient investment decisions, provided the successor has superior capabilities and the leaving manager can therefore expect to participate in the additional value created by the successor.

Overall, we find that the possibility to sell the bonus bank induces efficient investment decisions because the leaving manager is rewarded proportional to project value and participates in gains from trade in expectation. The probability of trade and the distribution of additional value creation between the two managers depends on the degree of uncertainty about managerial capabilities. Trade is more likely to occur when more information on managerial capabilities is available. Consequently, increasing transparency about the parameters to evaluate the project will enhance the likelihood of trade and thus the efficiency of the bonus bank solution.

Proposition 3 further provides the result that the bonus bank can induce robust goal congruence, if the conditions for strong goal congruence are met.

Proposition 3. *When the manager stays for the full length of the project, robust goal congruence is achieved when the conditions for strong goal congruence as defined in Lemma 1 are met. When the manager decides to leave the firm, the conditions for strong goal congruence outlined in Proposition 1, Proposition2, and Lemma 3 induce robust goal congruent investment decisions.*

When the manager leaves the firm before project completion, the criteria derived for strong goal congruent incentives under both symmetric and asymmetric information suffice to ensure robust goal congruence. The reason for this result is that the use of the bonus bank leads to a situation in which the manager's bonus payment is directly related to value creation. Consequently, for higher value creation she also receives higher bonus payments.

5 | Discussion and Conclusion

Bonus banks have become increasingly popular as a mechanism to improve alignment between managerial behavior and firm objectives (Bhagat and Bolton 2014; Bhagat and Romano 2009). The intention of the bonus bank is to achieve linear participation of managers in the positive and negative effects of their actions on firm value by implementing deferred performance-contingent bonus payments and, as a result, to create incentives for efficient investment decisions (Stewart 1991). Edmans et al. (2012) show that bonus banks provide a solution to the problem of managerial myopia when efficient market prices are available to measure realized performance. However, accounting research finds that market values are not always an appropriate measure of performance in incentive contracts, particularly when managers have private information about how their actions affect firm value. We extend this research by identifying the conditions under which bonus banks based on accounting information can be used to solve the problem of managerial myopia. More specifically, we examine whether the bonus bank based on the performance measure Excess Value Created (EVC) can solve the problem of myopic underinvestment as proposed by O'Hanlon and Peasnell (2002). In settings when market prices are not available to verify accounting information, firms frequently rely on internal negotiations to determine the value of firm shares. Consequently, we study whether an internal market solution provides incentives for truthful reporting and efficient investments.

We analyze a situation in which leaving managers can sell the bonus bank to their successors under symmetric and asymmetric information. The bargaining setting creates an internal market that reveals the value created by the leaving manager and balances the incentives of the parties. The analysis establishes that strong and robust goal congruence can be attained in such a bargaining setting, but only under restrictive conditions. Under symmetric information, incentives for efficient investment decisions are provided when the leaving manager can expect the successor to have at least equal capabilities. Under asymmetric information attaining efficient investments requires the successor to have superior capabilities compared with the leaving manager. This is due to the fact that the successor estimates the justified value of the bonus bank. He is willing to trade only if the value surplus he can generate due to his superior capabilities compensates for the uncertainty inherent in the valuation of the bonus bank.

The intuition of this internal transfer is that successors are generally well informed and may be considered the first best source of verification. The successor has a strong incentive to verify the value of the bonus bank because untruthful reporting will be revealed at project completion and would reduce bonuses paid to him. The additional value created by the successor is shared between the two managers. The leaving manager has strong incentives to sell the bonus bank to a successor who has strong capabilities to realize value from the existing investments. Consequently, the firm will benefit from identifying a successor with higher capabilities. Truthful reporting and efficient investment incentives are achieved if this is the case.

While our paper does not stipulate the selection process of the successor, the selectivity for the successor plays a key role in our setting. The analysis suggests that the leaving manager is incentivized to identify a successor with superior capabilities in realizing value from existing investments. At the same time, the successor's willingness to pay for the bonus bank can reveal hidden information about his capabilities to improve firm value. As the leaving manager is rewarded based on the additional value created in the unit during her employment regardless of her time horizon and the duration of projects, the internal market creates a situation in which a manager is treated like a partner of the business unit she is in charge of. Levin and Tadelis (2005) find that the key feature of partnerships is profit sharing, leading partners to be particularly selective as to whom they accept as new partners. We find that the selectivity for new managers allows for additional value creation, compensates for managers' incentives to overstate the value of their stake and induces truthful reporting. As the successor constitutes an authority of third-party verification, the internal market model further serves as a control mechanism that induces truthful reports.

Overall, our analysis establishes that the usefulness of the bonus bank crucially depends on its ability to reveal the manager's private information on project success. In a situation where the consequences of managers' actions on firm value are not known in the period when they leave the firm, the incentive problem becomes to determine value creation. The internal market may be used to reveal managers' private information. The internal market aggregates the private information of managers about how their capabilities affect firm value. In particular, our results show that the prices observed in the internal market reflect the leaving manager's and the successor's private information, which is not available to the firm or investors in an external market. Our results, in turn, imply that a bonus bank based on market prices obtained from a stock market that cannot observe managers' private information will not provide efficient investment incentives. Moreover, our results reveal that the conditions for the internal market to provide efficient incentives are very restrictive. Consequently, trade will not take place in many real-world situations and the bonus bank will fail to provide efficient investment incentives.

There are aspects of this approach that should be considered with caution. First, no restrictions in communication between the managers or between the principal and the managers are allowed in this examination.[17] It is the strong advantage of the Rogerson-approach that the principal can induce efficient investment decisions without any communication between the manager and the principal. This is largely based on the assumption that the principal himself has forward-looking information about the project's profitability. We relax this assumption and provide an alternative approach in which the problem of asymmetric information is solved in a bargaining setting between informed parties.

Secondly, the bargaining solution requires several critical assumptions. Efficient investment decisions are achieved by annuitizing the problem so that the manager can sell the bonus bank to a well-informed successor in each period. In particular, trade only takes place if the successor expects to realize at least the same future cash flows as the leaving manager. While the higher value created by the successor may also affect the efficient investment level in the initial investment decision, we do not explicitly take this into consideration. Also, we do not consider strategic negotiations where several potential buyers compete for the purchase of the bonus bank. Higher value creation by the successor depends on manager-specific human capital, which is difficult to value. How the firm organizes the selection process for the successor is a question for future research (Levin and Tadelis 2005).

A practical question that arises is whether there are institutional constraints for the internal transfer. The concept of rewarding the manager as a partner of the business unit she is in charge of can be observed quite frequently in practice. Some companies require managers in high level positions to prove ownership of a significant amount of company stock acquired with personal funds. For example, top-level executives at Siemens AG are required to be invested in Siemens stock worth one to two times their annual salary. Lower level executives, for example, in business units, have similar requirements to be invested in phantom shares of the respective unit. Also, many companies offer sign-on bonuses or interest free signing loans for new employees (Van Wesep 2010; WorldatWork 2014). Consequently, firms could encourage successors to use their sign-on bonuses or signing loans to purchase the bonus bank balance. Similarly, partnerships require the entering partner to buy shares from other partners. This is in line with the suggestion that the manager herself may contribute the opening balance of the bonus bank account (Stewart 1991) and creates incentives for the manager to act like an owner of the business.

Overall, our analysis suggests that contrary to regulators' presumptions, deferred bonus payments can only induce managers to make efficient long-term decisions under very restrictive circumstances. We provide a framework to theoretically analyze properties of this incentive scheme. The analysis identifies three main elements affecting the investment incentives created under a bonus bank: (i) deferral of bonus payments, (ii) uncertainty about receiving a granted bonus, and (iii) settlement of the bonus bank balance upon project completion or job termination. Firstly, the bonus bank model and our analysis assumes that managers are indifferent between immediate or deferred bonus payments, as long as the economic value of the bonus bank is maintained. Secondly, our model is based on the ex ante incentives of the bonus bank where bonuses are based on expectations of future performance. If these expectations are not met in the future, bonuses are not paid out from the bonus bank. We do not consider managers' reactions to performance realizations and our model abstracts from the incentive properties of the bonus bank in periods after project initiation. Thirdly, settlement addresses the treatment of the bonus bank account upon project or job termination. It plays a crucial role in our analysis as it provides the main mechanism to ensure truthful reporting. This suggests that a simple requirement of deferring a portion of the bonus to later periods, as suggested in the EU regulations, may not be sufficient to overcome myopia. As firms have significant leeway in the specification of deferred bonus payments when implementing these regulations, further research will be required to determine the interaction of these three elements and identify the circumstances under which regulatory requirements mitigate the principal-agent problem.

Nomenclature (B.1)

a	allocation rule
B	bonus payment
b	successor's bid
CE	capital employed
CF	cash flows
EVC	Excess value created
I	investment level
K	balance of the bonus bank
K_0	opening balance
l	managerial overstatement
NI	net income
NPV	net present value
P	purchase price
r	interest rate
$REVC$	Residual economic value created
RI	residual income
s	leaving manager's bid
S	project portfolio
t	time period
U	reservation utility
w	wage payment
δ	productivity parameter
ε	error term
υ	payout ratio (REVC-based bonus bank)
θ	manager specific productivity parameter
ξ	periodic participation rate
ρ	investment's relative productivity profile
τ	share of project's total NPV granted to the manager
ω	payout ratio in expectation (REVC-based bonus bank)

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Endnotes

[1] In Europe and Australia, financial institutions are required to defer a substantial portion of variable remuneration to later periods (Directive 2010/76/EU; Banking Executive Accountability Regime Division 4 Part IIAA, BEAR). The objective of the legislative bodies is to align managerial incentives with shareholder interests by linking compensation to sustainable value creation. The Sarbanes-Oxley Act of 2002 as well as the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 have introduced holdback and clawback provisions, that allow firms to recoup falsely granted payments (Brink and Rankin 2013; DeHaan et al. 2013; Hodge and Winn 2012; Fung et al. 2015). While clawback provisions allow the firm to recoup falsely granted bonuses, bonus banks are intended to prevent ineffective compensation in the first place (Edmans et al. 2012).

[2] Based on the informativeness principle (Holmstrom 1979), accounting research finds that the use of market- vs. accounting-based performance measures depends on the signal to noise ratio, that is, a performance measure's relative informativeness about an agent's actions (Lambert and Larcker 1987). In particular, empirical studies find that it depends on growth opportunities, business strategy and earnings volatility (Ittner et al. 1997) and other factors like knowledge of business unit managers or characteristics of the underlying accounting system (Indjejikian and Matejka 2012). While some of these results are driven by managerial risk aversion, some factors also hold for risk neutral managers. In an agency model with risk neutral managers, Bernardo et al. (2004) show that the relative weight placed on firm-wide vs. divisional performance measures depends on intra- and interfirm interdependencies, consistent with the empirical evidence in Bushman et al. (1996) and Keating (1997).

[3] Many firms refrain from enforcing clawbacks as the outcomes of such lawsuits are highly uncertain (Dvorak and Ng 2006; Lublin 2010; Weiss 2009) and legal enforcement costs such as lawyers' fees may exceed expected repayments. Additionally, directors with discretionary power about clawback enforcement may be concerned about detrimental effects of recouping bonuses to their relationship with firm executives and thus exercise their discretion not to enforce the clawback in order to avoid these social enforcement costs (Bebchuk and Jesse 2009; Fried and Shilon 2011). Bonus banks avoid both legal and social enforcement costs as they are based on automated mechanisms and do not require explicit firm intervention.

[4] Underinvestment problems are only due to managers' impatience. See Mohnen and Bareket (2007) and Rogerson (1997) for similar assumptions. A possible solution to the optimal contracting problem when the principal and the manager disagree on the risk-return trade off would be to adjust the capital charge when calculating RI (Christensen et al. 2002; Dutta and Reichelstein 2002). As a result, contracts including bonus payments based on current performance must be convex in order to offset the concavity of managers' utility functions and induce managers to behave in a less risk averse fashion. See for instance Lambert (1986), Demski and Dye (1999) or Feltham and Wu (2001).

[5] For $T^A < T$, the manager is assumed to leave the firm after the end of period T^A.

[6] For instance, let $\pi(I)$ denote the performance measure in the compensation contract, then $B_t(I) = w_t \pi_t(I)$. This notion captures the fact that the manager's investment decisions affect her bonus payment.

[7] This assumption differs from the model examined by Edmans et al. (2012) where the agent receives equity- and cash-based compensation until after retirement.

[8] Note that this assumption precludes the application of the Rogerson-solution (Rogerson 1997), which requires to determine RI based on a special cost-allocation procedure rather than GAAP. Although the application of relative benefit rules are permissible for some classes of leased assets under both IFRS and US-GAAP, we analyze whether bonus banks based on unadjusted GAAP accounting measures can induce efficient decision-making.

[9] Assuming truthful reporting, K_0 is proportional to project NPV: $K_0 = \xi REVC_0 = \xi NPV_0$.

[10] If effort-averse managers report about their private information, the principal typically has to solve understatement problems. Effort-averse managers understate performance to reduce the cost associated with reaching the "benchmark level" (Lambert 2001). However, because we abstract from moral hazard issues and assume that bonus payments are contingent on REVC, managers' objective is to maximize compensation and report the highest possible REVC.

[11] Suppose the principal determines which share of project NPV the manager should receive by choosing ξ. $\sum_{t=0}^{T} \omega_t = 1$ ensures that this portion ξ of the project's NPV is paid out to the manager. Alternatively, it would also be possible to use any set of nonnegative payout ratios $(\omega_0, \ldots, \omega_T)$, $\omega_t \geq 0 \; \forall t \in \{0, \ldots, T\}$ and $\sum_{t=0}^{T} \omega_t = n$ and simultaneously determine ξ_n and n such that $\xi_n \times n = 1$. This procedure ensures that the manager receives his portion ξ of project NPV. For ease of presentation and interpretation, we limit our attention to the first case.

[12] Managers are indifferent between receiving bonus payments now or later, as long as they can expect to receive their bonus compounded at the opportunity cost of capital at some point in time (Miller and Modigliani 1961).

[13] See Demski (1998) for similar assumptions. He presents a two-period model in which the manager has an option to misreport first-period performance. However, any misreport must be reversed in the second period, as total output is observed in the game's conclusion. Making a bonus payment in T based on the observed value creation requires the firm to identify cash flows from individual transactions and projects separately (Dutta and Reichelstein 2005). This may be problematic if projects overlap.

[14] We assume that managers will only misreport if they can strictly increase their utility by doing so.

[15] This assumption could easily be relaxed. If the successor's time horizon is shorter than the remaining duration of the project, the bargaining process can be repeated in each period.

[16] See Baldenius et al. (1999) or Edlin and Reichelstein (1995) for similar assumptions. In their models, bargaining takes place under symmetric information about all necessary parameters. In contrast to their results, we explicitly assume equivalent bargaining power by both managers. Technically, we consider a Nash-bargaining solution.

[17] However, in many agency models there is no need for communication to have a positive value. In other words, information delay can make both parties better off and an aggregation of information can actually improve both parties' welfare (Demski and Frimor 1999; Indejejikian and Nanda 1999; Arya et al. 1997).

[18] See for the definition of incentive compatibility Wilson (1968) and Ross (1973).

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Appendix A

Proof of Lemma 1 (A.1).

i. According to (15), managers will make efficient investment decisions if

$$B_t(I) = \xi \frac{\rho_t}{\sum_{i=1}^{T} \frac{\rho_i}{(1+r)^i}} \left(\sum_{t=1}^{T} \frac{\rho_t \delta(I,\theta)}{(1+r)^t} - I \right)$$

Under a REVC-based bonus bank concept as defined in (9) and (10), managers are compensated according to

$$K_t = \xi \sum_{i=0}^{t} REVC_i^l (1+r)^{t-i} - \sum_{i=1}^{t} B_i(I)(\cdot)(1+r)^{t-i} \;\forall\; t \in \{0, \dots, T\}$$

where

$$\mathrm{E}_0(B_t(I)) = \omega_t \xi REVC_0 (1+r)^t,\; \omega_t = \frac{\rho_t}{\sum_{i=1}^{T} \frac{\rho_i}{(1+r)^{(i-t)}}}$$

Recall that in the period of initiating a new investment project, REVC equals the NPV of the project ($REVC_0 = NPV_0$). Substituting (2) $REVC_0 = NPV_0 = \sum_{t=1}^{T} \frac{\rho_t \delta(I,\theta)}{(1+r)^t} - I$ completes the proof.

ii. To analyze the incentive properties of a REVC-based bonus bank as defined in (9) and (10), we examine the conditions for which bonus payments satisfy (12), ensuring goal congruence. According to (9), bonus payments $B_t(I)$ are as follows:

$$\mathrm{E}_0(B_t(I)) = \omega_t \xi REVC_0 (1+r)^t$$

Recall that at date $t = 0$, REVC equals the NPV of the project ($REVC_0 = NPV_0$) and $REVC_0 = \sum_{t=1}^{T} \frac{\mathrm{E}_0(\rho_t \delta(I,\theta))}{(1+r)^t} - I$ (2). $\hat{I}(\theta)$ maximizes $REVC_0$ when $\omega_t \geq 0$ is constant and nonnegative:

$$\omega_t \geq 0, \forall t \in \{0, \dots, T\}$$

The condition

$$\sum_{t=0}^{T} \omega_t \leq 1$$

suffices to ensure incentive compatibility.[18] Assume $\omega_0 > 1$, on the one hand managers would still choose the efficient investment level, but on the other hand, no financial advantage remains for the principal because managers would receive more than the whole NPV of the project. The last part of the proof can now be shown by complete induction. The REVC-based bonus bank concept as defined in (9) and (10) attains robust goal congruence if and only if the present value of bonus payments is linear in the NPV of a project j. According to (9), the present value of expected bonus payments from project j $\sum_{t=0}^{T} \frac{E_0(B_t^j(\cdot))}{(1+r)^t}$ are as follows:

$$\begin{aligned}\sum_{t=0}^{T} \frac{E_0(B_t^j(\cdot))}{(1+r)^t} &= \sum_{t=0}^{T} \frac{\omega_t \xi REVC_0^j (1+r)^t}{(1+r)^t} \\ &= \xi REVC_0^j \\ &= \xi NPV_0(I_j, \theta^j, \rho^j, T).\end{aligned}$$

iii According to Lemma 1(ii), managers will choose the efficient investment level if they are rewarded according to the bonus bank concept as presented in (10) with bonus payments based on the payout ratios as given in (18). The balance of the bonus bank K_T in T (before bonus payment B_T) can be written as

$$\begin{aligned}K_T &= \xi REVC_T + (1+r)K_{T-1} \\ &= \xi REVC_T + (1+r)\left[REVC_{T-1} + (1+r)K_{T-2}\right] \\ &= \xi \sum_{t=1}^{T} (1+r)^{T-t} REVC_t + (1+r)^T K_0 \\ &= \xi \sum_{t=1}^{T} (1+r)^{T-t} REVC_t + \xi(1+r)^T REVC_0 \\ &= \xi \sum_{t=0}^{T} (1+r)^{T-t} REVC_t \\ &= \xi \sum_{t=0}^{T} (1+r)^{T-t} \left(RI_t + \Delta NPV_t - rNPV_{t-1}\right) \\ &= \xi \sum_{t=1}^{T} (1+r)^{T-t} RI_t \\ &= \xi \sum_{t=0}^{T} (1+r)^{T-t} CF_t - I(1+r)^T \\ &= B_T\end{aligned}$$

Both bonus bank balance and bonus payment at date T are independent from l_t. Consequently, managers are not able to improve bonus payments by untruthful reports. Thus, the strategy of truthful reports is the Nash-equilibrium for the agent.

Proof of Proposition 1 (A.2). Within the Nash-bargaining solution (NBS), the optimal price P for the bonus bank is calculated as follows:

$$NBS(P) = \left(U_j^2(\cdot) - P\right)\left(P - U_j^1(\cdot)\right) \rightarrow \max_P$$

The first-order condition leads to

$$P = \frac{1}{2}\left(U_j^1(\cdot) + U_j^2(\cdot)\right)$$

Substituting conditions (20) and (21) yields

$$\begin{aligned}P &= \xi\Bigg(\sum_{i=1}^{j} RI_i(\theta_1)(1+r)^{j-i} \\ &\quad + \frac{1}{2}\left(\sum_{i=j+1}^{T} \left(E_j(RI_i(\theta_1)) + E_j(RI_i(\theta_2))\right)(1+r)^{j-i}\right)\Bigg) \\ &= \xi\left(EVC_j + \frac{1}{2}\left(\sum_{i=j+1}^{T} \left(E_j(RI_i(\theta_2)) - E_j(RI_i(\theta_1))\right)(1+r)^{j-i}\right)\right)\end{aligned}$$

From the perspective of the project's initiation date $t = 0$, the manager chooses the investment level $I^m(\theta_1)$ that maximizes P. Assume that the capabilities of the leaving manager and the potential buyer are equal in expectation ($E_0(\theta_1) = E_0(\theta_2) = \theta_c$). The expected purchase price P at date 0 is as follows:

$$\begin{aligned}E_0(P) &= \xi\Bigg(\sum_{i=1}^{j} E_0(RI_i(\theta_1))(1+r)^{j-i} \\ &\quad + \frac{1}{2}\left(\sum_{i=j+1}^{T} \left(E_0(RI_i(\theta_1)) + E_0(RI_i(\theta_2))\right)(1+r)^{j-i}\right)\Bigg) \\ &= \xi\Bigg(\sum_{i=1}^{j} E_0(RI_i(\theta_1))(1+r)^{j-i} \\ &\quad + \frac{1}{2}\left(\sum_{i=j+1}^{T} \left(E_0(RI_i(\theta_1)) + E_0(RI_i(\theta_1))\right)(1+r)^{j-i}\right)\Bigg) \\ &= \xi(1+r)^j\left(\sum_{i=1}^{T} E_0(RI_i(\theta_1))(1+r)^{-i}\right) \\ &= \xi(1+r)^j NPV_0(I, \theta_1, \rho, T)\end{aligned}$$

The term in brackets is maximized by $\hat{I}(\theta_1)$ which completes the proof. The expected purchase price is based on the project's NPV, thus providing no incentive to lie. It holds that $l_t^i = 0 \ \forall \ t \in \{0, \cdots, T\}$.

Proof of Lemma 2 (A.3). The proof follows the intuition of Baldenius (2000). Assume that both managers have incomplete information about each other's capabilities θ_i. The optimal bidding strategies are the solution to the following simultaneous optimization problem

$$\hat{s}(\theta_1, I) = \arg\max_s \int_{\underline{\theta}}^{\bar{\theta}} \left(\frac{s + b(\theta_2, I)}{2} - U^1(\theta_1, I)\right) 1_{s < b(\theta_2, I)} dF_2(\theta_2)$$

$$\hat{b}(\theta_2, I) = \arg\max_b \int_{\underline{\theta}}^{\bar{\theta}} \left(U^2(\theta_2, I) - \frac{s(\theta_1, I) + b}{2}\right) 1_{s(\theta_1, I) < b} dF_1(\theta_1)$$

Rewrite the utility of manager i as follows:

$$\begin{aligned}U_j^i(\theta_i, I) &= \xi\left(\sum_{k=1}^{j} RI_k(1+r)^{j-k} + \sum_{k=j+1}^{T} E_j(RI_k(\theta_i))(1+r)^{j-k}\right) \\ &= \xi(1+r)^j\left(\sum_{k=1}^{j} CF_k(1+r)^{-k} + \sum_{k=j+1}^{T} E_j CF_k(1+r)^{-k} - I\right) \\ &= \xi(1+r)^j\left(\sum_{k=1}^{j} CF_k(1+r)^{-k} + \theta_i \sum_{k=j+1}^{T} \rho_k \delta(I)(1+r)^{-k} - I\right)\end{aligned}$$

The first term in brackets is directly observable in $t = j$ and therefore independent of reports by manager 1. It follows that $l_t^i = 0, \ t \in 0, \ldots, j$. The second term in brackets reflects expected value creation. In the case that manager i remains with the firm until project completion the manager expects to be rewarded according to (19), which is independent from l_t^i.

Manager i's utility can be restated as a linear function dependent on θ_i

$$U_j^i(\theta_i, I) = \gamma + \phi\theta_i$$

with

$$\gamma = \xi\left(\sum_{i=1}^{j} CF_i(1+r)^{j-i} - I(1+r)^j\right)$$

$$= \xi\left(\sum_{i=0}^{j} CF_i(1+r)^{j-i} - I(1+r)^j - CF_0(1+r)^j\right)$$

and

$$\phi = \xi \sum_{i=j+1}^{T} \rho_i \delta(I)(1+r)^{j-i}$$

Define the following relations $\psi_i = \gamma + \phi\theta_i$, $\underline{\psi} = \gamma + \phi\underline{\theta}$, and $\overline{\psi} = \gamma + \phi\overline{\theta}$. By taking the boundary conditions of the indicator functions into account, the optimization problem becomes

$$\hat{s}(\psi_1, I) = \arg\max_s \int_s^{\hat{b}(\overline{\psi},I)} \left(\frac{s+b}{2} - \psi_1\right) dG_2(b, I)$$

$$\hat{b}(\psi_2, I) = \arg\max_b \int_{\hat{s}(\underline{\psi},I)}^{b} \left(\psi_2 - \frac{s+b}{2}\right) dG_1(s, I)$$

where the distribution function G_i are induced by (i) the underlying uniform distribution $\widehat{F}_i(\psi_i)$ and by (ii) the bidding strategies $\hat{s}$ and $\hat{b}$, where $G_1(\xi, I) = \widehat{F_1}(\hat{s}^{-1}(\xi, I))$ and $G_2(\xi, I) = \widehat{F_2}(\hat{b}^{-1}(\xi, I))$. Recall that $G_1(\hat{s}(\underline{\psi}, I), I) = 0$ and $G_2(\hat{b}(\overline{\psi}, I), I) = 1$. By integrating by parts, the leaving manager's problem can be restated as follows:

$$s(\psi_1, I) = \int_s^{\hat{b}(\overline{\psi},I)} \left(\frac{s+b}{2} - \psi_1\right) dG_2(b, I)$$

$$= \left[\left(\frac{s+b}{2} - \psi_1\right) G_2(b, I)\right]_s^{\hat{b}(\overline{\psi},I)} - \int_s^{\hat{b}(\overline{\psi},I)} \frac{1}{2} G_2(b, I) db$$

$$= \left[\left(\frac{s+\hat{b}(\overline{\psi}, I)}{2} - \psi_1\right) G_2(\hat{b}(\overline{\psi}, I), I) - (s - \psi_1) G_2(s, I)\right]$$

$$- \frac{1}{2} \int_s^{\hat{b}(\overline{\psi},I)} G_2(b, I) db$$

The first-order condition yields

$$\frac{1}{2}\left(1 - G_2(\hat{s}(\cdot), I)\right) - \left(\hat{s}(\cdot) - \psi_1\right) g_2(\hat{s}(\cdot), I) = 0$$

where $g_i(\cdot)$ denotes the density function of $G_i(\cdot)$. The successor's problem can be rewritten as follows:

$$b(\psi_2, I) = \int_{\hat{s}(\underline{\psi},I)}^{b} \left(\psi_2 - \frac{s+b}{2}\right) dG_1(s, I)$$

$$= \left[\left(\psi_2 - \frac{s+b}{2}\right) G_1(s, I)\right]_{\hat{s}(\underline{\psi},I)}^{b} + \int_{\hat{s}(\underline{\psi},I)}^{b} \frac{1}{2} G_1(s, I) ds$$

$$= \left[\left(\psi_2 - b\right) G_1(b, I) - \left(\psi_2 - \frac{\hat{s}(\underline{\psi}, I) + b}{2}\right) G_1(\hat{s}(\underline{\psi}, I), I)\right]$$

$$+ \int_{\hat{s}(\underline{\psi},I)}^{b} \frac{1}{2} G_1(s, I) ds$$

The first-order condition yields

$$-\frac{1}{2} G_1(\hat{b}(\cdot), I) + \left(\psi_2 - \hat{b}(\cdot)\right) g_1(\hat{b}(\cdot), I) = 0$$

Defining $x = \hat{b}^{-1}(\hat{s}, I)$ and $y = \hat{s}^{-1}(\hat{b}, I)$, we have $g_2(\hat{s}, I) = \frac{f_2(x)}{\hat{b}'(x,I)}$, $\psi_1 = \hat{s}^{-1}(\hat{b}(x, I), I)$, and $F_2(x) = G_2(\hat{s}, I)$. Further, $g_1(\hat{b}, I) = \frac{f_1(y)}{\hat{s}'(y,I)}$, $\psi_2 = \hat{b}^{-1}(\hat{s}(y, I), I)$, and $F_1(y) = G_1(\hat{b}, I)$. Hence, the first-order conditions can be restated as follows:

$$\hat{s}^{-1}(\hat{b}(x, I), I) = \hat{b}(x, I) - \frac{1}{2}\hat{b}'(x, I)\frac{1 - F_2(x)}{f_2(x)}$$

$$\hat{b}^{-1}(\hat{s}(y, I), I) = \hat{s}(y, I) + \frac{1}{2}\hat{s}'(y, I)\frac{F_1(y)}{f_1(y)}$$

The Bayesian–Nash equilibrium is the solution to these two linked differential equations. We restrict attention to linear bidding strategies

$$\hat{s}(\psi_1, I) = \lambda_1(I) + \eta_1(I)\psi_1$$

$$\hat{b}(\psi_2, I) = \lambda_2(I) + \eta_2(I)\psi_2$$

Recall that $F_i(\psi_1)$ is uniformly distributed on the interval $\left[\underline{\psi}, \overline{\psi}\right]$ and therefore

$$\hat{s}^{-1}(\hat{b}(\psi_2, I), I) = \lambda_2(I) + \eta_2(I)\psi_2 - \frac{1}{2}\eta_2(I)\left(\overline{\psi} - \psi_2\right)$$

$$\hat{b}^{-1}(\hat{s}(\psi_1, I), I) = \lambda_1(I) + \eta_1(I)\psi_1 + \frac{1}{2}\eta_1(I)\left(\psi_1 - \underline{\psi}\right)$$

By differentiation with respect to ψ_i, the solutions to this equation system are given by $\eta_1(I) = \eta_2(I) = \frac{2}{3}$ and $\lambda_1(I) = \frac{1}{4}\overline{\psi_2} + \frac{1}{12}\psi_1$ and $\lambda_2(I) = \frac{1}{12}\overline{\psi_2} + \frac{1}{4}\underline{\psi}_1$. Recall that $\psi_i = U_j^i(\theta_c, \theta_i, I) = \gamma(I) + \phi(I)\theta_i$. Hence, the optimal linear bidding strategy for the leaving manager is

$$\hat{s}(\theta_1, I) = \frac{1}{4}\left(\gamma(I) + \phi(I)\overline{\theta}\right) + \frac{1}{12}\left(\gamma(I) + \phi(I)\underline{\theta}\right) + \frac{2}{3}\left(\gamma(I) + \phi(I)\theta_1\right)$$

$$= \gamma(I) + \frac{1}{12}\phi(I)\left(3\overline{\theta} + \underline{\theta} + 8\theta_1\right)$$

The optimal bidding strategy for the successor is

$$\hat{b}(\theta_2, I) = \frac{1}{12}\left(\gamma(I) + \phi(I)\overline{\theta}\right) + \frac{1}{4}\left(\gamma(I) + \phi(I)\underline{\theta}\right) + \frac{2}{3}\left(\gamma(I) + \phi(I)\theta_2\right)$$

$$= \gamma(I) + \frac{1}{12}\phi(I)\left(\overline{\theta} + 3\underline{\theta} + 8\theta_2\right)$$

As a consequence, trade takes place if $4\theta_2 - \overline{\theta} \geq 4\theta_1 - \theta$. $\hat{s}(\theta_1, I)$ and $\hat{b}(\theta_2, I)$ are independent from l_t^i. Hence, there are no incentives to misreport, which completes the proof.

Proof of Proposition 2 (A.4). According to lemma 2, the purchase price at date j for the bonus bank is

$$P = \gamma(I) + \frac{1}{6}\phi(I)\left(\overline{\theta} + \underline{\theta} + 2\theta_1 + 2\theta_2\right)$$

$$\gamma = \xi\left(\sum_{i=1}^{j} CF_i(1+r)^{j-i} - I(1+r)^j\right)$$

and

$$\phi(I) = \xi \sum_{i=j+1}^{T} \rho_i \delta(I)(1+r)^{j-i}$$

if $\theta_2 - \theta_1 \geq \frac{\overline{\theta} - \underline{\theta}}{4}$. The manager's investment criterion is

$$I^m(\theta_1) \in \arg\max_I \sum_{t=1}^{T^A} \frac{E_0(B_t(I))}{(1+r)^t}$$
$$\Leftrightarrow I^m(\theta_1) \in \arg\max_I \left\{ \frac{E_0(P)}{(1+r)^j} \right\}$$

Expected investments are then given by

$$I^m(E_0(\theta_1)) = \xi \Bigg(\sum_{i=1}^{j} E_0(CF_i)(1+r)^{-i} - I + \frac{1}{6} E_0\left(\overline{\theta} + \underline{\theta} + 2\theta_1 + 2\theta_2\right) \sum_{i=j+1}^{T} \rho_i \delta(I)(1+r)^{-i} \Bigg)$$
$$= \xi \Bigg(\theta_c \sum_{i=1}^{j} \rho_i \delta(I)(1+r)^{-i} + \frac{1}{6} E_0\left(\overline{\theta} + \underline{\theta} + 2\theta_1 + 2\theta_2\right) \sum_{i=j+1}^{T} \rho_i \delta(I)(1+r)^{-i} - I \Bigg)$$

In $t = 0$, the leaving manager assumes that $\theta_c = E_0(\theta_1) = E_0(\theta_2)$. Hence, $\frac{1}{6} E_0\left(\overline{\theta} + \underline{\theta} + 2\theta_1 + 2\theta_2\right)$ reduces to $\frac{1}{6}\left(E_0\left(\overline{\theta} + \underline{\theta}\right) + 2\theta_c + 2\theta_c\right)\Big) = \frac{1}{6}\left(2\theta_c + 2\theta_c + 2\theta_c\right) = \theta_c$ and expected investments are

$$I^m(E_0(\theta_1)) = \xi \left(\theta_c \sum_{i=1}^{j} \rho_i \delta(I)(1+r)^{-i} + \theta_c \sum_{i=j+1}^{T} \rho_i \delta(I)(1+r)^{-i} - I \right)$$
$$= \xi \left(\theta_c \sum_{i=1}^{T} \rho_i \delta(I)(1+r)^{-i} - I \right)$$

Hence, $\hat{I}(\theta_c) = I^m(E_0(\theta_1))$ if managers' capabilities are distributed in the identical range, that is, θ_i is uniformly distributed with $\Theta_i = [\underline{\theta}, \overline{\theta}]$, $i = 1, 2$.

Proof of Lemma 3 (A.5). Suppose uniformly distributed state parameters θ_i and a trade decision at date $j \in \{0, \dots, T-1\}$. The optimal bidding strategies are the solution to the following simultaneous optimization problem:

$$\hat{s}^\star(\theta_1, I) = \arg\max_s \int_{\underline{\theta}_2}^{\overline{\theta}_2} \left(\frac{s + b(\theta_2, I)}{2} - U^1(\theta_1, I) \right) 1_{s < b(\theta_2, I)} dF_2(\theta_2)$$
$$\hat{b}^\star(\theta_2, I) = \arg\max_b \int_{\underline{\theta}_1}^{\overline{\theta}_1} \left(U^2(\theta_2, I) - \frac{s(\theta_1, I) + b}{2} \right) 1_{s(\theta_1, I) < b} dF_1(\theta_1)$$

Manager i's utility can be restated as a linear function dependent on θ_i

$$U_j^i(\theta_i, I) = \gamma + \phi\theta_i$$

with

$$\gamma = \xi \left(\sum_{i=1}^{j} CF_i(1+r)^{j-i} - I(1+r)^j \right)$$
$$= \xi \left(\sum_{i=0}^{j} CF_i(1+r)^{j-i} - I(1+r)^j - CF_0(1+r)^j \right)$$

and

$$\phi = \xi \sum_{i=j+1}^{T} \rho_i \delta(I)(1+r)^{j-i}$$

Baldenius (2000) examines a similar simultaneous optimization problem, assuming uniformly distributed state parameters λ_i in the respective range $\Lambda_i = [\underline{\lambda}_i, \overline{\lambda}_i]$, $i = 1, 2$:

$$s^\star(\lambda_1) = \arg\max_s \int_{\underline{\lambda}_2}^{\overline{\lambda}_2} \left(\frac{s + b(\lambda_2)}{2} - \lambda_1 + W_1 \right) 1_{s < b(\lambda)} dF_2(\lambda_2)$$
$$b^\star(\lambda_2) = \arg\max_b \int_{\underline{\lambda}_1}^{\overline{\lambda}_1} \left(\lambda_2 + W_2 - \frac{s(\lambda_1) + b}{2} \right) 1_{s(\lambda_1) < b} dF_1(\lambda_1)$$

The solution to the simultaneous optimization problem $s^\star$ and $b^\star$ is defined in Baldenius (2000) as follows:

$$s^\star(\lambda_1) = \begin{cases} a_b + \frac{2}{3}\underline{\lambda}_2, & \text{if } a_s + \frac{2}{3}\lambda_1 < a_b + \frac{2}{3}\underline{\lambda}_2 \\ a_s + \frac{2}{3}\lambda_1, & \text{if } a_b + \frac{2}{3}\underline{\lambda}_2 \leq a_s + \frac{2}{3}\lambda_1 \leq a_b + \frac{2}{3}\overline{\lambda}_2 \\ \lambda_1 - W_1, & \text{if } a_s + \frac{2}{3}\lambda_1 > a_b + \frac{2}{3}\overline{\lambda}_2 \end{cases}$$
$$= \begin{cases} a_b + \frac{2}{3}\underline{\lambda}_2, & \text{if } \lambda_1 < \frac{3}{2}(a_b - a_s) + \underline{\lambda}_2 \\ a_s + \frac{2}{3}\lambda_1, & \text{if } \frac{3}{2}(a_b - a_s) + \underline{\lambda}_2 \leq \lambda_1 \leq \frac{3}{2}(a_b - a_s) + \overline{\lambda}_2 \\ \lambda_1 - W_1, & \text{if } \lambda_1 > \frac{3}{2}(a_b - a_s) + \overline{\lambda}_2 \end{cases}$$
$$b^\star(\lambda_2) = \begin{cases} a_s + \frac{2}{3}\overline{\lambda}_1, & \text{if } a_b + \frac{2}{3}\lambda_2 > a_s + \frac{2}{3}\overline{\lambda}_1 \\ a_b + \frac{2}{3}\lambda_2, & \text{if } a_s + \frac{2}{3}\underline{\lambda}_1 \leq a_b + \frac{2}{3}\lambda_2 \leq a_s + \frac{2}{3}\overline{\lambda}_1 \\ \lambda_2 + W_2, & \text{if } a_b + \frac{2}{3}\lambda_2 < a_s + \frac{2}{3}\underline{\lambda}_1 \end{cases}$$
$$= \begin{cases} a_s + \frac{2}{3}\overline{\lambda}_1, & \text{if } \lambda_2 > \frac{3}{2}(a_s - a_b) + \overline{\lambda}_1 \\ a_b + \frac{2}{3}\lambda_2, & \text{if } \frac{3}{2}(a_s - a_b) + \underline{\lambda}_1 \leq \lambda_2 \leq \frac{3}{2}(a_s - a_b) + \overline{\lambda}_1 \\ \lambda_2 + W_2, & \text{if } \lambda_2 < \frac{3}{2}(a_s - a_b) + \underline{\lambda}_1 \end{cases}$$

with

$$a_s = \frac{1}{12}\left(3\overline{\lambda}_2 + \underline{\lambda}_1 - 9W_1 + 3W_2\right)$$

and

$$a_b = \frac{1}{12}\left(\overline{\lambda}_2 + 3\underline{\lambda}_1 - 3W_1 + 9W_2\right)$$

The simultaneous optimization problem $s^\star$ and $b^\star$ can be transformed into the simultaneous optimization problem $\hat{s}^\star$ and $\hat{b}^\star$ by setting

$$\lambda_i = \gamma + \phi\theta_i,\; i = 1, 2.$$

such that $\Lambda_i = U[\underline{\lambda}_i, \overline{\lambda}_i]$ with $\underline{\lambda}_i = \gamma + \phi\underline{\theta}_i$ and $\overline{\lambda}_i = \gamma + \phi\overline{\theta}_i$. Setting $W_1 = W_2 = 0$, the solutions to the simultaneous optimization problems $s^\star$ and $b^\star$ and $\hat{s}^\star$ and $\hat{b}^\star$ are related as follows:

$$\begin{aligned} s^\star(\theta_1) &= \hat{s}^\star(\gamma + \phi\theta_1), \\ b^\star(\theta_2) &= \hat{b}^\star(\gamma + \phi\theta_2). \end{aligned}$$

Inserting into the solution to the simultaneous optimization problem $s^\star$ and $b^\star$ yields

$$\begin{aligned} a_s &= \frac{1}{3}\gamma + \frac{1}{12}\phi\left(3\overline{\theta}_2 + \underline{\theta}_1\right), \\ a_b &= \frac{1}{3}\gamma + \frac{1}{12}\phi\left(\overline{\theta}_2 + 3\underline{\theta}_1\right), \end{aligned}$$

and

$$\hat{s}^\star(\theta_1, I) = \begin{cases} a_b + \frac{2}{3}\left(\gamma + \phi\underline{\theta}_2\right), & \text{if } \gamma + \phi\theta_1 < \frac{3}{2}(a_b - a_s) + \gamma + \phi\underline{\theta}_2 \\ a_s + \frac{2}{3}\left(\gamma + \phi\theta_1\right), & \text{if } \frac{3}{2}\left(a_b - a_s\right) + \gamma + \phi\underline{\theta}_2 \leq \gamma \\ & + \phi\theta_1 \leq \frac{3}{2}\left(a_b - a_s\right) + \gamma + \phi\overline{\theta}_2 \\ \gamma + \phi\theta_1, & \text{if } \gamma + \phi\theta_1 > \frac{3}{2}\left(a_b - a_s\right) + \gamma + \phi\overline{\theta}_2 \end{cases}$$

$$= \begin{cases} \gamma + \frac{1}{12}\phi\left(\overline{\theta}_2 + 3\underline{\theta}_1 + 8\underline{\theta}_2\right), & \text{if } \theta_1 < \underline{\theta}_2 - \frac{1}{4}\left(\overline{\theta}_2 - \underline{\theta}_1\right) \\ \gamma + \frac{1}{12}\phi\left(3\overline{\theta}_2 + \underline{\theta}_1 + 8\theta_1\right), & \text{if } \underline{\theta}_2 - \frac{1}{4}\left(\overline{\theta}_2 - \underline{\theta}_1\right) \\ & \leq \theta_1 \leq \overline{\theta}_2 - \frac{1}{4}\left(\overline{\theta}_2 - \underline{\theta}_1\right) \\ \gamma + \phi\theta_1, & \text{if } \theta_1 > \overline{\theta}_2 - \frac{1}{4}\left(\overline{\theta}_2 - \underline{\theta}_1\right) \end{cases}$$

$$\hat{b}^\star(\theta_1, I) = \begin{cases} a_s + \frac{2}{3}\left(\gamma + \phi\overline{\theta}_1\right), & \text{if } \gamma + \phi\theta_2 > \frac{3}{2}(a_s - a_b) + \gamma + \phi\overline{\theta}_1 \\ a_b + \frac{2}{3}\left(\gamma + \phi\theta_2\right), & \text{if } \frac{3}{2}\left(a_s - a_b\right) + \gamma + \phi\underline{\theta}_1 \leq \gamma \\ & + \phi\theta_2 \leq \frac{3}{2}\left(a_s - a_b\right) + \gamma + \phi\overline{\theta}_1 \\ \gamma + \phi\theta_2, & \text{if } \gamma + \phi\theta_2 < \frac{3}{2}\left(a_s - a_b\right) + \gamma + \phi\underline{\theta}_1 \end{cases}$$

$$= \begin{cases} \gamma + \frac{1}{12}\phi\left(3\overline{\theta}_2 + \underline{\theta}_1 + 8\overline{\theta}_1\right), & \text{if } \theta_2 > \overline{\theta}_1 + \frac{1}{4}\left(\overline{\theta}_2 - \underline{\theta}_1\right) \\ \gamma + \frac{1}{12}\phi\left(\overline{\theta}_2 + 3\underline{\theta}_1 + 8\theta_2\right), & \text{if } \underline{\theta}_1 + \frac{1}{4}\left(\overline{\theta}_2 - \underline{\theta}_1\right) \leq \theta_2 \\ & \leq \overline{\theta}_1 + \frac{1}{4}\left(\overline{\theta}_2 - \underline{\theta}_1\right) \\ \gamma + \phi\theta_2, & \text{if } \theta_2 < \underline{\theta}_1 + \frac{1}{4}\left(\overline{\theta}_2 - \underline{\theta}_1\right) \end{cases}$$

When $\theta_1 \sim F_1[\theta_1, \theta_1 + \Delta]$ where $\Delta \to 0$ and $\theta_1 \in \left(\underline{\theta}_2, \overline{\theta}_2\right)$, it follows that only the middle branch of $\hat{s}^\star$ is relevant because

$$\underline{\theta}_2 - \frac{1}{4}\left(\overline{\theta}_2 - \underline{\theta}_1\right) \to \underline{\theta}_2 - \frac{1}{4}\left(\overline{\theta}_2 - \theta_1\right) \leq \underline{\theta}_2 < \theta_1$$

and

$$\overline{\theta}_2 - \frac{1}{4}\left(\overline{\theta}_2 - \underline{\theta}_1\right) \to \overline{\theta}_2 - \frac{1}{4}\left(\overline{\theta}_2 - \theta_1\right) = \theta_1 + \frac{3}{4}\left(\overline{\theta}_2 - \theta_1\right) > \theta_1.$$

Hence, the optimal linear bidding strategy for the leaving manager is

$$\begin{aligned} \hat{s}^\star(\theta_1, I) &= \gamma + \frac{1}{12}\phi\left(3\overline{\theta}_2 + \underline{\theta}_1 + 8\theta_1\right) \to \gamma + \frac{1}{12}\phi\left(3\overline{\theta}_2 + 9\theta_1\right) \\ &= \gamma + \frac{1}{4}\phi\left(\overline{\theta}_2 + 3\theta_1\right). \end{aligned}$$

The optimal linear bidding strategy for the successor is

$$\begin{aligned} \hat{b}^\star(\theta_2, I) &= \begin{cases} \gamma + \frac{1}{4}\phi\left(\overline{\theta}_2 + 3\theta_1\right), & \text{if } if \theta_2 \geq \frac{1}{4}\left(\overline{\theta}_2 + 3\theta_1\right) \\ \gamma + \phi\theta_2, & \text{if } \theta_2 < \frac{1}{4}\left(\overline{\theta}_2 + 3\theta_1\right) \end{cases} \\ &= min\{\gamma + \phi\theta_2, \gamma + \frac{1}{4}\phi\left(\overline{\theta}_2 + 3\theta_1\right)\} \\ &= min\{U^2(\theta_2, I), \hat{s}^\star(\theta_1, I)\} \end{aligned}$$

As a consequence, trade takes place if $\theta_2 \geq \frac{1}{4}\left(\overline{\theta}_2 + 3\theta_1\right)$ and $\hat{s}^\star(\theta_1, I) = \hat{b}^\star(\theta_1, I)$, which results in the following purchase price for the bonus bank:

$$P^\star = \gamma(I) + \frac{1}{4}\phi\left(\overline{\theta}_2 + 3\theta_1\right)$$

Because θ_1 is known, manager 1 has no incentives to misreport, which completes the proof.

Proof of Proposition 3 (A.6). The situation $T = T^A$ is straightforward. Consider the case $T^A < T$ and a bargaining process under complete information (condition (23)), the present value of bonus payments is given as

$$\sum_{t=1}^{T^A} \frac{E_0(B_t^i(\cdot))}{(1+r)^t} = \xi\left(\sum_{s=1}^{j} E_0(RI_s^i(\theta_1^i))(1+r)^{-s} + \frac{1}{2}\left(\sum_{s=j+1}^{T} \left(E_0(RI_s^i(\theta_1^i)) + E_0(RI_s^i(\theta_2^i))\right)(1+r)^{-s} \right)\right)$$

The assumption $\theta_2 \geq \theta_1$ ensures that trade takes place and the assumption $\theta_c = \mathrm{E}_0(\theta_1^i) = \mathrm{E}_0(\theta_2^i)$ implies that

$$\begin{aligned} \sum_{t=1}^{T^A} \frac{E_0 B_t^i(\cdot)}{(1+r)^t} &= \xi\left(\sum_{s=1}^{T} E_0(RI_s^i(\theta_1^i))(1+r)^{-s} \right) \\ &= \xi NPV_0(I_i, \theta_1^i, \rho^i, T) \end{aligned}$$

which provides the relation between bonus payments and ranking of the projects. Turn to the case $T^A < T$ and a bargaining process under two-sided information asymmetry (condition (27)), the present value of bonus payments is given as

$$\sum_{t=1}^{T^A} \frac{E_0 B_t^i(\cdot)}{(1+r)^t} = \xi\left(\theta_c^i \sum_{s=1}^{j} \rho_s^i \delta(I_i)(1+r)^{-s} + \frac{1}{6} E_0\left(\overline{\theta^i} + \underline{\theta}^i + 2\theta_1^i + 2\theta_2^i\right) \sum_{s=j+1}^{T} \rho_s^i \delta(I_i)(1+r)^{-s} - I_i \right)$$

Trade takes place if $\theta_2^i - \theta_1^i = \frac{\overline{\theta^i} - \underline{\theta}^i}{4}$ and the condition $\Theta^i = [\underline{\theta}, \overline{\theta}]$ ensures that

$$\begin{aligned} \sum_{t=1}^{T^A} \frac{E_0 B_t^i(\cdot)}{(1+r)^t} &= \xi\left(\theta_c \left(\sum_{s=1}^{j} \rho_s^i \delta(I_i)(1+r)^{-s} + \sum_{s=j+1}^{T} \rho_s^i \delta(I_i)(1+r)^{-s} \right) - I_i \right) \\ &= \xi NPV_0(I_i, \theta_c^i, \rho^i, T) \end{aligned}$$

which completes the proof for two-sided information asymmetry. For $T^A < T$ and a bargaining process under one-sided information asymmetry (condition (33)), the present value of bonus payments is given as

$$\sum_{t=1}^{T^A} \frac{E_0 B_t^i(\cdot)}{(1+r)^t}$$
$$= \xi\left(\theta_c^i \sum_{s=1}^{j} \rho_s^i \delta(I_i)(1+r)^{-s} + \frac{1}{4} E_0\left(\overline{\theta}_2^i + 3\theta_1^i\right) \sum_{s=j+1}^{T} \rho_s^i \delta(I_i)(1+r)^{-s} - I_i\right)$$

Trade takes place if $\theta_2^i \geq \frac{1}{4}\left(\overline{\theta^i}_2 + 3\theta_1^i\right)$. Consequently, trade under one-sided information asymmetry leads to a present value of bonus payments

$$\sum_{t=1}^{T^A} \frac{E_0 B_t^i(\cdot)}{(1+r)^t} = \xi\left(\theta_c^i\left(\sum_{s=1}^{j} \rho_s^i \delta(I_i)(1+r)^{-s} + \sum_{s=j+1}^{T} \rho_s^i \delta(I_i)(1+r)^{-s}\right) - I_i\right)$$
$$= \xi NPV_0(I_i, \theta_c^i, \rho^i, T)$$

Because manager 1 participates in additional value created by superior capabilities of manager 2, she will continue to invest in any project portfolio that she would have invested in if trade occurred under symmetric information and investments will be efficient.