Performance Measurement, Value-Creation and Managerial Compensation: The Missing Link

Wolfgang Schultze
& Andreas Weiler

Discussion Paper No. 08-17

German Economic Association of Business Administration – GEABA
The discussion on value-based performance measures is centered around the concept of residual income. The main property of residual income is its connection to capital budgeting and the net-present-value-rule. This property is, however, not sufficient to guarantee strong goal congruence between management decisions and the firm’s objectives. So far, the literature suggests compensation schemes based on modified accounting rules in order to induce the manager to make optimal investment decisions. In contrast, we show that strong goal congruence is also attainable by modifying the compensation function. We develop an incentive scheme based on a bonus bank, which can be interpreted as a nonlinear contract. Within this concept, we provide a link between the incentive system and the actual creation of value, measured by a performance measure derived from Excess Value Created.

JEL-Classification: M40, M41, M46, J33, G31, G34, M52

Keywords: goal congruent compensation schemes, accounting adjustments, performance measurement, managerial incentives

*For helpful comments, the authors thank Michael Krapp, Wolfgang Kuersten, Dieter Pfaff, Thomas Pfeiffer, William P. Rogerson and workshop participants at the University of Augsburg, University of Goettingen, University of Jena, University of Technology, Munich, European Business School Oestrich-Winkel, the 30th EAA (European Accounting Association) Annual Congress in Lisbon (2007), and the 4th EIASM (European Institute for Advanced Studies in Management) Workshop on Performance Measurement and Management Control in Nice (2007).

†Department of Accounting, University of Augsburg, Universitätsstraße 16, 86135 Augsburg, Germany, Phone: +49-821-598-4130, Fax: +49-821-598-4224, Email: wolfgang.schultze@wiwi.uni-augsburg.de

‡Department of Accounting, University of Augsburg, Universitätsstraße 16, 86135 Augsburg, Germany, Phone: +49-821-598-4127, Fax: +49-821-598-4224, Email: andreas.weiler@wiwi.uni-augsburg.de.
1 Introduction, motivation and the problem of the impatient manager

The evaluation of a manager’s performance is a central issue in managerial accounting, especially if the manager not only makes operating decisions but also investment decisions for an organizational unit (Reichelstein 1997). The owner’s (principal’s) objective is to motivate the manager to accept all projects with a positive net present value in order to maximize the value of the investment portfolio. This delegation setting has been an important research area in recent years (e.g. Rogerson 1997, Reichelstein 1997, 2000, Dutta and Reichelstein 1999, 2002, 2005, Mohnen and Bareket 2007, and Pfeiffer and Schneider 2007).

Several performance measures are discussed in the literature regarding their ability to induce efficient investment decisions by the manager. An investment decision is called efficient, if the manager chooses an investment level that maximizes the net present value of a project. For example it is well known that the application of return on investment (ROI) as a performance measure leads to under-investment decisions. An alternative performance measure that is settled in the centre of discussions is residual income. The important property of residual income is that its present value is identical to the net present value of cash flows (so-called “conservation property”) (Preinreich 1937, Reichelstein 1997). This well explains the use of residual income in managerial compensation: if the manager is rewarded proportionately to residual income, the present value of his bonus payments from the project will be proportional to the net present value created by the project. Therefore he will choose the investment level that maximizes net present value, provided that he has the same time preferences as the owner of the firm. Consequently, residual income is considered a goal congruent performance measure.

Since the manager can affect future compensation by altering investment levels, the question arises whether the manager has private incentives to choose the efficient investment levels from the
perspective of shareholders. One major problem in this context is the manager’s "impatience". His time horizon may be shorter or his attitude towards risk may be different to the firm’s. Consequently, higher personal cost of capital or a shorter time horizon may induce the manager to underinvest relative to the efficient investment level (Rogerson 1997).

The solution to this problem provided by Rogerson (1997) has been taken up by a large part of the literature: Managerial compensation is often based on accounting measures of income. These performance measures are created by allocating investment expenditures to future periods which benefit from the investment. Matching revenues and costs is a typical virtue of accrual accounting. It is intended to create a more "accurate" measure of income on a period-by-period basis than directly comparing cash flows across time (Dechow 1994). Given a compensation scheme which rewards the manager proportional to residual income in every period, this allocation process can be used to solve the problem of the impatient manager: as the owner does not know how impatient the manager is, a strong incentive to choose the efficient investment level is provided by a performance measure which is positive in any period for a project with positive net present value. This basically "annuitizes" the original problem. Based on this intuition, Rogerson (1997) develops a special allocation rule for the investment outlay, called the relative marginal benefits allocation rule, which results in expected residual income having the same sign as the expected net present value of the project. This property is called strong goal congruence (Reichelstein 1997). It guarantees that the manager will choose the efficient investment level independent of his time preferences. Many articles have extended this analysis to other accounting issues such as research and development costs, inventories or construction contracts (e.g. Dutta and Reichelstein 2005). Mohnen and Bareket (2007) have recently shown that the basic principle can be extended to the case of capital constraints. In such a setting, a performance measure is considered as being perfectly goal congruent, if the ranking of projects with respect to the performance measure is identical to the ranking given by the net present value rule in each period. This property is called robust goal congruence.
The Rogerson-solution to the problem of the "impatient" manager does however require the principal to modify the rules of accounting used in the computation of residual income. It is unclear, if such goal-congruent accounting rules still result in information which is also relevant for other purposes of accounting, in particular for external users for making economic decisions. The stewardship function is the consequence of an asymmetric distribution of information and potential conflicts of interest (Demski and Feltham 1976, Christensen and Feltham 2005). Decision usefulness and stewardship being separate and distinct functions of accounting (Gjesdal 1981), the application of the Rogerson-solution requires different accounting rules for different purposes. Modified accounting rules may lead to information that is optimal in the sense of the stewardship function, but may be suboptimal for decision-making. In this paper, we therefore want to examine a solution which leaves the measurement basis unaffected.

Another possible solution to the problem of myopic behaviour, proposed by the consulting firms, has not yet found much attention in the theoretical literature (O’Hanlon and Peasnell 1998): the so-called bonus bank. In practice, value-based performance measures such as Economic Value Added (EVA), a trademark of Stern Stewart & Co., are often used in conjunction with a special reward plan for bonus payments (e.g. Stewart 1991). To date, no theory-based connection between value creation, the bonus payments, and their incentive properties does exist (Young and O’Byrne 2001). In view of this need, O’Hanlon and Peasnell (2002) establish the "missing link" between residual income and value creation. Value creation means that the manager initiates projects with a positive net present value, which lead to increases in shareholders’ wealth. In contrast, value realization describes the success in the later implementation and realization of the planned figures. O’Hanlon and Peasnell present a joint measure of value creation and value realization, termed "excess value created" (EVC) as a measure of the managers’ success in these tasks (Ohlson 2002). They do, however, not provide a periodic measure of performance or a formal connection to managerial compensation. It is left for others to formally analyze incentive schemes making use of their measure (O’Hanlon and Peasnell...
In this paper, we take up this task. We show that strong goal-congruence can also be achieved by the use of a bonus bank and a performance-measure based on EVC. We show that the above-mentioned allocation process needed to attain the Rogerson-solution can be established within a bonus bank, without making adjustments to the measurement basis. In this incentive scheme, the manager is rewarded proportionately to the net present value of the project. We develop an optimal bonus coefficient that reproduces the Rogerson-solution. Furthermore, we show that a large class of possible bonus coefficients exists, which are all sufficient to induce the manager to choose the optimal investment level even under capital constraints. Consequently, we attain strong and robust goal congruence without modifying the measurement basis in accounting rules.

In order to calculate optimal allocation rules, the principal must know the time pattern of the cash flows (Lambert 2001). We relax this assumption in the way that the principal is assumed to have no ex ante information about the cash flow structure. Instead, we explicitly include reports by the agent on the present value of future cash flows in the model. We assume that the realization of cash flows in one period generates new information about future cash flows. In each period a truthful report of the agent is needed. In this case, the cash flows can be considered as conditional expected values dependent on present and past information levels. With these new model assumptions, the principal is not able to calculate the optimal allocation ex ante. This leads to the problem that the optimal allocation policy cannot be fixed in a contract. We show that our approach provides a possible solution for this issue by creating goal congruent bonus payments from a bonus bank.

The paper is organized as follows. The next section provides a review of the related literature. In Section 3 we develop a model based on the assumptions of Rogerson (1997). As was described above, the manager will be rewarded directly dependent upon the net present value of the project. Therefore the question arises whether the principal is able to observe the net present value of the project or if he has to give the manager incentives to report his private information truthfully. In section 4 we discuss
optimal bonus payments when a truthful report by the agent about the net present value of the project is given. We extend the analysis in section 5 in the way that the principal implements a mechanism that ensures truthful reports by the agent. We show within our model assumptions that the strategy of truthfully reporting on the net present value of the project is always a Nash-equilibrium. Furthermore, we show that the manager will always choose the efficient investment portfolio even under capital constraints. We develop a performance measure on a period-by-period basis that provides information both on value creation and value realization, which can be incorporated in the bonus bank concept. Section 6 discusses our results in the context of the literature. We conclude with a summary.

2 Related literature

There is a wide discussion of asymmetric information and incentives for capital investments within organizations. In general, the literature discusses compensation schemes based on performances measures which induce managers to make optimal investment decisions. Thus, the calculation of a performance measure based on special allocation rules as well as on adjusted hurdle rates can lead to efficient investment decisions by the manager. However, not only adjusted performance measures, but also special compensation functions may be optimal in this context.

A major part of the literature focuses on allocation rules in order to induce an impatient manager to make decisions maximizing the firm’s net present value. Rogerson (1997) describes a model in which the principal delegates an investment decision to the better informed agent in a multi-period setting. The principal only has information about the cash flow structure but not on the absolute profitability of the project. Rogerson develops an allocation rule, the relative marginal benefits allocation rule, which guarantees that the residual income in each period is positive if and only if the net present value of the project is positive. Provided his model assumptions he shows that this allocation rule is unique. The underlying economic intuition is that the firm can essentially ”annuitize” the manager’s problem. The matching principle is used to allocate the investment costs dependent on the cash flow structure.
Consequently, this creates a situation in which every period provides the same investment incentive. That is, even if the manager cared only about his rewards of a single period, he would still choose the efficient investment level. This is true for every period and therefore the manager’s discount rate and time horizon are irrelevant for his evaluation of the desirability of a project. However, this solution requires the manager to remain on the project for at least one period. We will discuss this issue in section 5.4.

Reichelstein (1997) analyzes a sequence of investment opportunities. He concludes that the relative benefit depreciation schedule remains the unique allocation rule that induces efficient investment. Reichelstein (2000) extends the analysis to moral hazard. He shows that the agency costs of a satisfactory incentive scheme are lower under residual income based on the relative benefit depreciation schedule than under a performance measure based only on realized cash flows.

Wagenhofer (2003) develops an agency-model in which accrual accounting emerges as superior when the principal can only commit to short-term contracts. The key difference between his model and the model of Rogerson (1997) or Reichelstein (1997) is that the investment decision is subject to moral hazard and induces a disutility to the agent. He shows that in this case the optimal depreciation schedule is different from the relative benefit depreciation schedule. He points out that in the case that the investment is subject to moral hazard, the full expected return on the investment must be shifted to the period of initiation to provide appropriate investment incentives.

Mohnen and Bareket (2007) examine performance measurement for investment decisions under capital constraints. Based on Dutta and Reichelstein (2005), they provide a new characterization of goal congruence. The so-called robust goal congruence ensures periodic consistency between the expected performance measure and the ex ante ranking of investment projects according to net present value. Thus, the manager has an incentive to select the project or the portfolio of projects with the highest net present value regardless of his own time preferences. They conclude that in this case the optimal result is not attainable by solely relying on “forward-looking” cost depreciation. Therefore they
develop an optimal "forward looking" accounting rule for revenue recognition which "smoothes out" the operating cash flows during the project's life and therefore leads to additional accrual components. The integration of this revenue recognition rule in the calculation of the performance measure will lead to residual income which depends in a linear way on the net present value of each project. In contrast to the solution of Rogerson (1997) and Reichelstein (2000), their allocation rule is independent of the specific project structure. The problem of capital constraints is included in our analysis in section 5.5.

Moreover, the literature extends the discussion of adjusted accounting rules on other subjects in accounting like revenue recognition, inventory management or multi-year construction contracts. Dutta and Zhang (2002) analyze the impact of various revenue recognition rules on the incentives of accounting information in a stewardship setting. They show that if revenues are recognized according the realization principle, residual income provides optimal effort and production incentives. In this context, the realization principle means that products are carried at their historical costs on the balance sheet. Those costs are compounded over the period of production and subsequently expensed when products are sold and value is realized, leading to an intertemporal matching of costs and revenues. In contrast they point out that mark-to-market accounting generally does not provide efficient aggregation of raw information for the principal to solve the stewardship problem.

Baldenius and Reichelstein (2005) examine inventory management from an incentive perspective. They show that when a manager has private information about future revenues, a residual income based on historical cost leads to second-best incentives with regard to managerial effort as well as production and sales decisions. In situations where the manager receives new information after the initial contracting stage the lower-of-cost-or-market inventory-valuation rule becomes the optimal mechanism. However they point out that in this case accounting and market-based performance measures generally fail to align incentives for products with longer than two life cycles. The reason is that opportunity cost considerations will collide irreconcilably with sunk cost considerations.

Dutta and Reichelstein (2005) analyze alternative accounting rules from an incentive and control
perspective. In particular, they try to find the optimal accounting rule to deal with multi-period construction contracts. They develop a so-called present-value-percentage-of-completion-method that eliminates the time inconsistency of the percentage-of-completion-method and generates incentives for the manager to accept a contract if and only if he also expects a positive net present value. Consequently, their finding of matching costs and revenues is essentially the "mirror image" of the relative benefit depreciation schedule. Furthermore, they analyze accounting rules for long-term leases and asset disposals. They also analyze sequential investment decisions in the context of strategic costs like research and development. They point out that the optimal continuation policy requires the manager to view all previous expenditures as sunk. Therefore their analysis advocates full cost accounting rather than successful effort accounting. This means that the compounded value of the investment expenditure must be depreciated according to the relative benefit depreciation schedule even if the manager decides to abandon the project at the end of a period. They conclude that a common characteristic of accrual accounting rules is that value creating decisions increase the manager’s performance measure in every period of the project’s useful life. From this it follows that the residual income performance measure in each period is proportional to the net present value of the project. This is comparable to our findings since we will show that the optimal bonus payment can directly be derived from the net present value of any project.

Pfeiffer and Schneider (2007) extend the sequential investment setting of Dutta and Reichelstein (2005) by introducing a sequential adverse selection problem. That is, the manager sequentially obtains private information about the profitability of the project. They distinguish between centralized and decentralized investment decisions. For the case of centralized investment decisions they conclude that the manager only receives an expected information premium for his precontract information but not for his postcontract information. Furthermore they show that central management can use the abandonment option to reduce the manager’s information rents. This is interesting because our model in section 5 can be interpreted as a setting of centralized investment decisions in which truthful reports
of the manager are needed. However, we abstract from precontract information by the manager. If decentralized investment decisions are considered, their results extend the findings of Dutta and Reichelstein (2005) in the way that not only investment expenditures but also virtual costs (measured by a hazard rate and a disutility parameter) must be capitalized and allocated according to the relative marginal benefits allocation rule.

Pfeiffer (2000) shows that a strong goal congruent performance measure can be derived by adjusting allocation rules as well as by adjusting interest charges for capital employed. However, only limited attention has been paid to the fact that not only allocation rules or hurdle rates can be adjusted in an incentive scheme. Special compensation functions may also lead to optimal investment incentives for managers. Therefore we develop an incentive scheme based on bonus payments which are adjusted through a special compensation function. Allocation rules remain unaffected in this examination.

3 The model

Below we analyze the relationship between the owner of a firm and a manager in a principal-agent model. The principal delegates an investment decision to the better informed manager. In the following section we provide our underlying model assumptions.

3.1 Basic assumptions

Assume that the principal is risk neutral and has a cost of capital of \( r \). In our model assumptions we make no further statement about the risk attitude of the agent which means that he may be risk neutral as well as risk averse. Consider \( T + 1 \) periods indexed by \( t \in \{0, \ldots, T\} \). Therefore a possible project has the cash flow structure \((x, z_1, \ldots, z_T)\), where \( x \) denotes the level of investment in period 0 and \( z_t \) represents the cash flow at date \( t \) associated with the project. Let \( z = (z_1, \ldots, z_T) \) be the vector of all cash flows from the project. The underlying accounting system is able to directly measure both \( x \) and \( z_t \). However, in each period \( t \), the manager exerts an unobservable level of effort \( e_t \) that
affects the cash flow the firm receives from the project. Let $e = (e_1, \ldots, e_T)$ denote the vector of all the agent’s effort choices.

Assume that the manager is better informed about his own preferences and the marginal productivity of the investment. Formally we denote this private information as a multidimensional variable $\theta$, which is drawn from a set $\Theta$.

Obviously, the period $t$ cash flow is affected by $\theta$, the manager’s effort choice $e_t$, and the investment level $x$. Therefore the cash flows associated with the project are known only to the manager. Rogerson (1997) assumes the principal as well as the manager to have information about the relative productivity profile of the investment denoted by $\rho_t$. With these underlying assumptions, the period $t$ cash flow is formally determined by

$$z_t = \rho_t \delta(x, \theta) + \epsilon_t$$

where $\delta(x, \theta)$ is an increasing function of $x$ for every $\theta$, and $\epsilon_t$ is a random variable affected by the manager’s effort according to the conditional density $f(\epsilon_t | e_t)$ that is assumed to be normally distributed with expected value $e_t$ and the constant variance $\sigma^2_e$. Formally, the expected value and variance of the cash flow in period $t$ is given by

$$\mathbb{E}[z_t] = \rho_t \delta(x, \theta) + e_t$$

$$VAR[z_t] = \sigma^2_e$$

It is straightforward to see that with these model assumptions changing investment levels would not change the risk of the cash flows in each period.

In contrast to Rogerson (1997), we assume that the principal has no information about the patterns of the cash flows. Thus, a mechanism must be implemented which ensures truthful reports about the project’s profitability by the agent. In section 4, we assume that there already exists a mechanism which induces the agent to report all project’s parameters truthfully to the principal. Provided this assumption, we show that the solution by Rogerson (1997) can be reproduced by choosing a special
bonus coefficient which defines the bonus payment to the manager dependent on the net present value of the project. Furthermore, we show that efficient investment decisions by the manager can also be achieved if the manager only reports the net present value. In section 5, we provide our bonus bank approach which can be interpreted as a simulation of an internal market and show that this concept can be used to induce a truthful report by the agent about the net present value of the project.

The efficient investment level that maximizes expected discounted cash flows for the firm is the level that maximizes

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

Note that the maximization condition is independent of $\epsilon_t$. To guarantee that for every $\theta$ there exists a unique value of $x$ that maximizes the net present value of the future cash flows, we assume for every $\theta \in \Theta$ that $\delta (x, \theta)$ is continuously differentiable in $x$, strictly increasing in $x$, and strictly concave in $x$. This optimal investment is determined by the first-order condition

$$\frac{\partial}{\partial x} \left( \sum_{t=1}^{T} \frac{\rho_t \delta (x, \theta) + \epsilon_t}{(1 + r)^t} - x \right) = 0 \iff \frac{\partial \delta (x, \theta)}{\partial x} = \frac{1}{\sum_{t=1}^{T} \frac{\rho_t}{(1 + r)^t}}$$

Let $\hat{x} (\theta)$ denote the efficient investment level. Furthermore let $w = (w_1, \ldots, w_T)$ represents the vector of wage payments the manager receives in every period $t$ from the project, where

$$w_t = s + B_t$$

Let $s$ denote the fixed compensation the manager receives in each period. $B_t$ denotes the bonus payment the manager receives from the project. Let $u (w, e, \theta)$ denote the manager’s expected utility function, where $u (w, e, \theta)$ is weakly increasing in $w_t$ for every $t \in \{1, \ldots, T\}$ and let $\overline{u}$ be the reservation utility.

### 3.2 Contracts inducing efficient investment and optimal allocation rules

The principal hires a manager at the beginning of $t = 0$ to choose the efficient investment level in period 0 and then exert effort in each of the periods $1, \ldots, T$. The investment decision is delegated
to the manager because he is better informed about the profitability of the project. Therefore the principal offers the manager a contract which specifies the wage payments $w_t$ in every period $t$ to the manager as a function of the manager’s investment choice in period 0 and the actual performance. If the manager rejects the contract, he receives his reservation utility and the relationship is over. If the manager accepts the contract, he chooses an investment level $x$ at date 0 and exerts effort $e$ as long as he remains on the project.

A contract is optimal if the principal is able to predict the manager’s behavior conditional on $\theta$ (Rogerson 1997). Therefore the optimal contract is a contract which maximizes the net present value of the project, inducing the manager to choose the investment level $\hat{x}(\theta)$. A contract $\phi$ induces efficient investment if, for every possible $\theta$ respectively $e$, the manager maximizes his expected utility by choosing the efficient investment level. The expected utility of the manager is formally given by

$$U(x, e, \theta, \phi) = \int u(\phi(x, z), e, \theta) f(e|e) \, de$$

(7)

Therefore a contract $\phi$ induces the efficient investment level if the manager has a strong incentive to choose the investment level $\hat{x}(\theta)$. That is, as we have shown provided our assumptions, the unique investment level that maximizes the net present value of the project. Formally, the manager chooses the efficient investment level if

$$\hat{x}(\theta) = \arg\max_x U(x, e, \theta, \phi)$$

(8)

Let $a = (a_1, \ldots, a_T)$ be a vector of real numbers, where $a_t$ denotes the investment cost allocated to the period $t$ for every monetary unit invested. The allocation costs equal depreciation plus interest charges on the remaining book value of the investment. Let $y_t$ denote the firm’s residual income in period $t$, conditional on the investment level $x$, cash flows $z$, and allocation rule $a$. Such a function is given by

$$y_t = z_t - a_t x$$

(9)

Let $y$ be the vector of the accounting income from the project. An allocation rule is therefore said
to induce efficient investment if the created contract induces efficient investment. Rogerson (1997) shows that there exists only one unique allocation rule that induces efficient investment. It is called the relative marginal benefits (RMB)-allocation rule given \((\rho, r)\) and is denoted by \(a^{\rho,r}_t\). It is given by

\[
a^{\rho,r}_t = \frac{\rho_t}{\sum_{i=1}^{T} \rho_i (1+r)^i}.
\]

The main advantage to this solution is that the principal is able to design the contract without any reports from the agent. But two problems remain. First, modified measurement bases by altering allocation rules lead to different information needs for on the one hand stewardship and on the other hand decision-making. Second, a strong assumption is needed to derive the solution, i.e. the principal must have full knowledge about the cash flow structure in \(t = 0\).

Our objective is to find a bonus payment that implements the same result. In the first step we examine optimal bonus payments when a truthful report by the agent about the net present value of the project is given. Lateron, we relax this assumption in section 5.

4 The principal knows the net present value of the project

In the following section we develop an optimal bonus payment that induces the manager to choose the efficient investment level. We assume that a mechanism is established which ensures truthful reports by the manager. In the first step we assume the agent to communicate the full dimensionality of his information. Thus, the principal knows the net present value of the project as well as the structure of cash flows. In a second step we relax this assumption.

Let \(\alpha\) be the share the manager receives of residual income \((y_t)\) in each period. Considering an income based contract, the optimal bonus payment \(\overline{B}_t\) which the manager receives from the project, based on the RMB-allocation rule, can be calculated in each period \(t\) as

\[
\overline{B}_t = \alpha y_t = \alpha \left[ \rho_t \delta(x, \theta) + \epsilon_t - \frac{\rho_t}{\sum_{i=1}^{T} \frac{\rho_i}{(1+r)^i}} x \right].
\]
As we will show, this bonus payment can also be derived directly from the net present value of the project. Note that the model does not explicitly include a possible participation constraint. With respect to the optimal bonus payment, the principal can select a contract from the entire class of contracts that specifies the optimal bonus coefficient in order to find the best possible solution to moral hazard or risk sharing problems.

**Proposition 1.** Suppose that the relative productivity profile of the investment in period \( t \) is \( \rho_t \) and the principal’s cost of capital is \( r \). In each period the manager receives a bonus payment \( \hat{B}_t \) from the project that can be derived directly from the net present value of the project. So the optimal contract must fix both the optimal bonus coefficient and a mechanism that induces truthful reporting. Formally, the optimal bonus coefficient \( \beta_t \) can be calculated as follows

\[
\hat{B}_t = \beta_t \left( \sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta) + e_t}{(1 + r)^t} - x \right)
\]

where

\[
\beta_t = \frac{\alpha \rho_t}{\sum_{i=1}^{T} \frac{\rho_i}{(1 + r)^i}} \cdot \left[ \frac{\sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta)}{(1 + r)^t}}{\sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta) + e_t}{(1 + r)^t}} \right] + \frac{\alpha e_t}{\sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta) + e_t}{(1 + r)^t}} \cdot \left( \frac{\sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta)}{(1 + r)^t}}{\sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta) + e_t}{(1 + r)^t}} \right) - x
\]

The consequence is that the principal can obtain the optimal bonus structure by paying the manager in each period \( t \) a share of the net present value, calculated with the optimal bonus coefficient \( \beta_t \). This incentive system is independent of income determination, accounting rules and a performance measure. But, the bonus payments depend on the reports of the agent.

Assume \( \mathbb{E}(e_t) = 0 \), which means that the effort of the manager is not expected to have any influence on the cash flow at date \( t \). The following corollary provides the intuitive result that in this case the optimal coefficient is, with respect to \( \alpha \), the relative productive profile of the investment in period \( t \) divided by the present value of all relative productive profiles of the investment. With other words, the effort of the agent is not expected to shift the mass of probability of the cash flows in each period.

**Corollary 1.** If the manager’s effort choice is expected to have no impact on the cash flows (\( \mathbb{E}(e_t) = 0 \)), the optimal bonus payment to the manager can be calculated as

\[
\hat{B}_t = \frac{\alpha \rho_t}{\sum_{i=1}^{T} \frac{\rho_i}{(1 + r)^i}} \cdot \left( \frac{\sum_{t=1}^{T} \rho_t \delta(x, \theta)}{(1 + r)^t} - x \right)
\]
It remains to be shown that the optimal payment stream, defined in proposition 1, actually induces the manager to choose the efficient investment level. Therefore the manager will always make the investment decision that maximizes the net present value independent of his time preferences.

**Proposition 2.** Consider the same assumptions as in proposition 1. The agent receives a contract that includes the optimal bonus coefficient \( \beta_t \) that leads to the bonus payment which is defined in proposition 1. Then it is optimal for the manager to choose the efficient investment level \( \hat{x}(\theta) \).

As a result, we can conclude that the bonus coefficient \( \beta_t \) reproduces the bonus payment which would result from rewarding the manager dependent on residual income determined based on the RMB-allocation rule.

Rogerson (1997) shows that the RMB-allocation rule is unique in inducing the efficient investment level. Within our framework we are able to show that this result does not hold for bonus coefficients. If we adjust the bonus coefficient and therefore the bonus payment instead of the measurement basis, we are able to induce the manager to choose the optimal investment level with every bonus coefficient that ensures the manager a positive bonus payment if and only if the net present value of the project is positive.

Note that the solution above requires the principal to know the parameters of net present value. In the following we relax this assumption and instead assume that the manager only reports the correct amount of the net present value of the project. An economic intuition behind this assumption is that international financial reporting standards require the cash generating units of a firm to measure and report its value of goodwill, which is economically identical to its net present value. Given that the net present value is reported truthfully, we can show that a large class of such optimal contracts exists where the optimal bonus coefficients can freely be chosen. Therefore an optimal contract can be calculated within an optimization problem under participation and incentive compatibility constraints. The optimal coefficients must then be calculated with respect to possible moral hazard or risk sharing problems. The main result is that such a coefficient suffices to induce the manager to choose the
efficient investment level. Hence, the optimal bonus coefficient $\beta_t$ that reproduces the bonus payment that results by applying the RMB-allocation rule is not unique any more. This result is presented in the proposition below.

**Proposition 3.** Suppose that the relative productivity profile of the investment is $\rho_t$ and the principal’s cost of capital is $r$. In each period the manager receives a bonus payment $\hat{B}_t$ from the project which can be calculated as

$$
\hat{B}_t = \xi_t \cdot \left( \sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta) + e_t}{(1 + r)^{t}} - x \right)
$$

where $\xi_t$ is real-valued and

$$
0 \leq \xi_t \ \forall t \in \{0, \ldots, T\} \quad \text{and} \quad \sum_{t=0}^{T} \frac{\xi_t}{(1 + r)^t} \leq 1
$$

Then it is optimal for the manager to choose the efficient investment level $\hat{x}(\theta)$.

It is to note that this procedure is similar to the results of Dutta and Reichelstein (2005). They point out that accounting rules must lead to a residual income that is proportional to the net present value of a project in order to induce optimal incentives. Therefore the residual income in period 0 can indicate the whole value of the project by ”frontloading” the entire present value of a transaction in the initial period. That leads to a full fair-value accounting. A different approach would be to backload the managerial performance measure to ensure strong goal congruence. Thus, a bonus payment based on such residual income will lead to efficient investment decisions. In contrast, we can achieve the same bonus payments without adjusting accounting rules by generating a stream of bonus payments via a bonus bank.

Note that this bonus coefficient does not require the principal to know the structure of the project, but only its net present value. How a contract can be designed to induce the manager to report his private information truthfully is analyzed in section 5.

As we will show now, the solution suggested by Mohnen and Bareket (2007) for the special case of capital constraints can also be reproduced by selecting special bonus coefficients $\xi_t$. According to their result, the bonus payment $B_t$ which the manager receives must be consistent with the ex ante
net present value ranking. Thus, the condition of robust goal congruence can formally be denoted as

$$B_t^i > B_t^j \forall t \in \{1, \ldots, T\} \iff \left( \sum_{t=1}^{T_i} \rho_t \delta(x_i, \theta_i) + e_t \right) (1 + r)^{-t} - x_i > \left( \sum_{t=1}^{T_j} \rho_t \delta(x_j, \theta_j) + e_t \right) (1 + r)^{-t} - x_j$$

(17)

where $i$ and $j$ characterize different investment opportunities. Without loss of generality, we assume that the projects have the same time horizon $T = T_i = T_j$. The proposition below provides the insight that in this case the optimal bonus coefficient is exactly the annuity factor dependent on $\alpha$.

**Proposition 4.** For any $\alpha \in (0, 1]$, the bonus payment in (15) leads to efficient investment decisions even under capital constraints if

$$\xi_t = \frac{\alpha r \cdot (1 + r)^T}{(1 + r)^T - 1} \forall t \in \{1, \ldots, T\}$$

(18)

In order to highlight the main result we conclude that optimal investment decisions can always be achieved for the principal by rewarding the manager directly based on the value he created. We show that the bonus structure which is defined in (15) and (16) suffices to induce the manager to choose optimal investment levels. In particular, no adjustments of the measurement basis, and accounting rules, are necessary. For practical application, it is worthwhile to note that the consequence of the described scheme is that the manager is treated like a partner of the business unit he is in charge for. An internal capital market is created where value created is captured and from which the manager benefits. As we will show below, this is achievable with the concept of a bonus bank. But two questions are left to be answered. First, is there any mechanism that ensures a truthful report about the project’s profitability of the manager? Second, how can one integrate possible differences between actual, realized figures and the original projections? A possible solution for these problems is provided below.

One main advantage of the results of Rogerson (1997) is that the principal can induce efficient investment decisions regardless of the agent’s time preferences or his utility function. Due to the fact that the manager receives positive bonus payments if and only if the net present value of the whole project is positive, he will also make efficient investment decisions regardless of his time preferences.
Since the same bonus payments which are attained by the use of the RMB-allocation rule can also be achieved with the bonus bank, this advantage of the Rogerson-approach is maintained in our concept.

In the following section we stress our assumptions in the sense that the principal is not able to observe the net present value of the project. Therefore we develop a mechanism that leads to a solution in which the strategy of a truthful report by the manager about the net present value of the project is always a Nash-equilibrium.

5 A special bonus structure that induces truthful reporting by the agent

In contrast to our analysis above, we now analyze the case in which a mechanism must be implemented that ensures truthful reports by the agent. As was shown by Myerson (1979), any mechanism that involves nontruthful reporting by the agent can be duplicated or beaten in terms of expected utilities by an equilibrium mechanism that induces truthful reporting. The principal could then observe the net present value and will reward the manager directly dependent on it. In this context the question arises on how optimal contracts must be designed. We show that in our approach the strategy of a truthful report is exactly an equilibrium strategy for the agent.

If we allow for information asymmetries, it is possible that the manager may not report truthfully on the expected performance of the project. When he is rewarded based on the net present value, he may have an incentive to overstate future performance. According to the section above, we assume that the manager has to report the net present value of the project. Let $l_t$ be real-valued, where $l_t > 0$ denotes the manager’s overstatement for period $t$ in his reporting. Thus, the reported net present value may be based on possible biased cash flows $z^l_t$ which are formally defined as

$$ z^l_t = \mathbb{E} [z_t] + l_t = \mu_t \delta (x, \theta) + e_t + l_t $$

(19)

Typically, the original projections will not exactly be met in later periods. Thus an important virtue of a performance measure is to inform about the degree to which expectations where met in a particular
period under consideration. An ideal performance measure would therefore inform both on newly created value as well as on deviations from original projections. In this sense, we assume that the agent receives new information about future cash flows at the end of each period.

As was assumed above, the manager is better informed about his own preferences and the marginal productivity of the investment. In contrast to section 3.1, we assume now that the cash flow in each period depends on a relative productivity profile of the investment $\rho_t$ that is assumed to be normally distributed with the expected value $\mu_t$ and the constant variance $\sigma^2_{\rho}$. This parameter can change during the life of the project depending on different levels of information $i_t$ in period $t$. Formally, let $i = (i_0, \ldots, i_{T-1})$ be the $T$-dimensional vector of the level of information about the future cash flow structure. In order to formalize this issue, we write $\rho_t = \rho_t (i_0, \ldots, i_{t-1})$. Assume that at the end of each period the agent receives new information about the future pattern of cash flows. Note that in our analysis we do not need the principal to have any information about future cash flows. With these underlying assumptions, the period $t$ cash flow $z_t$ is formally determined by

$$ z_t = \rho_t (i_0, \ldots, i_{t-1}) \delta (x, \theta) + \epsilon_t $$

Furthermore, the random variables $\epsilon_t$ and $\rho_t$ are independently distributed and therefore, the cash flow $z_t$ in each period $t$ is a normally distributed random variable with

$$ E[z_t|i_0, \ldots, i_{t-1}] = \mu_t (i_0, \ldots, i_{t-1}) \delta (x, \theta) + \epsilon_t $$

$$ VAR[z_t|i_0, \ldots, i_{t-1}] = \delta^2 (x, \theta) \sigma^2_{\rho} + \sigma^2_e $$

Thus, the manager’s expected wage payments are also normally distributed due to a linear transformation of random variables which are independent and normally distributed. However, if we include planning revisions in the analysis, the manager has to report the present value of future cash flows in each period. According to (19), the reported present value of future cash flows in each period may be based on possible biased cash flows $z_t'$ which are formally defined as

$$ z_t' = E[z_t|i_0, \ldots, i_{t-1}] + l_t = \mu_t (i_0, \ldots, i_{t-1}) \delta (x, \theta) + \epsilon_t + l_t $$
Within this formulation, differences between reported figures and lateron realized values can be traced back to (i) an untruthful report by the agent \((l_t > 0 \text{ for any } t)\), (ii) variances from the expected values.

It is to note that with our new model assumptions, the variance of the cash flows depends on the agent’s investment decision. Consider the optimal contracting case in which the principal and the agent may disagree on how to trade off risk and return. A possible solution would be to adjust the capital charge by calculating residual income (Christensen et al. 2002, Dutta and Reichelstein 2002). Thus, contracts including bonus payments based on current performance measures must be convex in order to offset the concavity of the agent’s utility function and therefore induce the agent to behave in a less risk averse fashion (Lambert 1986, Feltham and Wu 2001, Demski and Dye 1999).

Furthermore, the realized value of the relative productivity is \(\nu_t\). Formally, a realized residual income measure can therefore be defined as

\[
y_t = \nu_t \delta(x, \theta) + \epsilon_t - a_t x
\]

where \(a_t\) is an allocation rule with which the conservation property holds. Provided the information levels \(i_0, i_1, \ldots, i_{t-1}\), the planned income measure at date \(t\) is formally denoted as

\[
E[y_t|i_0, \ldots, i_{t-1}] = \mu_t(i_0, \ldots, i_{t-1}) \delta(x, \theta) + \epsilon_t - a_t x
\]

We assume that the manager has to report the present value of future cash flows in each period. Note that our suggested solution also works if we allow the manager to report the present value of future residual income in each period. At date \(t = 0\), the present value of residual income is equivalent to the net present value of the project. The reported present value of future residual income may be based on biased residual income \(y'_t\) which are formally given by

\[
y'_t = z'_t - a_t x = \mu_t(i_0, \ldots, i_{t-1}) \delta(x, \theta) + \epsilon_t + l_t - a_t x
\]

Due to possible changes in the project’s profitability, we have to allow for differences of initially planned figures on the one hand and lateron realized figures on the other hand. It is therefore important to be
able to measure newly created value and its later actual realization. Such a measure of performance is presented in section 5.1.

### 5.1 Measurement of value creation and value realization and the concept of residual economic income

Residual income is not a measure of value creation. It only answers the question whether profits exceed the firm’s cost of capital. The present value of expected residual income is equivalent to net present value and as such, to the expected value creation. But there is no immediate link between residual income observed in one particular period and value creation. O’Hanlon and Peasnell (2002) provide this ”missing link”: they define a measure of value creation, the so-called ”excess value created” ($EV_C$), which consists of two components, promised goodwill ($GW$) and realized goodwill. Realized goodwill is identical to all residual income $y_t$ earned and accumulated to date $t$, accrued at the discount rate $r$. Promised goodwill is equivalent to the present value of the expected future residual income. The $EV_C$ is formally given by

$$EV_C_t = \sum_{s=1}^{T} y_s (1 + r)^{t-s} + \sum_{s=1}^{T} \mathbb{E}[y_{t+s}] (1 + r)^{-s}$$

From the perspective of the principal, who has only limited information about the projects profitability, the present value of expected residual income $\sum_{s=1}^{T} \mathbb{E}[y_{t+s}] (1 + r)^{-s}$ needs to be substituted by the reported present value of residual income $\sum_{s=1}^{T} y_{t+s} (1 + r)^{-s}$ by the manager. With (26), the $EV_C$ dependent on the agent’s report is formally given by

$$EV_C_t = \sum_{s=1}^{t} y_s (1 + r)^{t-s} + \sum_{s=1}^{T} y_{t+s} (1 + r)^{-s}$$

$EV_C$ thus includes the value generation which has already been realized and the value generation which was initiated but is still to be realized in the future. In other words, a segregation of the past and the future part of value generation is achieved. $EV_C$ contains the accumulated generation of value over time. To capture the performance of a single period, changes of $EV_C$ need to be considered. An
increase in $EVC$ in the single period $t$ ($\Delta EVC_t$) is given by:

$$\Delta EVC_t = EVC_t - EVC_{t-1}$$

$$= \sum_{s=1}^{t} y_s (1 + r)^{t-s} - \sum_{s=1}^{t-1} y_s (1 + r)^{t-1-s} + \Delta GW_t$$

$$= y_t + r \cdot \sum_{s=1}^{t-1} y_s (1 + r)^{t-1-s} + \Delta GW_t$$

(29)

EVC will increase over time, even without initiating any new projects, at a rate equivalent to the cost of capital, solely due to the passing of time. This time-effect needs to be controlled for when judging performance. We call the resulting measure "Residual Economic Income" ($REI$):

$$REI_t = \Delta EVC_t - r \cdot EVC_{t-1}$$

$$= y_t + r \cdot \sum_{s=1}^{t-1} y_s (1 + r)^{t-1-s} + \Delta GW_t - r \cdot EVC_{t-1}$$

$$= y_t - r \cdot GW_{t-1} + \Delta GW_t$$

$$= \nu_t \delta(x, \theta) + c_t - a_t x$$

$$- r \cdot \sum_{s=1}^{T} (\mu_{t+s-1}(i_0, \ldots, i_{t-2}) \delta(x, \theta) + e_{t+s-1} + l_{t+s-1} - a_{t+s-1} x) (1 + r)^{-s}$$

$$+ \sum_{s=1}^{T} (\mu_{t+s}(i_0, \ldots, i_{t-1}) \delta(x, \theta) + e_{t+s} + l_{t+s} - a_{t+s} x) (1 + r)^{-s}$$

$$- \sum_{s=1}^{T} (\mu_{t+s-1}(i_0, \ldots, i_{t-2}) \delta(x, \theta) + e_{t+s-1} + l_{t+s-1} - a_{t+s-1} x) (1 + r)^{-s}$$

(30)

The above formulation shows that a positive value for $REI$ indicates that additional value was created, whereas the opposite holds true for value-destruction. A value of 0 indicates that the original projections were exactly met.

O’Hanlon and Peasnell (2002) also present a special form of $EVC$ for the case that the measurement process of value creation and value realization is initialized at some beginning date $b$ after initiating the project but before period $t$ ($0 \leq b \leq t$). $EVC_b^t$ denotes the generated $EVC$ in the periods between $t$ and $b$. In order to examine the deviation of actual and planned figures as well as of planning revisions, they provide the concept of "excess residual income" ($ERI$) which is the excess of a realized over a
planned residual income. The following equation shows the \( EV_C \) based on ERI:

\[
EV_C^b_t = \sum_{s=1}^{t-b} [y_{b+s} - \mathbb{E}_b [y_{b+s}]] (1 + r)^{t-(b+s)} + \sum_{s=1}^{T} [\mathbb{E}_t [y_{t+s}] - \mathbb{E}_b [y_{t+s}]] (1 + r)^{-s} \tag{31}
\]

A positive or negative \( EV_C \) thus results from planning revisions or deviations of actual and planned performance. A performance measure on a period-by-period basis could therefore be calculated as follows \((b = t - 1)\):

\[
EV_C^{t-1} = y_t - \mathbb{E}_{t-1} [y_t] + \sum_{s=1}^{T} [\mathbb{E}_t [y_{t+s}] - \mathbb{E}_b [y_{t+s}]] (1 + r)^{-s}
\]

\[
= y_t - \mathbb{E}_{t-1} [y_t] + \sum_{s=1}^{T} \mathbb{E}_t [y_{t+s}] (1 + r)^{-s} - \sum_{s=1}^{T} \mathbb{E}_{t-1} [y_{t+s}] (1 + r)^{-s}
\]

\[
= y_t + GW_t - \sum_{s=0}^{T} \mathbb{E}_{t-1} [y_{t+s}] (1 + r)^{-s} \tag{32}
\]

\[
= y_t + GW_t - (1 + r) \cdot GW_{t-1}
\]

\[
= y_t + \Delta GW_t - r \cdot GW_{t-1}
\]

\[
= REI_t \tag{33}
\]

This shows that a one period \( EV_C^{t-1} \) is identical to \( REI_t \). That is, \( REI \) is an ideal measure of performance in the sense that it informs both about newly created value as well as about deviations between original plans and realized figures. However, by itself it does not provide an adequate solution to the agency-problem. We show in the next sections how \( REI \) can be incorporated in a compensation scheme and how the principal can ensure truthful reports by the agent.

### 5.2 The structure of the bonus bank

As was described above, our suggested solution requires the manager to be treated like a partner of the business unit he is in charge for. It simulates an internal financial market where value is created and from which the manager benefits. That is, the manager’s share of the created value is credited to the bonus bank at the initiation date.
In this concept, bonuses are not paid out immediately, but are credited to the bonus bank. Based on realized values, the bonuses are paid out in subsequent periods (O’Hanlon and Peasnell 1998 and Stewart 1991). As we have shown above, it is optimal to reward the manager directly based on the value created. With (15) and (16), the present value of the bonus payments depend on the net present value of the project in a linear way:

\[
\sum_{t=0}^{T} \frac{B_t}{(1+r)^t} = \eta \cdot \left( \sum_{t=1}^{T} \frac{\mu_t(x, \theta) + e_t}{(1+r)^t} - x \right)
\]

(34)

where \( \eta \) is real-valued, \( 0 < \eta \leq 1 \) and therefore it is

\[
\sum_{t=0}^{T} \frac{\xi_t}{(1+r)^t} = \eta \in (0, 1)
\]

where \( \xi_t \geq 0 \forall t \in \{0, \ldots, T\} \) (35)

As mentioned above, the manager has a strong incentive to choose the efficient investment level regardless of his own time preferences. However, the agent’s time preference is different to the principal’s in many cases. In general, when the agent discounts his future bonus payments at the same discount rate as the principal, he will be indifferent between an immediate payout of the bonus and its retention and compounding at the discount rate (Miller and Modigliani 1961), as long as he can transform increases in the value of his bonus account to cash, without transaction costs. For this to hold, an internal capital market is needed in which the bonus bank can be traded. This ensures the irrelevance of the dividend policy to remain valid for "internal" capital markets.

Without loss of generality, we assume that the full value created is captured by the bonus bank \( (\eta = 1) \). The results remain valid for any \( \eta \in (0, 1) \). In this case the manager chooses the set of decisions that maximizes the firm’s net present value even if mutually exclusive projects are considered. Formally, we denote the balance of the bonus bank in period \( t \) as \( K_t \). At date \( t = 0 \), the balance of the bonus bank is given by

\[
K_0 = \sum_{t=1}^{T} \frac{E_0[z_t|i_0]}{(1+r)^t} + l_t - x = \sum_{t=1}^{T} \frac{\mu_t(i_0) \delta(x, \theta) + e_t + l_t}{(1+r)^t} - x = REI_0
\]

In subsequent periods, the balance of the previous period is compounded at the cost of capital. Any deviations from original projections are part of \( REI_t \) which are added to (subtracted from) the bonus
bank. Obviously, payouts $B_t$ from the bonus bank to the manager decrease the balance of the bonus bank. Consequently, the balance of the bonus bank $K_t$ at date $t$ is formally given by

$$K_t = (1 + r) \cdot K_{t-1} + REI_t - B_t$$

$$= \sum_{i=0}^{t} REI_i (1 + r)^{t-i} - \sum_{i=1}^{t} B_i (1 + r)^{t-i} \forall t \in \{0, \ldots, T\}$$

(36)

The bonus payment at date $t$ depends on the balance of the bonus bank $\tilde{K}_t$ before $B_t(\tilde{K}_t)$ is paid out. According to (36), $\tilde{K}_t$ is formally given by

$$\tilde{K}_t = \sum_{i=0}^{t} REI_i (1 + r)^{t-i} - \sum_{i=1}^{t-1} B_i (1 + r)^{t-i}$$

(37)

According to the incentive scheme given by (6), the wage payments $w_t$ to the manager are formally determined by

$$w_t = s + B_t(\tilde{K}_t) = s + B_t(REI_0, \ldots, REI_t, B_1, \ldots, B_{t-1})$$

(38)

In consequence, the suggested bonus bank solution leads to nonlinear contracts based on past and current $REI$ and dependent on past bonus payments.

Note that in order to calculate $REI$ in each single period $t$, a report about the present value of the remaining future cash flows is needed. The remaining unanswered question is how the principal can ensure that the manager reports his private information truthfully. As we will show, the construction of an internal capital market via the bonus bank can be used to induce truthful reporting ($l_t = 0 \forall t \in \{1, \ldots, T\}$) in each period. We start with the case that the manager remains responsible for the project until it is over. Next, we extend the analysis to cases in which he leaves the project before its completion.

### 5.3 The manager remains for the full length of the project

When the manager stays until the end of the project, any untruthful report can be detected by observing the actual realizations of the project.\(^9\) Thus, a scheme in which the manager receives bonus
payments based only on the ex post realized compounded value of the project will take away from him any advantage from untruthful reporting on the project’s value. We therefore assume in the following that bonus payments are only made at the end of the project’s life, based on ex post realized value creation.

Thus, bonus payments are only paid out based on the realized cash flows $z_t$ at the end of the project, when all realizations are known. Formally, if the manager remains in the firm until the project is over, he receives the following bonus payments during the project’s life

$$B_t = 0 \forall t \in \{0, \ldots, T - 1\}$$

$$B_T = (1 + r)^T \left( \sum_{t=1}^{T} \frac{z_t}{(1 + r)^t} - x \right) = \sum_{t=1}^{T} z_t \cdot (1 + r)^{T-t} - x \cdot (1 + r)^T$$

Note that the balance of the bonus bank during the project’s life depends on reported figures and therefore especially on $l_t$. With equations (36), (39), and (40) however, the balance of the bonus bank $K_T$ at date $T$ (before $B_T$ is paid out) is given by

$$K_T = (1 + r) \cdot K_{T-1} + REI_T$$

$$= (1 + r) \left( (1 + r) \cdot K_{T-2} + REI_{T-1} \right) + REI_T$$

$$\vdots$$

$$= (1 + r)^T \cdot K_0 + \sum_{t=1}^{T} REI_t \cdot (1 + r)^{T-t}$$

$$= \sum_{t=0}^{T} REI_t \cdot (1 + r)^{T-t}$$

$$= \sum_{t=1}^{T} z_t \cdot (1 + r)^{T-t} - x \cdot (1 + r)^T$$

$$= B_T$$

In other words, the balance of the bonus bank at date $T$ is independent of any reports by the manager. Note that the bonus payment in period $T$ is exactly the balance of the bonus bank. That is, the
manager expects in $t = 0$ to receive $B_T$ at date $T$. According to proposition 3, he has a strong incentive to choose the efficient investment level regardless of his time preferences. If the manager discounts future bonus payments with the cost of capital $r$, the present value of the bonus payments is with (40) and (41) exactly the present value of the project. Formally, it is

$$\sum_{t=1}^{T} \frac{B_t}{(1+r)^t} = \frac{B_T}{(1+r)^T} = \frac{(1+r)^T \cdot \left(\sum_{t=1}^{T} \frac{z_t}{(1+r)^t} - x\right)}{(1+r)^T} = \sum_{t=1}^{T} \frac{z_t}{(1+r)^t} - x$$

(42)

Every possible bonus payment that is calculated according to (15) and (16) leads to efficient investment decisions. The following proposition provides the result that the strategy of a truthful report is indeed the Nash-equilibrium for the manager.

**Proposition 5.** If the manager is rewarded based on the ex post realized value, he has a strong incentive to choose the efficient investment level and has no incentive to overstate in his reporting.

If the manager is rewarded according to (39) and (40), he will indeed be rewarded based on actual performance and has no incentive to report his information not truthfully. The keynote is that for each project a manager is reviewed at the end of period $T$ on the basis of the ex post realized value.

We now consider the case in which the manager decides to leave the firm.

### 5.4 The manager decides to leave the project

Now we analyze the case in which the manager decides to leave the project before it is over. The manager has no incentive to choose the optimal investment level if he is not rewarded accordingly. Thus, the bonus payment given by (39) and (40) will not induce the manager to choose the efficient investment level if he leaves the project at any date $t < T$. From this, the problem arises how to reward the manager if he intends to leave the project before its completion. Based on our model assumptions, one appealing solution is to create an internal market and to allow the leaving manager to sell the bonus bank.
Therefore, the manager negotiates with a possible buyer of his bonus bank in period $t$. We assume that, in contrast to the principal, both managers have the same knowledge about the absolute profitability $\delta(x, \theta)$. Assume, there always exists at least one additional agent who has the necessary information about $\theta$ and the information levels $i_0, \ldots, i_{t-1}$ and who is able to exert at least the same level of effort as the agent who is supposed to choose the efficient investment level. For simplicity, we assume that both agents have the same risk attitudes and the same time preference unknown to the principal.

Manager 1 has to decide about the efficient investment level. Especially, he is characterized by his level of effort $e^1$. In other words, his expected cash flow in period $t$ is formally denoted by

$$E[z_t] = \mu_t(i_0, \ldots, i_{t-1}) \delta(x, \theta) + e^1_t$$  \hspace{1cm} (43)

In contrast, a possible buyer (manager 2) of the bonus bank has the effort strategy $e^2$. Note that $e^1$ is a $T$-dimensional, $e^2$ is a $T - t$-dimensional vector if the manager enters the project at date $t$. In order to make the formulation complete, manager 2 expects the following cash flow

$$E[z_t] = \mu_t(i_0, \ldots, i_{t-1}) \delta(x, \theta) + e^2_t$$  \hspace{1cm} (44)

The expected utilities of managers 1 and 2 are formally given by

$$U(x, e^{1,2}, \theta, \phi) = \int u(\phi(x, z), e^{1,2}, \theta) f(\epsilon|e^{1,2}) d\epsilon$$  \hspace{1cm} (45)

As we assumed before, the utility function of manager 2 is equal to the one of manager 1. Without loss of generality, we assume both managers to discount their futures bonus payments at the cost of capital $r$.

Each manager has two alternatives. On the one hand, manager 1 can continue with the project that guarantees him a bonus payment at date $T$ based on (40). Assume, manager 1 sells the bonus bank at date $j \in \{0, \ldots, T - 1\}$. According to (43), the value of the bonus bank $U_j(x, e^1, \theta, \phi)$ for
manager 1 if he remains on the project is formally given by

\[
U_j (x, e^1, \theta, \phi) = \frac{1}{(1 + r)^T} \cdot \left[ \sum_{t=1}^{j} z_t \cdot (1 + r)^{T-t} + \sum_{t=j+1}^{T} \mathbb{E} [z_t] \cdot (1 + r)^{T-t} - x \cdot (1 + r)^T \right]
\]

\[
= \sum_{t=1}^{j} z_t \cdot (1 + r)^{T-t} + \sum_{t=j+1}^{T} \left[ \mu_t (i_0, \ldots, i_j) \delta (x, \theta) + e^1_t \right] \cdot (1 + r)^{T-t} - x \cdot (1 + r)^T
\]

\[
(1 + r)^{T-j}
\]

(46)

This represents his reservation utility. On the other hand, he can sell the bonus bank for a price \(P\) and move to a new project where he gets additional payment in the amount of \(\Delta \geq 0\).

In contrast, manager 2 can buy the bonus bank or he can invest in identical financial assets on the capital market. Thus, the reservation utility of manager 2 is an alternative investment in financial assets with identical properties. If manager 2 enters the project, he has to pay \(P\) to manager 1 in exchange for the bonus bank. According to (44), the value of the bonus bank for manager 2 \((U_j (x, e^2, \theta, \phi))\) at date \(j\) is formally given by

\[
U_j (x, e^2, \theta, \phi) = \sum_{t=1}^{j} z_t \cdot (1 + r)^{j-t} + \sum_{t=j+1}^{T} \left[ \mu_t (i_0, \ldots, i_j) \delta (x, \theta) + e^2_t \right] \cdot (1 + r)^{j-t} - x \cdot (1 + r)^j
\]

(47)

The difference between both utilities depends on the effort levels \(e^1\) and \(e^2\). As assumed above, we have \(e^2 \geq e^1\) and therefore \(U_j (x, e^2, \theta, \phi) \geq U_j (x, e^1, \theta, \phi)\).

Obviously, the upper bound for a possible purchase price \(P\) is the value of the bonus bank for manager 2. In other words, he will pay no price \(P\) that exceeds his expectations in the project. In turn, manager 1 will only sell the bonus bank, if he receives a price \(P\) and an additional payment \(\Delta\) which exceed his value of the bonus bank. Formally, the boundaries of the purchase price are given by

\[
U_j (x, e^1, \theta, \phi) - \Delta \leq P \leq U_j (x, e^2, \theta, \phi)
\]

(48)

We now examine the optimal mechanism for the determination of the purchase price of the bonus bank. As a possible solution, we analyze the Nash-bargaining solution (Nash 1950, 1953). The
following proposition provides the intuitive result that, within our assumptions, the Nash-bargaining solution leads to a situation in which both managers receive equivalent shares of the additional utility of manager 2 that exceeds the utility of manager 1. In this case, both managers have a strong incentive to agree.

**Proposition 6.** *If the purchase price \( P \) for the bonus bank is calculated within a Nash-bargaining solution, both managers receive equivalent shares of the additional utility of manager 2 that exceeds the utility of manager 1 and the advantage of leaving the project of manager 1.*

According to equation (46) and (47), the optimal purchase price \( P \) at date \( j \) can be calculated as follows

\[
P = U(x, e^1, \theta) + \frac{U(x, e^2, \theta, \phi) - U(x, e^1, \theta, \phi)}{2} - \frac{\Delta}{2}
\]

\[
= \sum_{t=1}^{j} z_t \cdot (1 + r)^{j-t} + \sum_{t=j+1}^{T} \left[ \mu_t (i_0, \ldots, i_j) \delta(x, \theta) + e^1_t \right] \cdot (1 + r)^{j-t} - x \cdot (1 + r)^j
\]

\[
+ \frac{\sum_{t=j+1}^{T} e^2_t \cdot (1 + r)^{j-t} - \sum_{t=j+1}^{T} e^1_t \cdot (1 + r)^{j-t}}{2} - \frac{\Delta}{2}
\]

\[
= \sum_{t=1}^{j} z_t \cdot (1 + r)^{j-t} + \sum_{t=j+1}^{T} \left[ \mu_t (i_0, \ldots, i_j) \delta(x, \theta) + e^1_t \right] \cdot (1 + r)^{j-t} - x \cdot (1 + r)^j
\]

\[
+ \frac{\sum_{t=j+1}^{T} (e^2_t - e^1_t) \cdot (1 + r)^{j-t}}{2} - \frac{\Delta}{2} \quad (49)
\]

The following proposition provides the result that manager 1 has an incentive to choose the efficient investment level even if he leaves the project before its completion and that he has no incentive to overstate in his reporting.

**Proposition 7.** *The manager can leave the project at any date \( t \in \{0, \ldots, T\} \). If the manager is able to sell the bonus bank for a price given by (49) at any date \( t \in \{0, \ldots, T - 1\} \), or he receives the bonus payment given by (40) at date \( T \), he will choose the efficient investment level and he has no incentive to overstate in his reporting.*

Provided this formulation, we are able to calculate the purchase price for different situations. As we will show, additional value is created from the perspective of the principal if the successor has a greater impact on future cash flows than the present manager. We begin the analysis with the case
that both managers have the same impact on cash flows \((e_1 = e_2)\). That is, both managers expect the same future cash flows from the project. Furthermore, we assume that manager 1 receives no additional payment \((\Delta = 0)\) from an alternative project if he sells the bonus bank. If manager 1 sells the bonus bank at any date \(j \in \{0, \ldots, T-1\}\) and manager 2 will remain on the project until it is over, manager 2 receives at date \(T\) the bonus payment (40). According to (49), the optimal price for the bonus bank \(P\) is exactly

\[
P = U \left(x, e_1, \theta, \phi \right)
\]

\[
P = \sum_{t=1}^{j} z_t \cdot (1 + r)^{j-t} + \sum_{t=j+1}^{T} \left[ \mu_t (i_0, \ldots, i_{t-1}) \delta(x, \theta) + e_t^2 \right] \cdot (1 + r)^{j-t} - x \cdot (1 + r)^j
\]

In other words, manager 1 receives the value of the bonus bank at date \(j\) by selling the bonus bank to his successor. Furthermore, the optimal purchase price is independent of any untruthful report by manager 1. Thus, manager 1 can leave the project in any period \(t \in \{0, \ldots, T\}\) and receive a bonus payment subject to the created value, independent of any untruthful report. Therefore, he has no incentive to overstate in his reporting because his bonus payments remain unaffected.

Manager 2 pays \(P\) to manager 1 and therefore he receives the bonus bank at date \(j\). His utility from the purchase of the bonus bank is formally given by

\[
U_j \left(x, e_2, \theta, \phi \right) - P
\]

\[
= \sum_{t=1}^{j} z_t \cdot (1 + r)^{j-t} + \sum_{t=j+1}^{T} \left[ \mu_t (i_0, \ldots, i_{t-1}) \delta(x, \theta) + e_t^2 \right] \cdot (1 + r)^{j-t} - x \cdot (1 + r)^j
\]

\[
- \sum_{t=1}^{j} z_t \cdot (1 + r)^{j-t} - \sum_{t=j+1}^{T} \left[ \mu_t (i_0, \ldots, i_{t-1}) \delta(x, \theta) + e_t^2 \right] \cdot (1 + r)^{j-t} + x \cdot (1 + r)^j
\]

\[
= 0
\]

Note that for every \(\Delta > 0\), the utility of the purchase of the bonus bank for manager 2 is strictly positive. In other words, an additional payment for manager 1 due to an alternative project leads to a decreasing purchase price \(P\) and therefore to a strong incentive for manager 2 to buy the bonus bank even if he does not expect to have a greater impact on cash flows as manager 1.
Now we consider the case in which manager 2 has a greater impact on future cash flows. Formally, there exists any \( i \in \{ j + 1, \ldots, T \} \) with \( e_{2i}^2 > e_{1i}^1 \) and \( e_{2k}^2 = e_{1k}^1 \) for any \( k \in \{ j + 1, \ldots, T \}, k \neq i \). The additional value created \((\Delta NPV_j(x, \theta, e))\) at date \( j \) due to the higher effort level by manager 2 is given by

\[
\Delta NPV_j(x, \theta, e) = \sum_{t=j+1}^{T} \left[ \mu_t (i_0, \ldots, i_j) \delta (x, \theta) + e_{1t}^1 \right] \cdot (1 + r)^{j-t} - \sum_{t=j+1}^{T} \left[ \mu_t (i_0, \ldots, i_j) \delta (x, \theta) + e_{2t}^2 \right] \cdot (1 + r)^{j-t} = (e_{2i}^2 - e_{1i}^1) \cdot (1 + r)^{j-i}
\] (50)

That is, additional value is created from the perspective of the principal if manager 2 expects to have a greater impact on future cash flows compared to manager 1. According to (49), the optimal purchase price \( P \) at date \( j \) is formally given by

\[
P = \sum_{t=1}^{j} z_t \cdot (1 + r)^{j-t} + \sum_{t=j+1}^{T} \left[ \mu_t (i_0, \ldots, i_j) \delta (x, \theta) + e_{1t}^1 \right] \cdot (1 + r)^{j-t} - x \cdot (1 + r)^{j} + \left( \frac{e_{2i}^2 - e_{1i}^1}{2} \right) \cdot (1 + r)^{j-i} - \frac{\Delta}{2}
\]

\[
P = P e_{1i}^2 + \left( \frac{e_{2i}^2 - e_{1i}^1}{2} \right) \cdot (1 + r)^{j-i}
\] (51)

Thus, the utility of manager 1 from the sale of the bonus bank is given by

\[
P + \Delta - U_j(x, e^1, \theta, \phi) = \left( \frac{e_{2i}^2 - e_{1i}^1}{2} \right) \cdot (1 + r)^{j-i} + \frac{\Delta}{2}
\] (52)

In contrast, the utility of manager 2 of the purchase of the bonus bank can be calculated as follows

\[
U_j(x, e^2, \theta, \phi) - P = \left( \frac{e_{2i}^2 - e_{1i}^1}{2} \right) \cdot (1 + r)^{j-i} + \frac{\Delta}{2}
\] (53)

That is, both managers receive an additional amount of \( \left( \frac{e_{2i}^2 - e_{1i}^1}{2} \right) \cdot (1 + r)^{j-i} \) relative to the case when \( e^1 = e^2 \). The interesting result is that both managers benefit from the additional payment manager 1 receives from an alternative project as well as from the higher future cash flows due to a higher effort level by manager 2. Thus, both managers have a strong incentive to cooperate. Furthermore, we have
shown that the sale of the bonus bank can lead to a situation where additional value is created. In other words, we show that by creating an internal capital market, additional value may be created by managers who have an incentive to take over a project when they are able to outperform the former manager. Different types of managers may have different abilities in the initiation as compared to the realization of projects. It may therefore be beneficial for a realization-type manager to take over a project from an initiator-type manager for both managers as well as for the firm.

In order to solve the problem of the impatient manager, the agency literature discusses compensation schemes based on performance measures such as residual income. However, this requires the manager to remain on the project for at least one period. He receives his first bonus payment at the end of period 1 based on realized residual income. In contrast, in our concept the manager can leave the firm immediately after choosing the efficient investment level by selling the bonus bank to a successor. Thus, in our bonus bank approach the manager can be rewarded solely for the initiation of value creation. That is, he is rewarded for the creation of value separate from the realization of value.

In summarizing, we have shown that the simulation of an internal financial market via a bonus bank can be used to induce truthful reports of the agent. Furthermore, the trading of the bonus bank can also increase the utility of the principal. In the next section we examine the case in which the agent is supposed to choose the investment level which maximizes the net present value of a portfolio of projects. As we will show, this problem can also be solved with our suggested bonus bank solution.

5.5 The case of capital constraints

Now we consider the case of capital constraints. Instead of strong goal congruence we now require robust goal congruence. That is, the agent should always choose the investment levels which maximize the net present value of a portfolio of projects. Molten and Bareket (2007) develop accounting rules which lead to an annuity-residual income and therefore induce an impatient manager to choose the investment levels which maximize the net present value of the investment portfolio. We consider the
case in which the manager has to choose between two projects. The projects are characterized by the efficient investment levels $x_1$ and $x_2$ as well as the private information levels $\theta_1$ and $\theta_2$ of the agent.

The manager will only choose the net present value maximizing portfolio, if his utility of project 1 is higher than that of project 2 if and only if the net present value (NPV) of project 1 is higher than that of project 2. Obviously, the projects may have different time horizons $T_1$ and $T_2$. Formally it is

$$U(x_1, e, \theta_1, \phi) \geq U(x_2, e, \theta_2, \phi) \iff NPV(x_1, \theta_1) \geq NPV(x_2, \theta_2)$$

(54)

with

$$NPV(x_i, \theta_i) = \sum_{t=1}^{T_i} \mu_t(i_0)\delta(x, \theta) + e_t(1 + r)^t - x_i$$

(55)

The following proposition shows that provided our bonus bank approach, the agent will always choose the efficient investment portfolio. This intuition results from the fact that the manager is rewarded proportionately to the value created by the project.

**Proposition 8.** The agent is rewarded according to the bonus bank concept mentioned above. The inherent risks of the projects have the same effect on the utility function of the agent. Then it is optimal for the manager to choose the efficient investment portfolio.

### 6 Discussion of the results

Above, we have shown that rewarding the agent directly based upon the value created is optimal in order to induce efficient investment decisions. As Lambert (2001) mentioned, a major challenge confronting researchers in the field of agency theory is constructing multi-period models which are tractable enough to solve incentive problems but have also interesting information and performance measurement issues. Furthermore, a shorter time horizon of the agent leads to the need of a “forward-looking” performance measure in order to motivate the manager to be “long-term” in his thinking. However, the principal cannot solve the incentive problem by simply waiting until the end of the project and paying the agent then. The reason is that the agent can leave the firm before the project is over. However, in our model the agent will be rewarded in either of two ways. First, he may stay in
the firm until the project is over and will be rewarded based on the ex post realized value. Second, he may leave the project and receive a bonus payment by selling his bonus bank at its current value. As the buyer will only pay a price based on the actual payoff of the project, there will be no incentive for the seller to overstate the project’s performance in earlier periods and truthful reporting is warranted. It is to note that the agent receives bonus payments from the principal only based on realized figures which are independent of any report.

The incentive for truthful reporting results from the agents' anticipating that they will only be rewarded based on actual (ex post-) performance. Therefore untruthful reporting does not pay. In our multi-period setting, the bargaining between well-informed agents leads to truthful reporting. On a contracting perspective, the competition among informed agents can be used to reduce information rents which otherwise the principal would have to give up (Lambert 2001).

However, there are a few aspects of our approach that should be discussed critically. First, no restrictions in communication between the agents among themselves or between the principal and the agents are allowed in our examination. 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, Indejejikan and Nanda 1999, Arya et al. 1997). It is the strong advantage of the Rogerson-approach that the principal can induce efficient investment decisions without any communication between the agent and the principal. This is largely based on the assumption that the agent has also superior information about the time pattern of the cash flows, which we have relaxed as a consequence. We conclude that the problem of the impatient manager can be solved without adjusting allocation rules even if capital constraints are considered.

Second, the principal must assure a possible buyer that he will receive the same share of the ex post created value as the manager who has decided to leave the company. This could be critical for risk allocation purposes. Future research on the optimal contracting in such a setting is indicated.
Furthermore, in contrast to the recent agency-literature, we are able to induce the agent to choose efficient investment levels even if he decides to leave the company immediately after the initiation of the project. In contrast, standard agency-analysis requires the agent to remain in the company at least until the period $t = 1$ is over. In our model, efficient investment decisions are achieved by annuitizing the problem in the way that the manager can sell the bonus bank in each period. In order to achieve this result, we assume that there always exist at least one additional manager who has the same information about the project’s profitability. The suggested mechanism leads to a situation in which the manager has no incentive to issue untruthful reports. That is, we use a self-interested manager in order to achieve truthful reporting.

For this solution, a well informed successor is needed. This is a strong assumption. On the other hand, this solution is intuitively appealing. Obviously, a firm has a strong incentive to replace a manager with a skilled and well-informed successor. It seems reasonable to use a self-interested agent to uncover untruthful reports. A successor will have the same proximity to the information of a particular project or business unit. He is therefore the best possible person to investigate into the reports of decentralized managers. Furthermore, the underlying process is very similar to that of partnerships, where the entering partner has to buy shares from other partners. The concept of rewarding the manager as a partner of the business unit he is in charge for (e.g. phantom stocks) can be observed quite frequently in practice.

There are many different further research directions. One direction should be to further analyze goal-congruent accounting rules with respect to their usefulness in the context of the decision usefulness function. Only then can one draw conclusions from agency models for standard setting. Furthermore the model we presented can be extended by including stochastic processes based on changeable levels of information as is indicated in section 5.1. In particular, this would be interesting if sequential investment decisions were considered. In order to analyze the role of the manager as a partner or associate of the firm, further investigation about different concepts of external and internal
asymmetrically distributed information is indicated.

One interesting aspect within the framework of our model could be the question of how to integrate the fact that a possible successor might not be able to monitor the necessary parameter $\theta$ or the information levels $i_0, \ldots, i_{t-1}$ when he wants to buy the bonus bank at the beginning of date $t$. In this case the above mentioned structure would fail. This question is equivalent to the well-known lemon problem (Akerlof 1970) and requires further research.

Another future research direction could be to calculate optimal contracts when different risk-attitudes or time preferences of the agents are considered. As mentioned above, the principal must try to find a contract that balances different risk-attitudes or time preferences between the agents out. Therefore, additional constraints must be placed by solving the optimization problem in order to calculate optimal contracts. Managers may have different capabilities with respect to different tasks. Therefore, it may be optimal for the firm to find a successor who buys the bonus bank when he expects to have a greater impact on future cash flows than the current manager. The principal may hire either managers making optimal investment decisions or managers who exert high effort levels in the realization of the project.

7 Summary and conclusions

In this paper we examine incentive problems which result from delegated investment decisions in an agency-theoretic context. So far the literature concentrates on modifying accounting rules resulting in goal congruent performance measures. As such modified accounting rules may or may not be useful for other uses of accounting information (decision usefulness), we analyze a model in which only the compensation scheme, but not the performance measures are modified in order to achieve strong goal congruence.

In our model, we conclude that the principal must reward the manager directly based on the value he has created. Therefore truthful reports about the created value are needed from the manager. We
show within an agency-framework that the manager has no incentive to overstate performance if an appropriate control-mechanism is implemented. When he is only rewarded based on actual ex-post-performance, he will have no incentive to overstate performance ex ante. If the manager decides to leave the firm before the project is over and wants to benefit from the value-generation he initiated, he needs to find a successor to buy the bonus bank from him. The price for the bonus bank is developed within a Nash-bargaining solution. Even in this case, truthful reports are optimal for the manager. These results are maintained even when mutually exclusive projects and planning revisions are considered.

Furthermore, we show that by creating such an internal capital market, additional value may be created by managers who have an incentive to take over a project due to better prospects. Different types of managers may have different abilities in the initiation as compared to the realization of projects. It may therefore be beneficial for a realization-type manager to take over a project from an initiator-type manager for both the individual managers and the firm.

The typical performance measures that are settled in the centre of the discussion of performance measurement are not appropriate to give information about value creation and value realization. In this sense, O’Hanlon and Peasnell (2002) establish the ”missing link” between performance measurement and value creation. We integrate the results of O’Hanlon and Peasnell in a compensation scheme that can be used to induce efficient investment decisions. We conclude that the bonus bank concept can be seen as the ”missing link” between value generation and management compensation. A theoretical approach was provided in this paper.

In summarizing we can conclude that the well-known agency-problem of the ”impatient manager” can be solved by a special bonus scheme as well as by modified accounting rules. Overall, the determination of optimal bonus payments and the underlying optimal design of contracts should be part of future investigation and analysis.
A Proofs

Proof. Proof of Proposition 1. The optimal coefficient $\beta_t$ can be calculated by equating (11) and (12):

$$
\beta_t \left( \sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta) + e_t}{(1 + r)^t} - x \right) = \alpha \left[ \rho_t \delta(x, \theta) + e_t - \frac{\rho_t}{\sum_{t=1}^{T} \rho_t (1 + r)^t} x \right]
$$

For $\beta_t$ therefore follows:

$$
\beta_t = \frac{\alpha \left[ \rho_t \delta(x, \theta) + e_t - \frac{\rho_t}{\sum_{t=1}^{T} \rho_t (1 + r)^t} x \right]}{\left( \sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta) + e_t}{(1 + r)^t} - x \right)}
$$

$$
= \frac{\alpha \rho_t \left[ \delta(x, \theta) - \frac{x}{\sum_{t=1}^{T} \rho_t (1 + r)^t} \right] + \alpha e_t}{\left( \sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta) + e_t}{(1 + r)^t} - x \right)}
$$

$$
= \frac{\alpha \rho_t \left[ \sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta)}{(1 + r)^t} - x \right]}{\sum_{t=1}^{T} \rho_t (1 + r)^t} + \frac{\alpha e_t}{\sum_{t=1}^{T} \rho_t (1 + r)^t - x}
$$

Thus, the same bonus payments resulting from the residual income calculated with the RMB-allocation rule can equally be derived from the net present value of the project by using optimal bonus coefficients.

Proof. Proof of Corollary 1. The proof follows directly from the proof of proposition 1.

Proof. Proof of Proposition 2. With the equations (12) and (13), the optimal bonus payment $\hat{B}_t$ is exactly

$$
\hat{B}_t = \frac{\alpha \rho_t}{\sum_{t=1}^{T} \rho_t (1 + r)^t} \left( \sum_{t=1}^{T} \frac{\rho_t \delta(x, \theta)}{(1 + r)^t} - x \right) + \alpha e_t
$$

The term in the brackets is independent of $t$. We know from equation (5) that $\hat{x}(\theta)$ is the unique investment level that maximizes this term. Let $B = (B_1, \ldots, B_T)$ be the vector of all bonus payments the manager receives during the relevant period. Therefore, for every $\theta$, the distribution over $B$ induced by $\hat{x}(\theta)$ first-order stochastic dominates the distribution over $B$ induced by any another $x$. By assumption, the manager’s expected utility function is weakly increasing in the wage income.
Note, this result is independent of the agent’s risk attitude as well as the inherent risk of the project.
With the FSD-theorem it is clear that the manager weakly prefers the distribution of bonus payments generated by choosing \( \hat{x}(\theta) \) to the distribution of bonus payments generated by any other choice of \( x \).

**Proof.** Proof of Proposition 3. The optimal bonus payment \( \hat{B}_t \) is exactly

\[
\hat{B}_t = \xi_t \cdot \left( \sum_{t=1}^{T} \frac{\rho_t \delta(x_t, \theta_t) + e_t}{(1 + r)^t} - x \right)
\]

The term in the brackets is independent of \( t \). We know from equation (5) that \( \hat{x}(\theta) \) is the unique investment level that maximizes this term. From here on, the proof is equivalent to the proof of proposition 4.2. Note that the optimality is independent of \( \xi_t \). The condition (16) suffices to ensure incentive compatibility.\(^{11}\) Assume, there is \( \xi_0 > 1 \), on the one hand the manager would still choose the efficient investment level, but on the other hand, no financial advantage remains for the principal as he has to pay the manager more than the whole net present value of the project. The last part of the proof can now be shown by complete induction.

**Proof.** Proof of Proposition 4. In order to proof the proposition, we have to develop a bonus coefficient which satisfies (17):

\[
\left( \sum_{t=1}^{T} \frac{\rho_t \delta(x_t, \theta_t) + e_t}{(1 + r)^t} - x_i \right) > \left( \sum_{t=1}^{T} \frac{\rho_t \delta(x_j, \theta_j) + e_t}{(1 + r)^t} - x_j \right)
\]

\[\Leftrightarrow \exists \xi > 0 : \quad B_{ti} = \xi \cdot \left( \sum_{t=1}^{T} \frac{\rho_t \delta(x_t, \theta_t) + e_t}{(1 + r)^t} - x_i \right) > B_{tj} = \xi \cdot \left( \sum_{t=1}^{T} \frac{\rho_t \delta(x_j, \theta_j) + e_t}{(1 + r)^t} - x_j \right)\]

According to (15) and (16), \( \exists \alpha \in (0, 1] \) and \( \xi \) satisfies the following condition:

\[
\sum_{t=1}^{T} \frac{\xi}{(1 + r)^t} = \alpha \quad \Leftrightarrow \quad \xi \cdot \sum_{t=1}^{T} \frac{1}{(1 + r)^t} = \alpha
\]

\[
\Leftrightarrow \quad \xi \cdot \frac{(1 + r)^T - 1}{(1 + r)^T \cdot r} = \alpha
\]

\[
\Leftrightarrow \quad \xi = \frac{\alpha (1 + r)^T \cdot r}{(1 + r)^T - 1}
\]
Thus, the optimal bonus coefficient $\xi$ for the problem of capital constraints is exactly the annuity factor dependent on $\alpha$.

**Proof.** Proof of Proposition 5. According to proposition 3, the manager will choose the efficient investment level if he gets the bonus payment which is given by (39) and (40). Provided equation (40) and (41), both bonus bank level and bonus payment in date $T$ are independent from $l_t$. Consequently, the manager is not able to improve his bonus payments by an untruthful report. Thus, the strategy of a truthful report is indeed the Nash-equilibrium for the agent.

**Proof.** Proof of Proposition 6. Within the Nash-bargaining solution (NBS), the optimal price $P$ for the bonus bank is calculated as follows

$$NBS(P) = (U(x, e^2, \theta, \phi) - P) \cdot ((P + \Delta) - U(x, e^1, \theta, \phi)) \rightarrow \max_P$$

First-order condition leads to

$$\frac{\partial NBS(P)}{\partial P} = \frac{\partial (U(x, e^2, \theta, \phi) - P) \cdot ((P + \Delta) - U(x, e^1, \theta, \phi))}{\partial P}$$

$$\Leftrightarrow 2P = U(x, e^2, \theta, \phi) + U(x, e^1, \theta, \phi) - \Delta$$

$$\Leftrightarrow P = \frac{U(x, e^2, \theta, \phi) + U(x, e^1, \theta, \phi) - \Delta}{2}$$

$$\Leftrightarrow P = U(x, e^1, \theta, \phi) + \frac{U(x, e^2, \theta, \phi) - U(x, e^1, \theta, \phi)}{2} - \frac{\Delta}{2}$$

Thus, both managers receive an equivalent share of the additional value created by manager 2 and the advantage of of leaving the project of manager 1 ($\Delta$).

**Proof.** Proof of Proposition 7. According to proposition 5, the manager will choose the efficient investment level if he remains on the project until it is over. Now, we assume without loss of generality that manager 1 sells the bonus bank at date $j = 0$ for a price given by (49). The optimal price $P$ is given by

$$P = \left[ \sum_{t=1}^{T} [\mu_t (i_0) \delta(x, \theta) + e^1_t] \cdot (1 + r)^{-t} - x \right] + \sum_{t=1}^{T} \left( \frac{e^2_t - e^1_t}{2} \cdot (1 + r)^{-t} - \frac{\Delta}{2} \right)$$
The last two terms are independent of \( x(\theta) \). The manager chooses the investment level \( x(\theta) \) that maximizes the term in the brackets which is exactly the expected net present value of the project, because this investment decision leads to a bonus payment which first-order stochastic dominates all other bonus payments given any other possible investment decision. We know from equation (5) that \( \hat{x}(\theta) \) is the unique investment level that maximizes this term. Thus, the manager will choose the efficient investment level.

Furthermore, the bonus payment \( P \) the manager receives due to a sale of the bonus bank is independent of \( l_t \). Consequently, the strategy of a truthful report to the principal about the project’s net present value is indeed the Nash-equilibrium for manager 1. As was shown in proposition 5, the strategy of a truthful report by manager 2 is also a Nash-equilibrium for him if he remains on the project until its completion. If he leaves the project before its completion, he can sell the bonus bank and the mechanism described above works for any number of sales und purchases of the bonus bank.

**Proof.** Proof of Proposition 8. The manager considers two investment opportunities. Due to capital constraints he is only able to conduct one of them. Both projects are characterized by the efficient investment level \( x_1 \) and \( x_2 \) as well as the private information level \( \theta_1 \) and \( \theta_2 \) of the agent. According to equation (46), the value of the bonus bank of project 1 (2) at date \( j \) for the manager is formally given by

\[
U_j (x_{1,2}, c, \theta_{1,2}, \varphi) = \sum_{t=1}^{j} z_t \cdot (1 + r)^{j-t} + \sum_{t=j+1}^{T} [\mu_t (i_0, \ldots, i_j) \cdot \delta (x_{1,2}, \theta_{1,2}) + \epsilon_t] \cdot (1 + r)^{j-t} - x \cdot (1 + r)^j
\]

Assume, the manager will choose the efficient investment portfolio if he prefers investment 1 due to his bonus payments if and only if the net present value of project 1 is higher than the net present value of project 2. At the initiation date, the expected change in the value of the project \( (REI_t \neq 0) \) is zero. Formally, it is \( \mathbb{E} [REI_t] = 0 \ (\forall t \in \{1, \ldots, T\}) \) and therefore, the expected utility of the manager
at date 0 is given by

\[
E_0 \left[ U_j \left( x_{1,2}, e, \theta_{1,2}, \phi \right) \right] = \sum_{t=1}^{j} [\mu_t (i_0) \delta (x_{1,2}, \theta_{1,2}) + e_t] \cdot (1 + r)^{j-t} + \sum_{t=j+1}^{T} [\mu_t (i_0) \delta (x_{1,2}, \theta_{1,2}) + e_t] \cdot (1 + r)^{j-t} - x \cdot (1 + r)^j
\]

\[= (1 + r)^j \cdot NPV \left( x_{1,2}, \theta_{1,2} \right) \]

In other words, the expected utility of the manager in each period \( j \) resulting from project 1 is higher than the one resulting from project 2 if also the net present value of project 1 is higher than the net present value of project 2. Formally, it is \((\forall j \in \{1, \ldots, \min (T_1, T_2)\})\)

\[E_0 \left[ U_j \left( x_1, e, \theta_1, \phi \right) \right] > E_0 \left[ U_j \left( x_2, e, \theta_2, \phi \right) \right] \Leftrightarrow NPV \left( x_1, \theta_1 \right) > NPV \left( x_2, \theta_2 \right)\]

That is, if the manager remains on the project, he will choose the efficient investment portfolio. Now we assume that the manager sells the bonus bank to a successor. Manager 1 has a strong incentive to choose the efficient investment portfolio, if he expects a higher price \( P_{1,2}^j \) for the bonus bank of project 1 than of project 2 at date \( j \). Formally, the manager chooses the efficient investment portfolio, if he expects \( E_0 \left[ P_1^j \right] - E_0 \left[ P_2^j \right] > 0 \). According to the optimal price mechanism given by (49), it is

\[E_0 \left[ P_1^j \right] - E_0 \left[ P_2^j \right] = (1 + r)^j \cdot NPV \left( x_1, \theta_1 \right) + \frac{\sum_{t=j+1}^{T} \left( e_{1}^2 - e_{1}^1 \right) \cdot (1 + r)^{j-t}}{2} - \frac{\Delta}{2} - (1 + r)^j \cdot NPV \left( x_2, \theta_2 \right) - \frac{\sum_{t=j+1}^{T} \left( e_{2}^2 - e_{2}^1 \right) \cdot (1 + r)^{j-t}}{2} + \frac{\Delta}{2} \]

\[= (1 + r)^j \cdot NPV \left( x_1, \theta_1 \right) - (1 + r)^j \cdot NPV \left( x_2, \theta_2 \right) > 0\]

By annuitizing the problem, the manager can sell the bonus bank of project 1 in each period for at least the same price as for project 2. Thus, the manager will always make investment decisions maximizing the investment portfolio of the firm.
Notes

1. In another context, the literature discusses the design of hurdle rates in a contracting setting including agency costs imposed by asymmetric information. See for instance Antle and Eppen 1985, Antle and Fellingham 1990, Christensen et al. 2002, Dutta and Reichelstein 2002, Baldenius 2003, Baldenius and Ziv 2003. They conclude that the optimal design of hurdle rates trades off organizational slack and capital rationing. Thus, the optimal hurdle rate differs from the firm’s cost of capital. Consequently, the standard prescriptions in the value based management literature about calculating risk adjusted cost of capital are generally not consistent with optimal incentive contracting.

2. The following model is basically identical to that of Rogerson (1997). The only difference lies in the level of information the principal is assumed to have. While Rogerson assumes him to have information on the cash flow structure, we explicitly include reports of the agent in the examination. That is, the model assumptions by Rogerson (1997) need the principal to know the complete cash flow structure of the project. In contrast, we assume the principal to have no information about the project and therefore he is dependent on reports by the agent about the net present value of the project.

3. In contrast to the sequential investment setting by Pfeiffer and Schneider (2007), we abstract from precontract information by the manager.

4. “Behavior” includes whether the manager will accept the contract or not, as well as the manager’s investment and effort decisions conditional on accepting the contract.

5. Incentive contracts should be based on verifiable variables. That is, the use of verifiable variables in incentive contracts allows either of the parties to present a case before a court of law with proof of breach of contract in order to demand that the contract be fulfilled (Macho-Stadler and Perez-Castrillo 2001). As long as the goodwill is verified by an independent auditor, it represents a verifiable variable.

6. This is similar to the approach of Rogerson (1997), where monotone income based contracts are calculated in order to find the best solution for the moral hazard problem. Reichelstein (2000) explicitly includes agency costs in the way that the manager has personal costs when he exerts effort. Also Dutta and Reichelstein (2002) add moral hazard problems that depend on one-period actions and not on the investment undertaken. Wagenhofer (2003) extends the moral hazard aspects in considering a model where the investment leads to disutility to the agent. In contrast, we abstract from moral hazard aspects in our analysis.

7. If \( T_i > T_j \), the bonus coefficient calculated based on \( T_i \) leads to the optimal result.


9. However, this requires the principal to identify cash flows from individual transactions and projects separately.
(Dutta and Reichelstein 2005). This may be critical if overlapping projects are considered. Similar assumptions can be found in Demski (1998). 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.

Note that comparable assumptions can be found in Baldenius et al. (1999) or Edlin/Reichelstein (1995). In their models, the bargaining process take place under symmetric information about all necessary parameters. In contrast to their results, we explicitly base our price mechanism on the Nash bargaining solution and therefore assume equivalent bargaining power by both managers.

See for the definition of incentive compatibility Wilson (1968) and Ross (1973).
References


