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Interdependence, participation, and coordination in the budgeting process

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Abstract This article studies the role of participation in the budgeting process when the company has to coordinate two interdependent divisions. The focus lies on the design of the budgeting process (top-down vs. participative budgets) and the underlying supply of information. This is studied in a principal agent model where two divisions (agents) jointly generate earnings. With the participative budgeting process, the company (principal) implements an information system that provides the division managers with private information. Two economic effects occur. First, the company can benefit from the division managers' private information by perfectly coordinating the divisions' operations. Second, the company has to induce the managers to provide productive effort and with participation, to additionally report truthfully. Thus, the company incurs incentive costs. The two considered budgeting processes trade off these effects diametrically. For a low importance of coordination, the company prefers the top-down budgeting process and not installing an information system that allows the managers to obtain private information. Otherwise, the participative budgeting process is used. In contrast to the company, managers always prefer the participative budgeting process. In addition, the model predicts that a higher earnings potential increases the attractiveness of participative budgets.

Keywords Interdependence · Coordination · Budgeting process · Participation

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1 Introduction

In practice, the design of the budgeting process among companies is not homogeneous (Shastri and Stout 2008). Companies can choose from a broad spectrum of design possibilities for the budgeting process. The two generic design possibilities, top-down and participative, represent the two ends of this spectrum. Lately, the participative budgeting process and the associated reporting behavior of managers has attracted considerable attention by experimental research (see Shields and Young 1993; Evans III et al. 2001; Fisher et al. 2002; Hannan et al. 2006; Matuszewski 2010; Rankin et al. 2008; Altenburger 2017). A significant part of this research has focused on the consequences of participation in the budgeting process and not its antecedents (a comprehensive literature review is provided by Shields and Shields 1998). However, the reasons for the use of participation in the budgeting process have often been neglected. This paper studies the role of participation in the budgeting process if company's divisions are confronted with interdependence. In particular, the company's preference for implementing a top-down or a participative budgeting process is examined.

Interdependencies among divisions frequently occur. According to economic theory, several transactions are organized within a single company whenever the joint organization yields a higher outcome than the outcome generated by the market mechanism. In particular, a company with several organizational units obtains a higher outcome compared to the sum of the outcomes generated by each organizational unit acting independently on the market (see Coase 1937). Therefore, the value of a company arises from interdependencies among the units. If a company did not have interdependencies, the market would perfectly coordinate the units and the units would act as separate companies. Hence, a company is regularly subject to interdependencies. Coordination among the units of a company regarding their operations is often seen as a crucial element for the company's success. Weber and Camerer (2003), for example, find evidence that failures to coordinate may have substantial negative effects. They find that failures to coordinate different corporate cultures contribute to the failure of corporate mergers.

One management accounting tool regularly used for coordinating interdependencies is budgets and the associated budgeting process. The budgeting process allows the managing owner to formulate a consistent plan for the whole company including its divisions by considering the existing interdependencies. Budgets are widely used in practice (Libby and Lindsay 2007; Shastri and Stout 2008) and they help the company to focus on important actions to satisfy its customers' needs (Horngren et al. 2015, pp. 220–221). Accordingly, the majority of managers thinks that budgets are indispensable (Libby and Lindsay 2007). Practitioners perceive budgets especially useful for operational control, planning, and communication (Shastri and Stout 2008).

The communication function of budgets comes into effect when division managers are potentially better informed about their divisions' contribution to the success of the company than the managing owner (superior). However, managers often have incentives to misreport their private information. The misreporting harms

the company by providing the divisions with excessive payments and distorting the coordination. However, the company can affect the provided payments and the reporting behavior of the managers through the design of the budgeting process. With a top-down budgeting process, the superior (she) determines the level of the budget without any information provided by her subordinates. When a participative budgeting process is implemented, the superior asks her subordinates for information regarding their immediate environmental conditions [see Zimmerman (2017, pp. 229–230), Atkinson et al. (2012, pp. 381–382), and Weetman (2006, p. 316)]. Hence, the managers' private information can be used. The results of Shields and Shields (1998) highlight that, in practice, participative budgets are particularly important for vertical information sharing and coordinating interdependencies.

The design of the budgeting process is studied in a setting in which two divisions of a company are confronted with interdependence. For example, one division is responsible for marketing and the other for R&D. Both divisions' operations together determine the probability of the company to earn high earnings. Each division manager can privately learn his division's contribution to the probability of the company to obtain high earnings. The company can only observe the realized earnings and does not learn the contribution of a single division. Specifically, the marketing manager and the R&D manager can privately learn how good the aspired marketing strategy and the aspired product design fit the market needs, respectively. Even if one division's fit is low, the company may still earn high earnings. However, the probability to obtain high earnings is smaller. For example, if the marketing division's aspired marketing strategy is not very successful in marketing the product, the potential customers may still buy some of the products if they realize that the product design meets their needs. On the other hand, if the product design does not meet the market needs, the marketing division may still succeed in persuading some potential customers to buy the product.

Another example is two divisions operating in separate markets. One division is responsible for all the operations regarding selling the products of the company in market A and the other in market B. However, due to the known interdependence, the accounting system reports only one earnings number. For example, separate sales areas within a geographical area are often aggregated. The division manager in market A and the division manager in market B can privately learn how good their aspired division operations fit the market needs of market A and B, respectively. Clients who are attracted by the internationality of the company and the corresponding brand might purchase the company's products in market A and market B.

In the considered setting, two economic forces are at work. On one hand, when the managing owner enables the managers to obtain private information about the operation's market fit of their division, this information can be used by her to coordinate the operations of the interdependent divisions. For the example of a marketing and R&D division, coordination manifests itself in matching the marketing strategy and the product design. For the example of two divisions operating in market A and B, coordination can be that the marketing campaigns of both divisions are matched, a joint standard for sale-related services is determined (e.g., the same terms of delivery or procedure to handle complaints), or the public

appearance in both markets is aligned. A successful coordination of the divisions enhances the expected profitability of the company. On the other hand, the managers incur personal costs for providing productive effort. The unobservable effort supply allows the managers to misreport to the company without any threat of detection. The design of the budgeting process enables the managing owner to either use or not use the managers' potential private information regarding the market fits. With a participative budgeting process, the company incurs costs for having productive effort supplied and for inducing truthful reporting by the managers. Then, the company benefits from using this accurate information for a perfect coordination. In a top-down budgeting process, the managing owner does not install an information system that allows the managers to obtain the coordination relevant private information. Nevertheless, the company provides incentives to induce the managers to provide productive effort. This results in smaller incentive costs than in a participative budgeting process. Without the accurate information, the managing owner performs the coordination according to her prior beliefs. This results in imperfect coordination. Thus, the company forfeits the benefit from perfectly coordinating the divisions in favor of saving on the costs for inducing the managers to truthfully report their private information.

The model shows that, in the case of a low importance of coordination, the loss from imperfect coordination in a top-down budgeting process is outweighed by the additional costs for inducing truth-telling in a participative budgeting process. That is, the company prefers to implement a top-down budgeting process and to keep the managers uninformed. For a high importance of coordination, the use of a participative budgeting process is optimal. The results illustrate that the company might prefer to use a top-down budgeting process instead of a participative budgeting process. However, this is not true for the managers of the divisions. The managers receive higher positive expected rents with participation than they receive with top-down budgets. Thus, the managers always prefer to have a participative budgeting process in place.

A raise in the earnings potential intensifies the effect of coordination on the expected earnings. Thus, the negative effect of an imperfect coordination by the managing owner increases. Imperfect coordination only occurs in a top-down budgeting process. The incentive costs with both a top-down and a participative budgeting process are unaffected by an increase in the earning potential. In sum, the economic effect of coordination becomes stronger, whereas the incentive costs are unaffected. Therefore, an increase in the earnings potential makes the use of a participative budgeting process more attractive relative to the use of a top-down budgeting process.

This paper contributes to the literature in three ways. First, it complements the insights generated by the analytical literature on managers' participation in the budgeting process. Given a budget-based bonus scheme, Magee (1980) establishes that a manager's participation in the budgeting process is detrimental for the company, because the manager maximally misreports. Baiman and Evans III (1983) highlight that the company prefers the participative budgeting process only when the manager is induced to report the private decision-relevant information truthfully. Contrary to Magee (1980) and Baiman and Evans III (1983), the present paper

illustrates that the top-down budgeting process might be preferred by the company due to lower incentive costs, although the managers report truthfully in the participative budgeting process. Penno (1990) finds that the company solely prefers a manager's participation in the budgeting process when the compensation contract can be based on the reported private information. Despite basing the compensation contract on the reported private information in the participative budgeting process, the present paper shows that the top-down budgeting process is preferred for a low importance of coordinating the divisions' interdependence. Kirby et al. (1991) study participation in a setting where the manager is induced to set unbiased hurdles by a compensation scheme belonging to a class of budget-based performance evaluation schemes. Participation can reduce the manager's informational rents and, therefore, be preferred by the company. The present paper's finding complements this result by highlighting that the top-down budgeting process might be preferred because of lower informational rents. Heinle et al. (2014) illustrate that the company prefers a top-down budgeting process whenever the level of information asymmetry between the manager and her superior is small. The present paper adds to this finding by showing the impact of the importance of coordinating the divisions' operations on the design of the budgeting process.

Second, this paper adds to the analytical literature on choosing an information system and the manager's participation in the budgeting process. Christensen (1982) provides an example in which the company is better off when a risk-averse manager neither obtains private decision-relevant information nor participates in the budgeting process compared to obtaining the information and participating in the budgeting process. This is in line with the present paper's findings. While Christensen's finding stems from a shift in the trade-off of risk sharing and inducing effort, the present paper illustrates the impact of the importance of coordination on the design of the budgeting process. Penno (1984) highlights that enabling a manager to obtain private decision-relevant information is beneficial for the company when the company can design the information system's characteristics. This result holds whether the manager participates in the budgeting process or not. In the present paper, the company cannot choose the information system's characteristics. Thus, in line with Penno (1984), the company does not want the managers to obtain private information in the top-down budgeting process. This is discussed in more detail in Sect. 6. In addition, the present paper shows that participation is preferred for a high importance of coordinating the interdependent divisions' operations, although the managers are informed in the participative budgeting process. Given a participative budgeting process, Rajan and Saouma (2006) examine the merits of different levels of information asymmetry between the company and the manager ranging from perfectly informative, to somewhat informative, to not informative at all. They find that the company prefers an uninformed manager when the possible levels of the manager's productivity are similar. Otherwise, a fully informed manager is preferred. The uninformed manager's report does not convey any information, and therefore, this setting is comparable to the present paper's top-down budgeting process. This means that Rajan and Saouma (2006) show that the similarity of the productivity levels determine whether the manager participates in the budgeting process. Holding the

productivity levels' similarity constant, the present paper depicts the effect of the importance of coordination on the design of the budgeting process.

Third, this paper contributes to the literature on capital budgeting. The analytical literature on capital budgeting (see Antle and Eppen 1985; Antle and Fellingham 1990; Fellingham and Young 1990; Arya et al. 1994, 1996, 2000; Antle and Fellingham 1995; Baiman et al. 2013) considers situations in which one or more managers have access to investment projects. The manager(s) learn(s) the investment projects' (expected) profitability. The superior has access to financial resources and has to decide whether and under which conditions to finance the investment project(s). This literature stresses the adverse selection problem inherent in the budgeting process. In these models, communication of the managers is optimal for the company, i.e., the participative budgeting process is always preferred. The present study shows that the use of the top-down budgeting process is optimal for a low importance of coordinating the company's divisions. For a high importance of coordination, a participative budgeting process yields a higher expected profit. With a participative budgeting process, perfect coordination is achieved. The associated benefits exceed the additional incentive costs of inducing truthful reports from the managers when the importance of coordination is high.

The article proceeds as follows. In the next section, the model is described and two benchmarks are displayed. As first benchmark, the first best solution is considered in which the managing owner observes both the managers' private information and their productive effort supplies. The second benchmark examines the setting when the managing owner learns the decision-relevant information, but does not observe the managers' productive effort supplies. Subsequently, in Sects. 3 and 4, the findings regarding the top-down and participative budgeting process are presented. Afterwards, in Sect. 5, the findings for the top-down and the participative budgeting process are compared. In addition, the role of the environmental conditions on the design choice and empirical implications of the findings are discussed. Section 6 concludes the paper.

2 The model

The model described in this paper is a principal two agent model with different objectives and an information asymmetry among the principal and the agents. A risk-neutral managing owner (principal, P) leads a company with two divisions. Each division is run by a risk-neutral division manager (agent $i, A_i, i = 1, 2$). While working for the principal, the agents may have the possibility to acquire private information regarding the respective division's market fit. The divisions' market fits affect the expected profitability of the company. Agent i 's fit with market needs is denoted by η_i , where $\eta_i = \eta_H$ and $\eta_i = \eta_L$ are equally likely for $i = 1, 2$ with $0 < \eta_L < \eta_H < 1/2$. The small value η_L denotes a low fit with market needs and an associated small probability to obtain high earnings. The random variables η_1 and η_2 are assumed to be independent.

At the beginning of the period, the principal designs the budgeting process. The principal has two options for the design of the budgeting process. She can either

implement a top-down (TB) or a participative (PB) budgeting process. With a participative budgeting process in place, the agents obtain private information and the principal asks the agents to report on their private information. She cannot observe whether the reports are truthful or not. The report of agent i on his private information is denoted by r_i and can either be η_L or η_H . When the principal implements a top-down budgeting process, the agents neither obtain private information nor are asked to send a report. This means, whereas, in the participative budgeting process, the principal implements an information system that privately informs the agents about their divisions' market fit, no information system is installed in the top-down budgeting process. The information system can, for example, regard market research, target costing, or value engineering which is relevant for the divisions' operations. Because specific expertise is needed for interpreting the provided information each agent can solely observe her division's information. Installation costs of the information system are not explicitly modeled.¹ However, the implicit assumption is made that the principal does not install a costly information system in the top-down budgeting process, because the information cannot be elicited and, thus, not used by the principal. The assumption that the agents do not obtain private information in a top-down budgeting process is critically reflected in Sect. 6.

Next, agent i supplies personally costly productive effort e_i . Agent i can choose between two levels of productive effort $e_i \in \{0, 1\}$. With the high effort supply $e_i = 1$, the probability to obtain high earnings is higher than with $e_i = 0$. Agent i incurs personal costs $\psi_i(e_i)$ for providing effort with $\psi_i(1) = c > 0$ and $\psi_i(0) = 0$. The principal does not learn the chosen level of productive effort supplied by agent i . Throughout the analysis, the assumption is made that the principal benefits from inducing high effort provision.

At the end of the period, both divisions jointly generate earnings x . The earnings are either low, $x = x_L$, or high, $x = x_H$, where $0 \leq x_L < x_H$. Without loss of generality, low earnings x_L are set equal to zero. The probability to generate high earnings is denoted by θ and is not observable. With probability $1 - \theta$, low earnings are achieved. The earnings x can be observed by all parties and are contractible.

The probability to obtain high earnings θ is affected by both divisions' market fits, by both agents provided productive effort, and the principal's conducted coordinating adaptations a . The principal can choose her coordinating adaptations between $2\eta_L$ and $2\eta_H$. She does not incur costs from coordination. The importance of coordination is denoted by $\beta > 0$. β captures the impact of perfect coordination compared to imperfect coordination. When the principal fails to perfectly coordinate the divisions' operations, the company suffers from a reduced probability to obtain high earnings. A high β indicates that the principal can substantially increase the probability to earn high earnings θ by providing perfect coordination instead of imperfect coordination. The probability to obtain high earnings θ is given by the following:

¹ If installation costs of the information system exist, the net benefit of the participative budgeting process decreases. Then, the interval of the importance of coordination for which the top-down budgeting process is preferred becomes larger. The qualitative results of the paper are not affected by (neglected) installation costs.

$$\theta = e_1\eta_1 + e_2\eta_2 - (1 - I_{e_1=0,e_2=0})\beta|\eta_1 + \eta_2 - a|, \quad (1)$$

where $I_{e_1=0,e_2=0}$ takes on the value 1 if both agents do not provide high effort supply, i.e., $e_1 = 0$ and $e_2 = 0$, or the value 0 in all other cases. This indicator variable is introduced for technical reasons. That is, the indicator variable ensures that the probability θ belongs to the interval $[0, 1]$ for all possible effort choices. In equilibrium, the principal induces the agents to provide high effort, so that $I_{e_1=0,e_2=0}$ takes on the value 0. The effect of coordination in Eq. 1 may seem peculiar, because coordination seems to be harmful. However, Eq. 1 captures that the probability to obtain high earnings is higher with perfect coordination than with imperfect coordination. In particular, with perfect coordination, i.e., $a = \eta_1 + \eta_2$, the term $-(1 - I_{e_1=0,e_2=0})\beta|\eta_1 + \eta_2 - a|$ is zero, whereas, with imperfect coordination, this term is negative. For example, η_1 and η_2 capture how much the aspired marketing strategy and the aspired product design fit the market needs, respectively. The implemented product design results in product features. With imperfect coordination, the implemented marketing strategy might not emphasize realized product features that are highly valued by customers. As a consequence, the probability to obtain high earnings diminishes. This is captured by the negative term $-(1 - I_{e_1=0,e_2=0})\beta|\eta_1 + \eta_2 - a|$ in Eq. 1. Perfect coordination is achieved when all realized product features that are highly valued by customers are conveyed by the implemented marketing strategy. That is, perfect coordination results in higher expected earnings. In this sense, perfect coordination is beneficial for the company.

The importance of coordination β is restricted to the interval $(0, \min\{2, \frac{\eta_H}{\eta_H - \eta_L}\})$ to ensure that the probability θ is non-negative and misreporting incentives exist. In particular, the assumption $\beta < \frac{\eta_H}{\eta_H - \eta_L}$ ensures that the probability θ is non-negative. For $\beta < \min\{2, \frac{\eta_H}{\eta_H - \eta_L}\}$, agent i has an incentive to misreport in a participative budgeting process. For $\beta \in [\min\{2, \frac{\eta_H}{\eta_H - \eta_L}\}, \frac{\eta_H}{\eta_H - \eta_L})$, agent i does not have any incentives to misreport in a participative budgeting process. Note that the interval $[\min\{2, \frac{\eta_H}{\eta_H - \eta_L}\}, \frac{\eta_H}{\eta_H - \eta_L})$ can be empty. To minimize the occurring case distinctions in Sect. 5, the analysis is restricted to the case of the existing misreporting incentives. This does not affect the qualitative results of Sect. 5.

At the end of the period, agent i is compensated. The compensation scheme is based on the realized earnings. Agent i receives a compensation payment $w_i^{j,l}$ when x_j has been realized and the budgeting process l is in place, where $j \in \{L, H\}$ and $l \in \{TB, PB\}$. The agents' reservation utility is zero and each agent is protected by limited liability.

The principal seeks to maximize her expected utility which corresponds to the expected profit of the company:

$$U_P^l = x - w_1^{j,l} - w_2^{j,l}, \quad (2)$$

where $j = H, L$ and $l = TB, PB$.

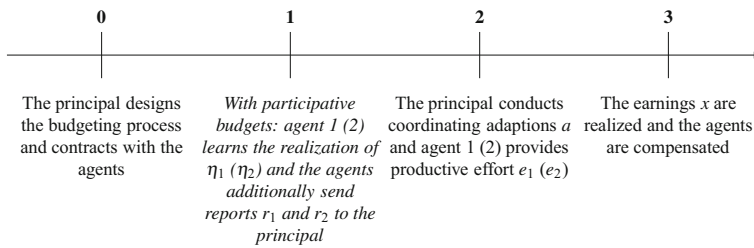


Fig. 1 Timeline

The agents are also expected utility maximizers. Agent i 's utility is determined by the following:

$$U_{A_i}^l = w_i^{j,l} - \psi_i(e_i), \tag{3}$$

where $i = 1, 2, j = H, L$, and $l = TB, PB$.

The sequence of events is illustrated in Fig. 1.

Next, two benchmarks are examined. First, the first best solution is considered. Here, the principal learns the realization of η_1 and η_2 and observes the agents' productive effort supplies. The principal uses the information and chooses her coordinating adaptations to maximize θ . This results in perfect coordination. To induce the agents to provide high productive effort, the principal has to reimburse the agents' personal costs c .

The first best solution is also obtained when the principal only observes the agents' effort provisions and implements the participative budgeting process. As each agent is reimbursed his personal costs c , they do not have an incentive to misreport the obtained private information. Thus, perfect coordination is achieved when the principal observes the agents' effort supplies.

Second, the setting when the principal learns the realization of the decision-relevant information η_1 and η_2 , but does not observe the provided productive efforts is considered as a benchmark. Learning the decision-relevant information enables the principal to perfectly coordinate the divisions' operations. However, she needs to provide the agents with adequate incentives to induce high effort supply. Specifically, the principal needs to pay a bonus in the case of the high earnings. With a low market fit, the probability to obtain high earnings is low. Thus, the bonus in the case of a low market fit needs to be higher than with a high market fit. Due to the moral hazard problem, each agent obtains a positive rent. The insights from the two benchmarks is formally stated in Observation 1.

Observation 1 *In the first best solution, that is the decision-relevant information and the agents' provided effort supplies are observed by the principal, each agent receives a payment $w_i^{fb} = c$ for providing high effort.*²

When the principal only observes the realization of the decision-relevant information η_1 and η_2 , she needs to provide a bonus, i.e., $w_i^{H,b2}(\eta_i) = c/\eta_i$ and

² The superscript *fb* indicates the first best solution.

$w_i^{L,b2}(\eta_i) = 0$ for $i = 1, 2$,³ to induce high effort provision by both agents. The expected compensation of each agent includes a positive rent.

Proof The proof is stated in the “Appendix”. □

3 Top-down budgeting process

This section addresses the second best solution with the top-down budgeting process in place. The agents do not learn the realization of the decision-relevant information and the principal does not ask the agents to send a report.

The principal chooses the coordinating adaptations a according to her prior beliefs. Thus, in expectation, she cannot perfectly coordinate the divisions. Taking the principal’s and the agents’ utilities into account (Eqs. 2 and 3) as well as the probability to obtain high earnings θ (Eq. 1), the principal solves the following program for $i, j = 1, 2, i \neq j$:

$$\max_{w_i^{H,TB}, w_i^{L,TB}, a} E \left[\theta (x_H - w_1^{H,TB} - w_2^{H,TB}) + (1 - \theta) (-w_1^{L,TB} - w_2^{L,TB}) \middle| e_1, e_2 \right] \quad (\text{P TB})$$

subject to:

$$w_i^{H,TB}, w_i^{L,TB} \geq 0 \quad (\text{LL TB})$$

$$E \left[\theta w_i^{H,TB} + (1 - \theta) w_i^{L,TB} - e_i c \middle| e_1, e_2 \right] \geq 0 \quad (\text{IR TB})$$

$$\begin{aligned} E \left[\theta w_i^{H,TB} + (1 - \theta) w_i^{L,TB} - c \middle| e_i = 1, e_j = 1 \right] \\ \geq E \left[\theta w_i^{H,TB} + (1 - \theta) w_i^{L,TB} \middle| e_i = 0, e_j = 1 \right] \quad (\text{IC TB}). \end{aligned}$$

The limited liability constraints (LL TB) ensure that the agents do not have to pay anything to the company. The individual rationality constraints (IR TB) make sure that the agents want to work for the principal, because they receive at least their reservation utility. The incentive compatibility constraints (IC TB) induce the agents to provide high productive effort.

In line with the second benchmark, the principal needs to pay a bonus in the case of the high earnings to induce high effort provision. However, as neither the principal nor the agents observe the realization of the decision-relevant private information the bonus is determined with the information’s expected probability $E[\eta_i]$, i.e., $w_i^{H,TB} = c/E[\eta_i]$. Thus, the principal incurs incentive costs because of the moral hazard problem. Imperfect coordination reduces the probability to obtain high earnings. However, this probability remains positive. Proposition 1 summarizes the findings for the top-down budgeting process.

³ The superscript *b2* indicates the second benchmark.

Proposition 1 *Under the top-down budgeting process, the optimal compensation scheme is $w_i^{H,TB} = \frac{c}{E[\eta_i]}$ and $w_i^{L,TB} = 0$ for $i = 1, 2$. The optimal coordinating adaptations are determined by the following:*

$$a^{TB} = E[\eta_1 + \eta_2].$$

The expected utility for the principal is given by the following:

$$E^{TB}[U_P] = \left(E[\eta_1 + \eta_2] - \frac{1}{2}(\eta_H - \eta_L)\beta \right) [x_H - w_1^{H,TB} - w_2^{H,TB}]. \tag{4}$$

The expected utility for agent $i, i = 1, 2$, is given by the following:

$$E^{TB}[U_{A_i}] = c \left[1 - \frac{(\eta_H - \eta_L)\beta}{E[\eta_1 + \eta_2]} \right] > 0. \tag{5}$$

Proof The proof is stated in the “Appendix”. □

Under a top-down budgeting process, the principal induces the agents to provide high productive effort. The effort provision is not observable by the principal. Therefore, the agents obtain a positive expected utility. This corresponds to a positive rent for each agent, because the agents’ reservation utility is zero.

By choosing the coordinating adaptations a^{TB} , the principal minimizes the expected loss incurred because of imperfect coordination. Compared to perfect coordination, imperfect coordination results in reduced expected earnings.

4 Participative budgeting process

When the principal decides to implement the participative budgeting system at date 0, she asks both agents to send reports r_1 and r_2 about their private information η_1 and η_2 at date 1, respectively. The optimal compensation scheme in the second benchmark (see Observation 1) illustrates that the bonus payment in the case of high earnings needs to be higher for a low market fit than for a high market fit for inducing high productive effort, that is $w_i^{H,b2}(\eta_L) = c/\eta_L > c/\eta_H = w_i^{H,b2}(\eta_H)$. When the importance of coordination β is smaller than 2 and if the principal used the same payment scheme in the second best setting with participative budgets, agent i would always claim to have observed a low market fit to obtain the high bonus payment. Although this would result in imperfect coordination which reduces agent i ’s probability to obtain the bonus, this reduction in the expected compensation is exceeded by the increase due to the higher bonus payment. As noted in Sect. 2, the importance of coordination β needs to be smaller than $\frac{\eta_L}{\eta_H - \eta_L}$ to ensure that the probability θ is non-negative. Thus, with the participative budgeting process and for $\beta < \min\left\{2, \frac{\eta_L}{\eta_H - \eta_L}\right\}$, truth-telling cannot be induced using the optimal compensation scheme of the second benchmark where the principal observes the realization of the private information. In the event that $2 < \frac{\eta_L}{\eta_H - \eta_L}$, a

different truth-telling incentive occurs for $\beta \in \left[2, \frac{\eta_L}{\eta_H - \eta_L}\right)$. Specifically, using the optimal compensation scheme of the second benchmark induces the agents to report truthfully. The intuition is as follows. If the agents misreport, the principal’s coordinating adaptations would be imperfect. This would lower the agents’ expected compensation. Contrary to the event of an importance of coordination smaller than 2, the increase in the agents’ expected compensation from the higher bonus payment does not outweigh the loss from imperfect coordination. Consequently, truth-telling is always optimal for the agents. For $\frac{\eta_L}{\eta_H - \eta_L} \leq 2$, the interval $\left[2, \frac{\eta_L}{\eta_H - \eta_L}\right)$ is empty, so that only the first case of misreporting incentives occur. To not unnecessarily complicate the exposition of the results, the analysis is restricted to $\beta < \min\left\{2, \frac{\eta_L}{\eta_H - \eta_L}\right\}$ as noted in Sect. 2. This does not affect the qualitative results regarding the comparison of the top-down and the participative budgeting process. For $\beta < \min\left\{2, \frac{\eta_L}{\eta_H - \eta_L}\right\}$, misreporting incentives exist and the principal needs to design the compensation scheme, so that each agent is induced to truthfully reveal his private information and to provide high productive effort. The revelation principle applies in this case. With the participative budgeting process, the principal has to solve the following program for $r_i \in \{\eta_L, \eta_H\}$, $i, j = 1, 2$ and $i \neq j$:

$$\begin{aligned} & \max_{w_i^{H,PB}(r_i), w_i^{L,PB}(r_i)} E \left[\theta [x_H - w_1^{H,PB}(r_1) - w_2^{H,PB}(r_2)] \right. \\ & \quad \left. + (1 - \theta) [-w_1^{L,PB}(r_1) - w_2^{L,PB}(r_2)] \mid r_1, r_2, e_1, e_2 \right] \tag{P PB} \\ & \text{subject to:} \\ & \quad w_i^{H,PB}(r_i), w_i^{L,PB}(r_i) \geq 0 \tag{LL PB} \\ & \quad E \left[\theta w_i^{H,PB}(\eta_i) + (1 - \theta) w_i^{L,PB}(\eta_i) - e_i c \mid r_1, r_2, e_1, e_2 \right] \geq 0 \tag{IR PB} \\ & \quad \theta(r_i = \eta_i, r_j = \eta_j, e_i = 1, e_j = 1) [w_i^{H,PB}(\eta_i) - w_i^{L,PB}(\eta_i)] \\ & \quad \quad + w_i^{L,PB}(\eta_i) - c \\ & \quad \geq \theta(r_i = \eta_i, r_j = \eta_j, e_i = 0, e_j = 1) [w_i^{H,PB}(\eta_i) - w_i^{L,PB}(\eta_i)] + w_i^{L,PB}(\eta_i) \tag{IC PB} \\ & \quad \theta(r_i = \eta_i, r_j = \eta_j, e_1 = 1, e_2 = 1) [w_i^{H,PB}(\eta_i) - w_i^{L,PB}(\eta_i)] + w_i^{L,PB}(\eta_i) \\ & \quad \geq \theta(r_i, r_j = \eta_j, e_1 = 1, e_2 = 1) [w_i^{H,PB}(r_i) - w_i^{L,PB}(r_i)] + w_i^{L,PB}(r_i) \tag{TT PB} \\ & \quad a \in \text{argmax}_a E[\eta_1 + \eta_2 - \beta|\eta_1 + \eta_2 - \hat{a} \mid r_1, r_2, e_1, e_2] \tag{ICP PB} \end{aligned}$$

The principal’s objective (P PB) illustrates that the compensation scheme is determined at date 0. The limited liability constraints (LL PB) restrict the compensation scheme to non-negative payments. The individual rationality constraints (IR PB) make sure that each agent receives at least his reservation utility. Thus, he wants to accept the contract offered by the principal at date 0. The incentive compatibility constraints for the agents (IC PB) ensure that both agents provide high productive effort. Truthful reporting by the agents is induced by meeting the truth-telling constraints (TT PB). The constraint (ICP PB) illustrates that the principal conducts the coordinating adaptations a after receiving both agents’ reports r_1 and r_2 .

The principal conducts these coordinating adaptations, so that the probability to achieve high earnings is maximized.

The agents’ reports affect the principal’s choice of coordinating adaptations. When the agents misreport, the principal conducts imperfect coordination. Thus, the probability to obtain high earnings is reduced compared to truthful reports. The agents’ compensation payments are linked to the observable realization of the earnings. A reduced probability to achieve high earnings hurts the agents’ probability to receive the compensation payment associated with high earnings. The principal sets the compensation payments, so that each agent finds it optimal to provide high effort and report truthfully. Compared to the top-down budgeting process, the additional truth-telling issue increases the principal’s incentive costs. The solution to the principal’s optimization program is summarized in Proposition 2.

Proposition 2 *Under the participative budgeting process, the principal determines the coordinating adaptations a and the compensation scheme for $i = 1, 2$ as follows:*

- $a^{PB} = \eta_1 + \eta_2$, and
- $w_i^{H,PB}(\eta_H) = \frac{c}{\eta_L} \frac{2\eta_H - (\eta_H - \eta_L)\beta}{2\eta_H}$, $w_i^{H,PB}(\eta_L) = \frac{c}{\eta_L}$, $w_i^{L,PB}(r_H) = w_i^{L,PB}(r_L) = 0$,
 where $w_i^{H,PB}(\eta_H) > w_i^{H,b2}(\eta_H)$ and $w_i^{H,PB}(\eta_L) = w_i^{H,b2}(\eta_L)$.

The principal’s expected utility is given by the following:

$$E^{PB}[U_P] = E[\eta_1 + \eta_2]x_H - \frac{c}{4\eta_H\eta_L} [8\eta\beta(\eta_H + \eta_L) - \beta(\eta_H - \eta_L)(3\eta_H + \eta_L)]. \tag{6}$$

The expected utility for agent $i, i = 1, 2$, is given by the following:

$$E^{PB}[U_{A_i}] = c \left(\frac{\eta_H}{\eta_L} - \frac{\beta(\eta_H - \eta_L)(3\eta_H + \eta_L)}{8\eta_H\eta_L} \right), \tag{7}$$

where $E^{PB}[U_{A_i}] > E^{TB}[U_{A_i}]$.

Proof The proof is stated in the “Appendix”. □

The compensation scheme for agent i ($w_i^{H,PB}(r_i), w_i^{L,PB}(r_i)$), $i = 1, 2$, reveals some interesting insights. If the importance of coordination is high, i.e., β is high, the principal needs to pay less compensation for a high report and high earnings. Thus, the rents to agent i for inducing a high effort supply and truthful reporting are diminished. The negative effect of agent i ’s misreporting on his expected compensation payment becomes more severe for a high importance of coordination. Thus, it becomes cheaper to induce high effort supply for a high report whenever coordination is very important. In addition, the agents’ compensation payments in the case of realized high earnings x_H are not affected by the level of x_H . The benefit from their joint production, i.e., the synergy, is arbitrarily split between the two agents. Comparing the compensation scheme in Proposition 2 with the one of the second benchmarks stated in Observation 1 reveals that only the bonus payment for a high report is adapted due to the truth-telling issue. Specifically,

$w_i^{H,PB}(\eta_H) > w_i^{H,b2}(\eta_H) = c/\eta_H$, i.e., the bonus payment for a high report in the participative budgeting process is higher than the corresponding payment in the second benchmark. Thus, the incentive costs with participative budgets comprise two components: one for inducing high productive effort and one for ensuring truth-telling.

By basing the coordinating adaptations a^{PB} on the agents' truthful reports, the principal provides perfect coordination. With perfect coordination, the probability to obtain high earnings and thus, the expected earnings are as high as possible. However, the principal also has to bear incentive costs which are larger than with top-down budgets.

Both agents jointly affect the principal's coordination choice by reporting relevant private information and providing productive effort. Arguably, they might have incentives to increase their expected utility by colluding. However, the agents do not want to collude under the participative budgeting process. They neither jointly agree on their reports sent to the principal nor on their effort choice. If one agent misreports his private information η_i , the other agent's compensation scheme is not affected. Misreporting has a negative effect on the principal's coordinating adaptations a . The probability θ to attain high earnings declines. This reduces the expected compensation payment for each agent. A reduction in the expected compensation payment is not in the interest of either agent. Therefore, the agents refrain from collusion with regards to reporting. Neither do the agents benefit from having only one or neither agent perform high effort. With low productive effort, the probability to obtain the bonus payment decreases. The reduction in both agents' expected compensation payments exceeds the reduction in personal costs by providing low effort instead of high effort. As a consequence, the agents also refrain from collusion with regards to effort provision. This finding is summarized in Corollary 1.

Corollary 1 *The agents never find it optimal to collude if the principal implements the participative budgeting process.*

Proof The proof is stated in the “[Appendix](#)”. □

5 Comparison of the top-down and the participative budgeting process

At date 0, the principal decides whether to implement a top-down or a participative budgeting process. According to the given environmental conditions, she prefers one or the other budgeting processes. The importance of coordination β is critical for the design of the budgeting process.

The principal deliberates whether to incur additional incentive costs regarding truthful reporting and thus being able to perfectly coordinate the agents' operations in a participative budgeting process, or to save on incentive costs and suffer from imperfect coordination in a top-down budgeting process. If the importance of coordination is low, the additional incentive costs exceed the benefits from perfect coordination. Consequently, the principal prefers to implement a top-down

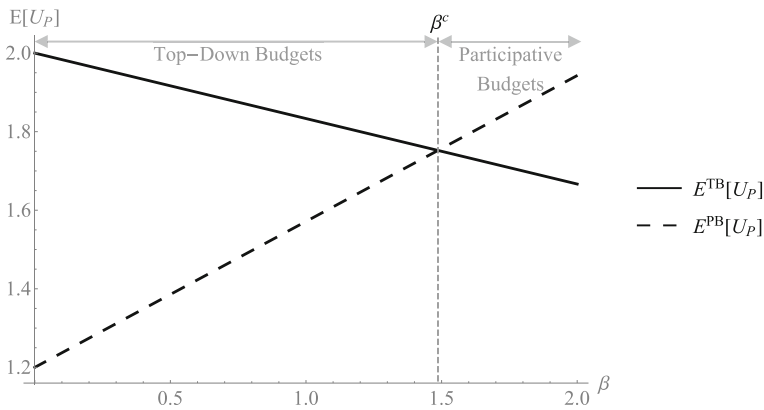


Fig. 2 top-down or participative budgets (plotted for $c = 1, \eta_L = 0.25, \eta_H = 0.35,$ and $x_H = 10$; $E[U_P]$ denotes the principal’s expected utility; TB (PB) stands for top-down (participative) budgets; β is the importance of coordination)

budgeting process. However, when the importance of coordination β is large, the benefits from improved coordination outweigh the additional incentive costs for inducing truthful reporting by the agents. Therefore, the principal implements a participative budgeting process. The findings are summarized in Proposition 3 and visualized in Fig. 2.

Proposition 3 For a low importance of coordination $\beta < \beta^c$, the principal prefers to implement the top-down budgeting process.

For a high importance of coordination $\beta \geq \beta^c$, the principal prefers to implement the participative budgeting process.

The cut-off level β^c is determined by the following:

$$\beta^c = \frac{8c\eta_H(\eta_H + \eta_L)}{c(3\eta_H^2 - 4\eta_H\eta_L + \eta_L^2) + 2\eta_H\eta_L(\eta_H + \eta_L)x_H} > 0. \tag{8}$$

Proof The proof is stated in the “Appendix”. □

Proposition 3 states the main result of this paper. The principal faces a trade-off between additional incentive costs and coordination benefits. For both the top-down and the participative budgeting process, the principal incurs incentive costs for inducing high productive effort supply. The additional incentive costs ensure that the agents report truthfully with participative budgets. With truthful reports about their private decision-relevant information, the principal can perfectly coordinate the agents’ operations. Imperfect coordination results in reduced expected earnings. Under a participative budgeting process, the principal incurs the additional incentive costs and benefits from perfect coordination. With top-down budgets, the principal does not need to provide additional incentives. Thus, she saves on the additional incentive costs. However, the principal suffers from reduced expected earnings because of imperfect coordination. In a situation of a low importance of

coordination β , the principal prefers to use a top-down budgeting process. Thus, a top-down budgeting process can be optimal for the principal. For a high importance of coordination, the principal uses a participative budgeting process. Then, a top-down budgeting process is never optimal for the principal. This finding is aligned with the empirical findings of Shields and Shields (1998). They illustrate that coordinating interdependence is one of the most important reasons for the participation of managers in the budgeting process. The model predicts that the principal prefers to use a participative compared to a top-down budgeting process for a high importance of coordinating the interdependent divisions.

The findings of the present paper highlight that the use of a top-down budgeting process might be optimal, too. The reason is that the principal can diametrically trade off additional incentive costs and coordination benefits through implementing either a top-down or a participative budgeting process.

Christensen (1982), Penno (1984), and Kanodia (1993) highlight the optimality of participative budgets in some operating budgeting settings. In these papers, the use of a top-down budgeting process would be suboptimal. Magee (1980) and Kirby et al. (1991) study a setting in which a top-down budgeting process might be preferred to a participative budgeting process. In contrast to the present setting, these studies consider exogenous compensation schemes. They highlight that given these compensation schemes, the principal might prefer to have no participation by the agents. Penno (1990) illustrates that participation by the agents might not always be strictly preferred to no participation, i.e., a top-down approach. However, Penno (1990) does not find a strict preference for a top-down budgeting process as is the case in the present paper.

Using Proposition 3, the model predicts that the importance of coordination is positively associated with the managers' participation in the budgeting process. For a high (low) importance of coordination, (no) participation in the budgeting process is expected to be observed in practice. Neither the importance of coordination nor the design of the budgeting process is usually disclosed in the annual report or other public sources. Thus, a case study or a survey seems appropriate for testing the model's empirical implication regarding the impact of the importance of coordination on the design of the budgeting process. When archival data are used for testing the model's empirical implication, proxies for the importance of coordination and the design of the budgeting process need to be used. A proxy for the use of the participative budgeting process can be a cooperative management style which is sometimes referred to in annual reports. Next, two possible proxies for the importance of coordination are discussed. First, the importance of coordination is presumably positively associated with the divisions' level of interdependence. For example, the divisions of a conglomerate might be less interdependent than the divisions of a company operating in a single industry. Then, the model predicts that conglomerates use a participative budgeting process at the division manager level less than companies operating in a single industry. That is, operating in a single industry might be a proxy for a high importance of coordinating the interdependent divisions. Second, both a high relevance of R&D and a large proportion of new products in the company's sales mix suggest a large interdependence of the R&D and the marketing division, and thus, a high importance of coordination. The

relevance of R&D can be captured by the ratio of R&D expenses to revenue. This proxy presumes that no survivor bias occurs.

The importance of coordination, captured by β , affects the height of the benefits from perfect coordination compared to imperfect coordination. When the principal's coordination is important for the company, i.e., β is high, the benefits from perfect coordination are also high. The incentive costs for inducing the agents to provide high productive effort and with participative budgets to also report truthfully are also affected by the importance of coordination. For an increase in the importance of coordination, the negative impact on the agents' expected compensation through not supplying high productive effort and misreporting is rising. In particular, the probability to obtain the high compensation payment in the case of high earnings declines. Thus, the principal can reduce the level of compensation payments needed to incentivize the agents. In sum, an increase in the importance of coordination affects both main economic forces at work in this setting, i.e., the incentive costs and the benefits from perfect coordination. The incentive costs are decreasing, whereas the benefits from perfect coordination are increasing in the importance of coordination. As a consequence, the principal's expected utility under the top-down budgeting process is decreasing as imperfect coordination becomes more harmful. The principal's expected utility under the participative budgeting process is increasing in the importance of coordination, because the incentive costs decrease and the benefits from perfect coordination raise. This is also depicted in Fig. 2.

Corollary 2 *The principal's expected utility using the top-down budgeting process is monotonically decreasing in the importance of coordination β .*

The principal's expected utility with the participative budgeting process is monotonically increasing in the importance of coordination β .

Proof The proof is stated in the “[Appendix](#)”. □

The principal's expected utilities with a top-down and a participative budgeting process are increasing in the earnings potential x_H . The relative attractiveness of a top-down and a participative budgeting process is captured by the cut-off level β^c . For an importance of coordination below this threshold, the top-down budgeting process yields a higher expected utility for the principal than a participative budgeting process. For an importance of coordination above the threshold β^c , the opposite is true. When the earnings potential x_H increases, the principal's expected utilities with a top-down and a participative budgeting process also increase. The increase is higher with a participative budgeting process than with a top-down budgeting process because of imperfect coordination with a top-down budget. Therefore, the cut-off level β^c is smaller for a higher earnings potential x_H . The range for which a top-down budgeting process is implemented, i.e., $[0, \beta^c)$, becomes smaller when the earnings potential increases. As a consequence, an increase in the earnings potential reduces the potential use of a top-down budgeting process. This is stated in Corollary 3 and displayed in Fig. 3.

Corollary 3 *The relative use of a participative compared to a top-down budgeting process is increasing in the earnings potential x_H .*

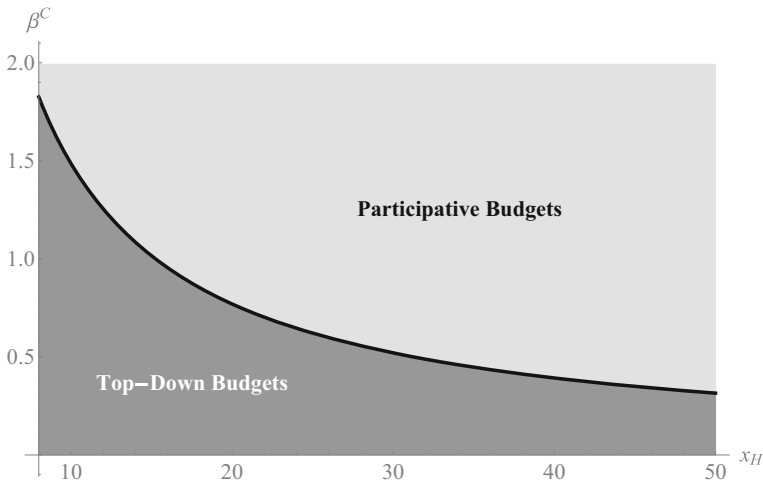


Fig. 3 top-down or participative budgets with regards to the earnings potential x_H (plotted for $c = 1$, $\eta_L = 0.25$, and $\eta_H = 0.35$; β^c denotes the cut-off level regarding the importance of coordination; x_H is the earnings potential)

Proof The proof is stated in the “[Appendix](#)”. □

When a top-down budgeting process is in place, the agents are not induced to provide truthful reports. Therefore, the agents only receive incentives for providing high productive effort. The resulting rent is positive, i.e., each agent’s expected utility exceeds his reservation utility of zero (Proposition 1). In the case of a participative budgeting process, the agents obtain additional rents, because the principal provides adapted compensation payments that induce the agents to truthfully report their private decision-relevant information. Consequently, if the agents designed the budgeting process in date 0, they would implement a participative budgeting process and obtain higher positive rents. This insight conforms with empirical findings. Practitioners would like to use more participation in the budgeting system (Libby and Lindsay 2010). Heinle et al. (2014) also illustrate that agents prefer a participative budgeting process to a top-down budgeting process. The intuition is similar. With a participative budgeting process, the agent controls the reporting and the productive effort supply. In a top-down budgeting process, the agent only controls the productive effort supply and the principal controls the reporting. Thus, in Heinle et al. (2014), the agent receives less rents with top-down budgets than under a participative budgeting process. In the present paper, the agents also control the effort supply and the reporting when a participative budgeting process is implemented. However, for a top-down budgeting process, the control over reporting is completely set mute. This means, neither the agents nor the principal controls the reporting. The findings of Corollary 4 correspond to the results of Heinle et al. (2014), i.e., the agents obtain more rents with a participative budgeting process compared to a top-down budgeting process.

Corollary 4 *The agents strictly prefer the participative budgeting process to the top-down budgeting process.*

Proof This directly follows from Proposition 2. □

6 Discussion and conclusion

This paper examines the design of the budgeting process when a company faces an interdependence among the divisions. In particular, two generic design possibilities are considered. The company can either implement a top-down or a participative budgeting process. The design of the budgeting process at the beginning of the period determines whether the managers will obtain and report private information or not. Under a top-down budgeting process, the managers do not obtain private information, whereas this information is obtained and acknowledged in a participative budgeting process.

The model design is subject to a couple of limitations. First, the assumption is invoked that, in a top-down budgeting process, the managers do not obtain private information. For example, this information can stem from market research, target costing, or value engineering and the managers' expertise is needed to interpret the provided information. Throughout this paper, the company decides not to implement the information system like market research, target costing, or value engineering when the top-down budgeting process is implemented. This means, the company does not enable the managers to obtain the information needed for coordination. If the managers also obtained the private information in the top-down budgeting process, the company would need to provide higher expected compensation to induce high effort supply. With private information, the managers know exactly how high effort affects the probability to obtain high earnings. Without private information, the managers know this only in expectation. Thus, more compensation is needed when the managers are informed. Due to the revelation principle, the top-down budgeting process never becomes strictly optimal when the managers are informed. However, as the compensation costs with a top-down budgeting process are smaller when the managers do not obtain the private information, the company does not want the managers to be informed. Hence, the company does not want the managers to obtain private information in a top-down budgeting process and the information system is not installed. The advantage of this assumption is that it enables the model to establish a strict preference of the top-down budgeting process for a low importance of coordination. This is in line with the empirical finding that both top-down and participative budgeting processes are implemented in practice (Shastri and Stout 2008). Next to this advantage, the assumption also bears a drawback. The budgeting process is connected to a specific information setup which is an exogenous restriction on the company's design of the information system. However, as outlined above, when the company chooses the design of the budgeting process and the information setup, it either chooses the top-down or the participative budgeting process as studied in the present paper.

Further limitations of the present study are the binary structure of private information, effort, and compensation, the symmetry of the divisions, and the independence of the (additional) incentive costs from the earnings potential. Alleviating these restrictions might yield additional interesting insights. Next to this disadvantage, these assumptions allow an easily comprehensible model analysis that illustrates how the importance of coordinating interdependent divisions affects the design of the budgeting process. Accordingly, these assumptions are used to have a parsimonious model that allows to concentrate on the two main economic effects prevailing in the studied setting.

The two economic effects regard benefits from coordination and additional incentive costs for inducing truthful reporting. First, the company can use the managers' private information to perfectly coordinate the divisions' operations. This results in high expected company earnings. Second, due to unobservable effort supply, the managers have an incentive to misreport their private information in the participative budgeting process. The company has to induce the managers to truthfully report the relevant private information. Thus, next to incentive costs for a high effort supply, the company incurs additional incentive costs for inducing truth-telling. Under a participative budgeting process, the company obtains the coordination benefits and bears the additional incentive costs. When a top-down budgeting process is implemented, the company forfeits the coordination benefits and saves on the additional incentive costs, because the managers are kept uninformed. The design of the budgeting process thus trades off these two economic effects in the opposite direction.

For a low importance of coordination, the company prefers to use a top-down budgeting process instead of a participative budgeting process. In the case of a low importance of coordination, the coordination benefits are small. The additional incentive costs exceed the coordination benefits. Whereas coordination benefits are increasing in the importance of coordination the additional incentive costs are decreasing. Thus, for a high importance of coordination, the coordination benefits outweigh the additional incentive costs. Then, the participative budgeting process is preferred by the company. Hence, the managing owner affects the company's profitability through the choice of the budgeting process.

Budgeting systems are often criticized for centralizing decision making (for example, see Hansen et al. 2003). Thus, practitioners would like to use more participation in the budgeting system (Libby and Lindsay 2010). This does not seem astonishing when taking the findings of this paper into account. The results indicate that managers favor the participative budgeting process. Hence, the call for more participation in the budgeting process is potentially driven by managers' self interest and might not always be in the best interests of the company. In particular, the present paper shows that, for a low importance of coordination, the company prefers a top-down budgeting process.

The relative attractiveness of a top-down and a participative budgeting process is affected by the earnings potential. An increase in the earning potential enhances the use of a participative compared to a top-down budgeting process.

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Appendix

Proof Observation 1

First, the first best solution is considered. Taking the principal’s and the agents’ utilities into account (Eqs. 2 and 3) as well as the probability to obtain high earnings θ (Eq. 1), the principal solves the following program for $i = 1, 2$:

$$\begin{aligned} & \max_{w_i^{fb}} E[\theta(x - w_1^{fb} - w_2^{fb})] && \text{(P fb)} \\ & \text{subject to:} \\ & \quad w_i^{fb} \geq 0 && \text{(LL fb)} \\ & \quad E[w_i^{fb} - c] \geq 0 && \text{(IR fb)} \\ & \quad a \in \operatorname{argmax}_{\hat{a}} |\eta_1 + \eta_2 - \beta|\eta_1 + \eta_2 - \hat{a}| && \text{(IC P fb)}. \end{aligned}$$

The incentive compatibility constraint (IC P fb) determines the first best level of coordinating adaptations, $a^{fb} = \eta_1 + \eta_2$. Thus, $\theta = \eta_1 + \eta_2$. The limited liability constraints (LL fb) and the individual rationality constraints (IR fb) imply that agent i receives a positive expected compensation payment. As the principal observes the provided effort level, she minimizes the compensation costs by paying $w_i^{fb} = c$ when she observes high effort supply. Thus, the principal obtains the following expected utility:

$$E^{fb}[U_P] = E[\eta_1 + \eta_2]x_H - 2c.$$

Agent i ’s expected utility is:

$$E^{fb}[U_{A_i}] = w_i^{fb} - c = c - c = 0. \tag{9}$$

Second, the second benchmark is examined. The principal solves the following program for $i = 1, 2$:

$$\max_{w_i^{H,b2}(\eta_i), w_i^{L,b2}(\eta_i)} E \left[\theta \left(x_H - w_1^{H,b2}(\eta_1) - w_2^{H,b2}(\eta_2) \right) + (1 - \theta) \left(-w_1^{L,b2}(\eta_1) - w_2^{L,b2}(\eta_2) \right) \middle| e_1, e_2 \right] \tag{P b2}$$

subject to:

$$w_i^{H,b2}(\eta_i), w_i^{L,b2}(\eta_i) \geq 0 \tag{LL b2}$$

$$E \left[\theta w_i^{H,b2}(\eta_i) + (1 - \theta) w_i^{L,b2}(\eta_i) \middle| e_1, e_2 \right] \geq 0 \tag{IR b2}$$

$$\begin{aligned} \theta(e_i = 1, e_j = 1) \left[w_i^{H,b2}(\eta_i) - w_i^{L,b2}(\eta_i) \right] + w_i^{L,b2}(\eta_i) - c \\ \geq \theta(e_i = 0, e_j = 1) \left[w_i^{H,b2}(\eta_i) - w_i^{L,b2}(\eta_i) \right] + w_i^{L,b2}(\eta_i) \end{aligned} \tag{IC b2}$$

$$a \in \text{argmax}_a \quad \eta_1 + \eta_2 - \beta | \eta_1 + \eta_2 - \hat{a} | \tag{IC P b2}$$

In this case, the principal sets $w_i^{H,b2}(\eta_i) = w_i^{L,b2}(\eta_i) = 0$. She chooses the coordinating adaptations so as to maximize $E[\theta]$, i.e., $a^{b2} = \eta_1 + \eta_2$. The limited liability constraints (LL b2) and the incentive compatibility constraints (IC b2) imply the individual rationality constraints. The incentive compatibility constraints (IC b2) imply $w_i^{H,b2}(\eta_i) \geq c/\eta_i$. Due to the principal’s objective function, the bonus payment is $w_i^{H,b2}(\eta_i) = c/\eta_i$. Thus, the principal obtains the following expected utility:

$$E^{b2}[U_P] = E[\eta_1 + \eta_2] x_H - c \frac{\eta_H^2 + 6\eta_H\eta_L + \eta_L^2}{2\eta_H\eta_L}.$$

Agent i ’s expected utility is

$$E^{b2}[U_{A_i}] = E \left[\theta w_i^{H,b2}(\eta_i) \right] - c = c + c \frac{(\eta_H + \eta_L)^2}{4\eta_H\eta_L} - c = c \frac{(\eta_H + \eta_L)^2}{4\eta_H\eta_L}, \tag{10}$$

where $E^{b2}[U_{A_i}] > 0$. Thus, compared to the first best solution, agent i obtains a positive rent, because $E^{b2}[U_{A_i}] > E^{fb}[U_{A_i}]$ according to Eq. 9. □

Proof Proposition 1

The individual rationality constraints (IR TB) are met because of the limited liability constraints (LL TB) and the incentive compatibility constraints (IC TB). The principal’s objective (P TB) highlights that positive compensation payments in the event of low earnings decrease the principal’s expected utility without any benefits. Thus, the compensation payments $w_i^{L,TB}$ for $i = 1, 2$ are optimally set equal to zero.

The principal chooses the coordinating adaptations so as to maximize $E[\theta]$, i.e., $a^{TB} = E[\eta_1 + \eta_2]$. The incentive compatibility constraints (IC TB) imply $w_i^{H,TB} \geq c/E[\eta_i]$. Due to the principal’s objective function, the bonus payment is $w_i^{H,TB} = c/E[\eta_i]$.

According to Eq. 2, the principal thus obtains the following expected utility:

$$E^{TB}[U_P] = \left(E[\eta_1 + \eta_2] - \frac{1}{2}(\eta_H - \eta_L)\beta \right) [x_H - w_1^{H,TB} - w_2^{H,TB}].$$

According to Eq. 3, agent i 's expected utility is given by

$$E^{TB}[U_{A_i}] = E[\theta w_i^{H,TB}] - c = c \left[1 - \frac{(\eta_H - \eta_L)\beta}{E[\eta_1 + \eta_2]} \right].$$

Because of

$$E[\eta_1 + \eta_2] - \beta(\eta_H - \eta_L) \underset{\beta < \frac{\eta_L}{\eta_H - \eta_L}}{>} 0.5\eta_H + 0.5\eta_L - \eta_L = 0.5(\eta_H - \eta_L) > 0,$$

agent i 's expected utility $E^{TB}[U_{A_i}]$ is positive. □

Proof Proposition 2

The following proof is organized in several steps.

Step (i) At date 2, the principal chooses the coordinating adaptations a according to the following:

$$a \in \operatorname{argmax}_{\hat{a}} E[\eta_1 + \eta_2 - \beta|\eta_1 + \eta_2 - \hat{a}| \mid r_1, r_2, e_1, e_2].$$

Thanks to the truth-telling constraints for the agents (TT PB), the agents' reports are truthful, i.e., $r_i = \eta_i$ for $i = 1, 2$. Thus, the optimal coordinating adaptations a become $r_1 + r_2$, i.e., $a^{PB} = r_1 + r_2 = \eta_1 + \eta_2$. The incentive compatibility constraints (IC PB) ensure that the agents provide high effort, i.e., $e_i = 1$ for $i = 1, 2$. In sum, $\theta(r_1 = \eta_1, r_2 = \eta_2, e_1 = 1, e_2 = 1) = \eta_1 + \eta_2$.

Step (ii) Due to the limited liability constraints (LL PB) the right-hand side of the incentive compatibility constraints (IC PB) is non-negative. Thus, the individual rationality constraints (IR PB) are met. According to the principal's objective (P PB), the principal's expected utility is decreasing in $w_i^{H,PB}(r_i)$ and $w_i^{L,PB}(r_i)$ for $i = 1, 2$. Thus, she would like to set the compensation payments as low as possible. The agents are risk-neutral. Having $w_i^{L,PB}(r_i) > 0$ does not alleviate the moral hazard problem. Thus, the principal sets $w_i^{L,PB}(r_i) = 0$.

Step (iii) For the incentive compatibility constraints (IC PB) and the truth-telling constraints (TT PB), the findings of steps (i) and (ii) are used, i.e., $a^{PB} = r_1 + r_2$ and $w_i^{L,PB}(r_i) = 0$. Then, the incentive compatibility constraint for agent i for $i, j = 1, 2$ is given by the following:

$$w_i^{H,PB}(\eta_i) \geq \frac{c}{\eta_i}. \tag{11}$$

This implies that agent i needs a higher bonus payment for $\eta_i = \eta_L$ to induce high effort supply than for $\eta_i = \eta_H$. According to the principal's objective (P PB), she prefers small compensation payments. Thus:

$$w_i^{\text{H,PB}}(\eta_L) = \frac{c}{\eta_L}. \quad (12)$$

If the principal paid agent i the bonus payment $w_i^{\text{H,PB}}(\eta_L) = \frac{c}{\eta_L}$ also for a high report, agent i would have no incentive to misreport. Thus, in the optimal solution:

$$w_i^{\text{H,PB}}(\eta_H) \leq \frac{c}{\eta_L}. \quad (13)$$

For $\eta_i = \eta_H$, the truth-telling constraints for agent i for $i, j = 1, 2$ and $i \neq j$ are given by the following:

$$w_i^{\text{H,PB}}(\eta_H) \geq \frac{c}{\eta_L} \underbrace{\frac{\eta_H + \eta_j - \beta(\eta_H - \eta_L)}{\eta_H + \eta_j}}_{\in(0,1)}. \quad (14)$$

For $\eta_i = \eta_L$, the truth-telling constraints for agent i for $i, j = 1, 2$ and $i \neq j$ are given by the following:

$$w_i^{\text{H,PB}}(\eta_L) \leq \frac{c}{\eta_L} \underbrace{\frac{\eta_L + \eta_j}{\eta_L \eta_L + \eta_j - \beta(\eta_H - \eta_L)}}_{>1}. \quad (15)$$

Inequality 13 implies that inequality 15 is fulfilled. Thus, the optimal compensation scheme is as small as possible and meets the inequality 11 for $\eta_i = \eta_H$, inequality 13, inequality 14 for $\eta_j = \eta_H$, and inequality 14 for $\eta_j = \eta_H$. Meeting the inequality 14 for $\eta_j = \eta_H$ implies that also the inequality 14 for $\eta_j = \eta_L$ is met. In addition, $\frac{c}{\eta_H} < \frac{c}{\eta_L}$ and $\frac{c}{\eta_L} \frac{2\eta_H - \beta(\eta_H - \eta_L)}{2\eta_H} < \frac{c}{\eta_L}$. In sum:

$$w_i^{\text{H,PB}}(\eta_H) = \max \left\{ \frac{c}{\eta_H}, \frac{c}{\eta_L} \frac{2\eta_H - \beta(\eta_H - \eta_L)}{2\eta_H} \right\}, \quad (16)$$

where

$$\frac{c}{\eta_L} \frac{2\eta_H - \beta(\eta_H - \eta_L)}{2\eta_H} \geq \frac{c}{\eta_H} \iff \beta \leq 2.$$

Thus, for $\beta \in \left(0, \min \left\{ 2, \frac{\eta_L}{\eta_H - \eta_L} \right\} \right)$, the optimal bonus payment for $r_i = \eta_H$ is as follows:

$$w_i^{\text{H,PB}}(\eta_H) = \frac{c}{\eta_L} \frac{2\eta_H - \beta(\eta_H - \eta_L)}{2\eta_H}. \quad (17)$$

Step (iv) Using truth-telling by the agents, $a^{\text{PB}} = \eta_1 + \eta_2$ from step (i), the payments $w_i^{\text{L,PB}}(r_i) = 0$ from step (ii), Eqs. 2, 3, 12, and 17 from step (iii), the principal's and agent i 's, $i = 1, 2$, expected utilities are calculated:

$$E^{PB}[U_P] = E[\eta_1 + \eta_2]x_H - \frac{c}{4\eta_H\eta_L} [8\eta_H(\eta_H + \eta_L) - \beta(\eta_H - \eta_L)(3\eta_H + \eta_L)].$$

$$E^{PB}[U_{A_i}] = c \left(\frac{\eta_H}{\eta_L} - \frac{\beta(\eta_H - \eta_L)(3\eta_H + \eta_L)}{8\eta_H\eta_L} \right).$$

For $\beta \in \left(0, \min\left\{2, \frac{\eta_H}{\eta_H - \eta_L}\right\}\right)$, comparing $E^{PB}[U_{A_i}]$ with $E^{TB}[U_{A_i}]$ as stated in Eq. 5 yields: $E^{PB}[U_{A_i}] > E^{TB}[U_{A_i}]$. □

Proof Corollary 1

Neither agent 1 nor agent 2 wants to misreport if the other agent reports truthfully. This is ensured by the incentive compatibility constraint (IC PB). Next, the impact of agent i 's misreporting on agent j 's expected utility is considered, $i, j = 1, 2, i \neq j$:

$$E^{PB}[U_{A_j} | r_j = \eta_j, r_i] = E[\eta_i + \eta_j - \beta|\eta_i - r_i|]w_j^{H,PB}(r_j) - c \tag{18}$$

$$\leq E[\eta_i + \eta_j]w_j^{H,PB}(r_j) - c = E^{PB}[U_{A_j} | r_i = \eta_i, r_j = \eta_j].$$

The inequality follows from the optimal report agent i can send from agent j 's viewpoint, i.e., $r_i = \eta_i$. This implies that the agent receives a higher expected utility when agent i reports truthfully. Thus, agent j does not benefit from agent i 's misreporting. In sum, neither agent wants the other agent to misreport on his behalf.

Next, the impact of both agents' misreporting on agent i 's expected utility is considered, $i, j = 1, 2, i \neq j$:

$$E^{PB}[U_{A_i} | r_i, r_j] = E[\eta_i + \eta_j - \beta|\eta_i + \eta_j - r_i - r_j|]w_i^{H,PB}(r_i) - c$$

$$\leq E[\eta_i + \eta_j - \beta|\eta_i - r_i|]w_i^{H,PB}(r_i) - c = E^{PB}[U_{A_i} | r_j = \eta_j, r_i].$$

Using, inequality 18 implies that agent i does not benefit from collusion. Both agents' expected utility is smaller when both agents misreport compared to when both agents report truthfully. Thus, the agents do not want to collude.

Next, the impact of agent i not supplying high effort on agent i 's and j 's expected utility is considered, $i, j = 1, 2, i \neq j$:

$$E^{PB}[U_{A_i} | e_i = 0, e_j = 1] = E[\eta_j w_i^{H,PB}(r_i)] < E[(\eta_i + \eta_j)w_i^{H,PB}(r_i)] - c,$$

$$E^{PB}[U_{A_j} | e_i = 0, e_j = 1] = E[\eta_j w_j^{H,PB}(r_j)] - c < E[(\eta_i + \eta_j)w_j^{H,PB}(r_j)] - c.$$

The first inequality follows from the incentive compatibility constraints (IC PB). Thus, both agents' expected utilities decline when the agents collude regarding effort supply. Collusion is not beneficial for the agents. □

Proof Proposition 3

Comparing the principal's expected utility with participative budgets as stated in Eq. 6 with her expected utility with top-down budgets as stated in Eq. 4 yields:

$$E^{PB}[U_P] - E^{TB}[U_P] \geq 0$$

$$\iff \beta \geq \beta^c := \frac{8c\eta_H(\eta_H + \eta_L)}{c(3\eta_H^2 - 4\eta_H\eta_L + \eta_L^2) + 2\eta_H\eta_L(\eta_H + \eta_L)x_H}.$$

Because of

$$3\eta_H^2 - 4\eta_H\eta_L + \eta_L^2 \underset{\eta_H^2 > \eta_L^2}{\geq} 2\eta_H^2 - 4\eta_H\eta_L + 2\eta_L^2 = (\sqrt{2}\eta_H - \sqrt{2}\eta_L)^2 \geq 0,$$

the denominator of β^c is positive. The numerator of β^c is also positive, and thus, $\beta^c > 0$. □

Proof Corollary 2

The principal’s expected utility with top-down budgets is monotonically decreasing in β :

$$\frac{\partial E^{TB}[U_P]}{\partial \beta} = -\frac{\eta_H - \eta_L}{2} \left[x_H - \frac{4c}{E[\eta_1 + \eta_2]} \right] < 0.$$

The principal’s expected utility with participative budgets is monotonically increasing in β :

$$\frac{\partial E^{PB}[U_P]}{\partial \beta} = \frac{c}{4\eta_H\eta_L} (\eta_H - \eta_L)(3\eta_H + \eta_L) > 0.$$

□

Proof Corollary 3

The cut-off level β^c is monotonically decreasing in x_H :

$$\frac{\partial \beta^c}{\partial x_H} = -\frac{16c\eta_H^2(\eta_H + \eta_L)^2}{(c(3\eta_H^2 - 4\eta_H\eta_L + \eta_L^2) + 2\eta_H\eta_L(\eta_H + \eta_L)x_H)^2} < 0.$$

Thus, for an increase in x_H the interval for β in which using a top-down budgeting process is optimal, i.e., $(0, \beta^c)$, becomes smaller, whereas the interval for β in which using a participative budgeting process is preferred, i.e., $\left[\beta^c, \min\left\{ 2, \frac{\eta_L}{\eta_H - \eta_L} \right\} \right)$, becomes larger. □

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