Groves Mechanism vs. Profit Sharing for Corporate Budgeting – an Experimental Analysis with Preplay Communication*

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Abstract

This paper experimentally explores the efficiency of the Groves mechanism and a profit sharing scheme in a corporate budgeting context. Specifically, it examines the effects of anonymous communication on both incentive schemes. The results show that although the Groves mechanism is analytically superior to the profit sharing scheme, the latter turns out to be advantageous for headquarters in our experiment. This is essentially due to the effects of communication on both incentive schemes. Under the profit sharing scheme, communication improves coordination and reduces inefficient resource allocation. Under the Groves mechanism, however, it leads to stable collusion strategies of the participants, and thus increases compensation costs.

Keywords: Budgeting, resource allocation, truth-telling, Groves mechanism, profit sharing, communication.

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1 Introduction

Budgeting is one of the most important instruments of management control and is used in nearly all hierarchical organizations (e.g. Hansen et al. (2003)). The multiple purposes of budgeting include coordination and planning functions, resource allocation, and employee motivation (Covaleski et al. (2003)). In order to successfully achieve these goals, headquarters of an organization has to rely on truthful *ex ante* information from subordinate managers, e.g. about projected profitabilities or input factor costs. However, traditional budgeting schemes provide incentives for managers to misrepresent information and to build slack into budgets (e.g. Jensen (2003)).

To avoid such misrepresentations, a number of truth-inducing budgeting mechanisms have been proposed and analyzed. While some of these mechanisms are designed for the relationship between headquarters and a single division (e.g. Weitzman (1976); Reichelstein and Osband (1984); Osband and Reichelstein (1985)), others consider interdependencies between multiple divisions of the firm. Our paper refers to the latter type of mechanisms in that it compares the truth-inducing properties of the so-called Groves mechanism and a profit sharing scheme. Under the Groves mechanism, a manager's compensation depends on his own division's actual profit as well as on the expected profits that all other divisions report to headquarters *ex ante*, whereas a profit sharing scheme simply links a manager's compensation to overall firm profit.

The Groves mechanism was first developed by Vickrey (1964), Clarke (1971) and Groves (1973), and later adapted to budgeting processes in divisionalized firms by Groves (1976) and Groves and Loeb (1979). Since then, there has been an intense debate in the management accounting literature about whether and how the Groves mechanism can be used in firms to deal with coordination problems arising from the interdependence of different divisions (e.g. Harris et al. (1982); Cohen and Loeb (1984); Kanodia (1993); Baldenius et al. (2005)). Such interdependencies include, but are not limited to, the allocation of physical resources or capital among different divisions, and the cost allocation for shared or mutually exclusive investment projects. One key task of management accounting in these situations is to provide mechanisms that serve as a coordination device.

Here, the Groves mechanism plays a central role from a theoretical perspective. Under certain assumptions, it solves such coordination problems as truthful reporting behavior represents a dominant strategy for every division manager.

This truth-inducing property can also be applied to comparable coordination problems in other fields of business economics, and consequently, the Groves mechanism is also a current topic of study in production management (e.g. Karabuk and Wu (2005); Kutanoglu and Wu (2006)), supply chain management (e.g. Garg et al. (2005)), computer science (e.g. Nisan and Ronen (2001); Dash et al. (2003)), and auction design (e.g. Isaac and James (2000); Yokoo et al. (2004)).

While under this mechanism, truth-telling is the dominant strategy for every division manager, a manager's compensation generally depends on the other managers' ex ante reports to headquarters about their expected profits. Thus, there generally exists an incentive for the managers to coordinate these reports and to manipulate their messages (e.g. Banker and Datar (1992)). However, if contracts in a coalition are not legally enforceable – which is a realistic assumption – and all division managers are individually rational, this does not represent an equilibrium strategy in the budget game (Loeb and Magat (1978); Budde et al. (1998)).

Consequently, one of the assumptions necessary for the Groves mechanism to induce truth-telling is that managers indeed play dominant strategies. While this may sound trivial at first glance, it excludes the possibility that coalition contracts are self-enforcing due to long-term relationships or 'informal' courts of the social environment (e.g. Tirole (1986), Crémer (1996)), and this might be a less realistic assumption than the lack of legal enforceability.[1] Moreover, in firms, communication between division managers is possible, and the extent of social contact between them may be high. Thus, it is an open question whether the mere fact that truth-telling represents the dominant strategy under the compensation scheme in use prevents the formation of coalitions in a firm.

Prior experiments have analyzed the Groves mechanism in situations without preplay communication of the participants. One of the principal findings derived from these studies is that although the Groves mechanism generally does not lead to truthful reporting behavior, these deviations from truth-telling cannot be traced back to collusive behavior of the participants (Waller and Bishop (1990); Chow et al. (1994); Chow et al. (2000)). Thus, the evidence for *tacit* collusion under the Groves mechanism is very weak. In contrast, this paper analyzes the effects of preplay communication on participants' behavior in order to bridge the gap between the conditions in the laboratory and those in corporate reality. Communication in our experiment was implemented via a chat program and was completely anonymous. Although this reduces social distance between the participants, it represents a very weak form of social contact compared to relationships between employees in a firm.[2] As in reality, the participants in our experiment could not make binding agreements during the communication.

Another important finding from prior experiments is that, despite its deviations from truth-telling, the Groves mechanism turns out to be superior in most cases when compared to other (truth-inducing) incentive schemes. For example, Waller and Bishop (1990) find that the Groves mechanism is more effective in inducing truthful reporting behavior than a division profit scheme. The results of Chow et al. (1994) show more truthful reports under the Groves mechanism than under a division profit scheme and a Weitzman scheme. Chow et al. (2000) find that both the frequency and the amount of misrepresentation are lower under the Groves mechanism than under an Osband-Reichelstein scheme, though they are larger than under a division profit scheme with resource allocation and audits from a third player. Similarly, there is also less misrepresentation under a division profit scheme with probabilistic audits (Chow et al. (1995)). However, none of these mechanisms is designed for a resource allocation context where multiple divisions in a firm compete for the same resources, and it can be analytically shown that these mechanisms do not provide incentives for truth-telling in such situations (Loeb and Magat (1978); Waller (1994)).

The alternative incentive scheme examined in this paper is a profit sharing scheme that links a manager's compensation to overall firm profit. A comparison between the Groves mechanism and the profit sharing scheme shows that, with respect to truth-telling, the Groves mechanism turns out to be analytically superior. Under profit sharing, truthful reporting behavior also represents an equilibrium for the division managers. But in contrast to the dominant strategy equilibrium under the Groves mechanism, truth-telling forms a Nash equilibrium under profit sharing, and additionally, this equilibrium is generally not unique (Loeb and Magat (1978)). Although this does not pose a problem from headquarters' perspective per se, the existence of multiple equilibria can lead to inefficient resource allocation due to coordination failures.

Still, further comparison reveals that, under the profit sharing scheme, there is no collusion possibility for the division managers as their maximum compensation (not the optimum in terms of an equilibrium) is reached if headquarters reaches its maximum too. In this case, the communication possibility can help to overcome coordination failures and to improve resource allocation.[3] Thus, this paper explores how the theoretical differences between these two incentive schemes translate into real behavior, and whether the Groves mechanism remains superior to profit sharing when implemented in practice.[4]

Our principal findings are: consistent with prior experimental studies, we find significant deviations from truth-telling but only weak evidence for collusion of the participants in the Groves treatment without communication. However, in contrast to prior results, when anonymous preplay communication is introduced we observe *stable* collusion strategies from the vast majority of participants.

In the profit sharing treatment without communication, we observe coordination failures of the participants between multiple equilibria. Now, the introduction of communication improves participants' coordination and strongly increases equilibrium play. The comparison of the Groves mechanism and the profit sharing scheme shows that both profit sharing treatments lead to less deviation from truth-telling than every Groves treatment. More importantly, headquarters' earnings net of compensation costs are larger in the profit sharing treatments than in all Groves treatments.

Thus, in contrast to prior experiments, we identify conditions under which stable collusion emerges under the Groves mechanism, and we provide an experimentally superior alternative to the Groves mechanism in the context of resource allocation. Although the Groves mechanism is superior from a theoretical perspective, the profit sharing scheme turns out to be superior in our experiment, essentially due to the effects of communication on the two incentive schemes. While the improved coordination under communication in the profit sharing scheme benefits headquarters, the communication possibility increases cooperation between the managers under the Groves mechanism, implying larger compensation costs for headquarters. With respect to corporate reality with its ample communication possibilities, these results are bad news for the Groves mechanism and support the use of profit sharing schemes.

The remainder of the paper is structured as follows: Section 2 presents the general setting of our experiment and derives the hypotheses. Section 3 describes the experimental design. The experimental results are presented in section 4, and section 5 concludes.

2 Hypotheses development

The setting of our experiment is adapted from Groves and Loeb (1979) in that headquarters of a divisionalized firm has to allocate $\overline{X}$ units of a scarce resource between two subordinate divisions ($i = 1, 2$). A division's profit function, $\Pi_i(P_i, X_i)$, is unambiguously determined by the division's productivity parameter P_i, and the profit depends on the number of resource units, X_i, allocated to the division. In the experiment, participants played ten rounds of the game. With respect to the distribution of information, we assume that there are different levels of information asymmetry in the firm. More precisely, at the beginning of every period, every division manager learns his own division's productivity parameter for this period but not the productivity parameter of the other division. That means that in every period, division manager i knows only his own profit function. However, it is known to the division managers ex ante that, for both divisions, P_i is a random variable on the interval $[P_{\min}, P_{\max}]$.

With respect to headquarters' information, we assume that headquarters generally has inferior information about the divisions' productivities compared to the division managers. Not only does headquarters not know the actual productivity parameters of the current period, but headquarters also has inferior information about the potential values of the productivity parameters ex ante. This assumption reflects that operating executives potentially have superior knowledge about the productivities of other operational units, compared to central accounting or financing departments. We assume that, from headquarters' perspective, the divisions' productivity parameters are random variables on the interval $[P_{\min} - \Delta, P_{\max} + \Delta]$, where $\Delta \geq 0$ is a measure for the ex ante information asymmetry between headquarters and division managers.[5] Furthermore, we assume that the resource is always scarce, and that it is never optimal to allocate all resource units to only one of the two divisions. Under these assumptions, headquarters needs truthful information from the managers about P_i in order to optimally allocate the resource units among the two divisions. Headquarters' allocation rule is the maximization of *reported* firm profit, i.e. headquarters maximizes expected firm profit based upon the reported productivities, $\widehat{P}_i$. This maximizes *actual* firm profit if truth-telling is optimal for the division managers given this allocation scheme.

First, we will analyze the case that the division managers are compensated via the Groves mechanism. Under this mechanism, manager i's compensation is strictly increasing in his own division's actual profit, Π_i, but also depends on division manager j's reported profit, $\widehat{\Pi}_j$. The reported profit is calculated based upon the reported productivity parameter, $\widehat{P}_j$, and the resource units, $\widehat{X}_j$, allocated due to the reported productivities. The general class of evaluation measures derived in Groves (1976) and Groves and Loeb (1979) takes on the following form for manager i in this context:

$$C_i = G_i(\widehat{P}_j) \cdot (\Pi_i + \widehat{\Pi}_j) + H_i(\widehat{P}_j), \tag{1}$$

where $G_i(\widehat{P}_j)$ is a strictly positive function that depends only on division manager j's reported productivity $\widehat{P}_j$, and $H_i(\widehat{P}_j)$ is an arbitrary function that depends only on $\widehat{P}_j$. Under this class of evaluation measures, truth-telling always represents the dominant strategy equilibrium. That means, independent of the other manager's reported productivity, every manager is best off reporting his actual productivity truthfully to headquarters. This is because headquarters maximizes firm profit based upon reported productivities, and thus, headquarters' allocation decision maximizes C_i if manager i truthfully reports his actual productivity. Thus, the division manager has no incentive to deviate from truth-telling (Loeb and Magat (1978)).

In the experiment, we set $G_i(\widehat{P}_j) = 1$ and $H_i(\widehat{P}_j) = 0$. That means, the managers' evaluation measure is $C_i = \Pi_i + \widehat{\Pi}_j$, and consequently, they are compensated based upon the sum of the own division's actual profit and the other division's reported profit. This has mainly two reasons: first, this evaluation measure is the natural counterpart of the profit sharing scheme that is widely used for the compensation of division managers in practice (e.g. Bushman et al. (1995); Wulf (2002); Murphy and Oyer (2003)) and will also be analyzed in our study; second, this version of the Groves mechanism was used in all other experimental studies on this mechanism conducted so far, which enables us to compare our results. We will further discuss our choice in section 5.

Under this version of the Groves mechanism, a manager's compensation depends positively on the other manager's *reported* productivity. Thus, managers can benefit from cooperating and manipulating their reported productivities upwards. However, a manager can increase his compensation further if, given the other manager's overstatement, he breaks the agreement and reports his productivity truthfully, a situation comparable to a prisoner's dilemma. The reason is that, as we have just described, headquarters' allocation decision maximizes the manager's evaluation measure $C_i = \Pi_i + \widehat{\Pi}_j$ only if he reports truthfully. Therefore, solving the multi period setting in our experiment by backwards induction shows that cooperation between the managers and overstatements of productivities cannot form an equilibrium if it is assumed that all players act in an individually rational way. Thus, we state the following hypothesis:

H1a: The Groves mechanism induces truthful reporting behavior.

However, even under standard theory, cooperation in a repeated game can emerge when the assumptions are slightly changed such that there is incomplete information about the players' preferences. In particular, Kreps et al. (1982) show that two individually rational players may cooperate in a finitely repeated prisoners' dilemma if there exists a (very small) chance that one of them follows a so-called tit-for-tat strategy, i.e. he cooperates at the beginning and cooperates in the following rounds if and only if his partner cooperated in the preceding round. In this case, cooperation between two rational players emerges because, in early rounds of the repeated game, rational players try to establish a reputation as a tit-for-tat player by playing cooperatively, in order to realize the additional payoffs from cooperation. In an extension of Kreps et al. (1982), Kunz and

Pfeiffer (1999) show that this rational cooperation also applies to the Groves mechanism. However, the cooperation – and thus, overstatements – will decline in the course of the game. Intuitively, this is because all rational players will defect in the last round at the latest and will report truthfully in this round. Thus, if we have to reject H1a, H1b is the only alternative hypothesis that can be formulated from a standard theoretical perspective:

H1b: Deviations from truth-telling decrease over trials with the Groves mechanism.

We will now examine the effects of communication on the theoretical predictions under the Groves mechanism. In general, unrestricted communication – as implemented in our experiment – can lead to a multitude of possible messages, and thus to a multitude of new equilibria. Therefore, in the following, we will particularly concentrate on communication strategies and messages which will be relevant for the experimental analysis.

In a game theoretical sense, the communication implemented in the experiment represents cheap talk. Cheap talk can matter if the players' announcements are self-committing and self-signalling. If a player's message is believed, it creates incentives to fulfill it (self-committing), and a player has an incentive to send a message if and only if it is true (self-signalling) (Farrell and Rabin (1996)). Under the Groves mechanism, the managers either have an incentive to truthfully report productivities to headquarters (H1a) or, in the first few rounds, to overstate their productivities (H1b). However, this incentive is independent of the messages sent to their partner during the communication phase, i.e. the messages sent neither create an incentive to fulfill them, nor can they serve as a signalling device. Thus, none of the two conditions is fulfilled and communication is irrelevant from a standard theoretical perspective under the Groves mechanism. Consequently, we can state the following hypothesis:

H2: Preplay communication (i) neither affects managers' reported productivities (ii) nor headquarters' earnings net of compensation costs under the Groves mechanism.

In the following, we will consider the compensation via a profit sharing scheme where both division managers receive a share of the actual firm profit. Under this compensation scheme, every manager desires headquarters to allocate the resource units in a way that maximizes overall firm profit. Thus, if every division manager assumes that the other manager will report his productivity parameter truthfully, he will also be motivated to report his true productivity. That means that truth-telling emerges as a Nash equilibrium under profit sharing (Loeb and Magat (1978)).

However, in contrast to the Groves mechanism, the truth-telling equilibrium is not a dominant strategy equilibrium and, moreover, it is generally not unique. Indeed, under the conditions implemented in the experiment, three pareto efficient Nash equilibria emerge: the truth-telling equilibrium, an equilibrium characterized by overstatements of the productivities, and an equilibrium characterized by understatements. The latter two equilibria emerge for the following reason: under the assumptions described above, both managers can always over- or understate their productivity parameters by at least Δ as the range of potential productivities is larger from headquarters' perspective than for the managers. If manager i assumes that manager j sends a biased message to headquarters, he will be motivated to compensate this deviation from truth-telling by biasing his own report in order to re-establish optimal resource allocation. Vice versa, if manager i acts in the way just described, it will indeed be optimal for manager j to send biased messages and, consequently, the pair of biased reports also forms a Nash equilibrium.

From headquarters' perspective, the existence of multiple equilibria does not pose a problem as long as the resource allocation is always efficient. However, this is exactly the difficulty if none of the multiple equilibria emerges as a 'focal' point to the players (e.g. Schelling (1966); Ochs (1995); Camerer (2003), chap. 7). The equilibrium selection problem in this case is essentially unsolved by game theory. Moreover, under the conditions implemented in the experiment, manager i's biased report is exactly compensated by manager j's deviation, and the same (efficient) resource allocation as in the truth-telling case is obtained. Thus, pareto efficiency cannot serve as a selection criterion in this game either. Consequently, inefficiencies in the profit sharing scheme may arise from inefficient resource allocation due to potential coordination failures, but not from the deviations from truth-telling themselves. Therefore, unless one of the multiple equilibria of the profit sharing scheme is 'focal' for the participants, we can state the following hypothesis:

H3: The profit sharing scheme without communication leads to coordination problems between multiple equilibria.

In contrast to the Groves mechanism, the profit sharing scheme fulfils the conditions for cheap talk to be relevant, so that the cheap talk implemented in the experiment can play an important role for the coordination of the division managers between different equilibria. If manager i communicates a deviation from truth-telling during the communication phase, he will also be motivated to report this deviation to headquarters, as manager j has an incentive to choose a correspondingly biased message. However, this does not necessarily imply that the two managers coordinate on the truth-telling equilibrium. If communication is two-sided and unrestricted, as it was in the experiment, the number of pareto efficient reporting strategies can increase even further compared to the case without communication. This is the case if players truthfully communicate their actual productivities to their partners during the communication phase. Then additional pareto efficient equilibria emerge because the managers are now able to deviate from their actual productivities by more than the ex ante information asymmetry of Δ without changing the (efficient) resource allocation. For example, if both managers have the same productivities, every situation in which they report identical productivities represents a Nash equilibrium as this always leads to efficient resource allocation.

Again, it cannot be determined from a theoretical perspective which of the multiple equilibria will be chosen if none of the equilibria is 'focal' for the players. Thus, in the communication case, we might observe deviations from truth-telling even more frequently than without communication. We state the following hypothesis:

H4: Preplay communication in the profit sharing scheme decreases the frequency of truthfully reported productivity parameters.

However, as we have explained above, due to the robustness of profit sharing, all these equilibria lead to efficient resource allocation. Therefore, despite a possibly lower frequency of truthfully reported productivities, communication is beneficial for headquarters under the profit sharing scheme, as it improves coordination and eliminates efficiency losses.

H5: Preplay communication in the profit sharing scheme increases (i) the frequency of coordinated reports and (ii) headquarters' earnings net of compensation costs.

Finally, we state two hypotheses with respect to the comparison of the Groves mechanism and the profit sharing scheme. Both the frequency of misrepresentation under the Groves mechanism that might emerge if there is a chance that players follow a so-called tit-for-tat strategy (H1b), as well as its effects on headquarters' earnings net of compensation costs, are not unambiguously predictable. They strongly depend on participants' assumptions about the probability that such players exist (Kunz and Pfeiffer (1999)). In this case, the comparison between the two incentive schemes is not clear. Thus, we refer to H1a and the truth-inducing property of the Groves mechanism in order to derive hypotheses about the comparison of the two incentive schemes tested in our experiment. Consequently, if all players act in an individually rational way, their dominant strategy under the Groves mechanism is truth-telling, whereas this is not the case under profit sharing. It follows:

H6: Truthful reports occur more frequently under the Groves mechanism both with and without communication, than under (i) the profit sharing treatment without communication and (ii) the profit sharing treatment with communication.

Furthermore, from a standard theoretical perspective, profit sharing can at best be equivalent to the Groves mechanism, as both compensation schemes should lead to full efficiency under communication, while this is not the case for the profit sharing scheme without communication. Thus, we state the final hypothesis:

H7: Headquarters' earnings net of compensation costs under the Groves mechanism with and without communication are (i) larger than under the profit sharing scheme without communication, and (ii) as large as under the profit sharing scheme with communication.

3 Experimental method

3.1 Participants

One-hundred and fifty-eight students and employees of the Clausthal University of Technology participated in this experiment, 38 in the Groves treatment without communication, 40 in every other treatment. We conducted two sessions for every treatment. No subject participated in more than one session. All participants received a show-up fee of 10 EUR, and the additional performance-contingent compensation was 12.40 EUR on average, with a minimum of 8.20 EUR and a maximum of 15.14 EUR.

3.2 Design

The experimental design was a 2 (incentive scheme: Groves vs. profit sharing) x 2 (communication: absent vs. present) x 10 (periods). Both incentive scheme and communication are between-subject factors, period is a within-subject factor. The effects of the incentive scheme on division managers' reported productivities were analyzed by varying the managers' compensation function in the experiment. It was either derived from the Groves mechanism or from a profit sharing scheme. Under the two incentive schemes, the communication factor was manipulated by either giving the subjects the possibility of anonymous preplay communication via a chat program or not. Finally, in order to examine the effect of time on reported productivities in repeated relationships, every treatment had 10 payoff rounds. Subjects were randomly paired before the first payoff round started, and pairs remained the same for all rounds.

While the compensation function was varied, the divisions' profit function and the resource allocation were kept constant across treatments. The divisions' profit function $\Pi_i(P_i, X_i)$ was given by:

$$\begin{aligned} \Pi_i(P_i, X_i) &= \begin{cases} P_i \cdot X_i - X_i = (P_i - 1) \cdot X_i & \text{for } X_i \leq 40 \\ 40 \cdot P_i + (X_i - 40) \cdot (P_i - 0.3) - X_i & \text{for } 40 < X_i \leq 100 \\ 40 \cdot P_i + 60 \cdot (P_i - 0.3) + (X_i - 100) - X_i & \text{for } 100 < X_i \end{cases} \\ \forall \;\; i &= 1, 2 \end{aligned} \tag{2}$$

with $P_i \in \{1.4, 1.5, ..., 2.1\}$. Marginal revenue is decreasing in X_i: for $X_i \leq 40$ it amounts to P_i, for $40 < X_i \leq 100$ it is equal to $P_i - 0.3$, and for all $X_i > 100$ it is equal to 1. The general shape of the divisions' profit function according to (2) was common knowledge, but the divisions' productivity parameters, P_i, were uncertain. At the beginning of every round, the values of P_i for both divisions were randomly determined, and every division manager was informed about his exact productivity parameter in the current round. We did not include a random variable into the profit function to avoid any distortions due to uncertainty. However, the participants were informed that headquarters would never know their actual productivity parameter of a given round. Therefore, the only consequences of a misrepresentation of the productivity were potential changes in the compensation.

Based upon the reported productivity parameters $\widehat{P}_i$ and $\widehat{P}_j$, headquarters allocated $\overline{X} = 120$ resource units between the divisions. If both managers reported the same productivity they both obtained 60 resource units. If one of them reported a higher productivity than the other, resource allocation was shifted towards the former. In case productivities differed by less than 0.3, the resource units were split {80,40}; in case the productivities differed by 0.3 or more, the resource units were split {100,20}. This allocation scheme is optimal if the productivities are reported truthfully.

As we described above, the factor 'incentive scheme' was manipulated by varying the managers' compensation function. During the experiment, participants collected points that were converted into Euros after the experiment. 7 points corresponded to 1 Euro. In the Groves treatments, they received:

$$POINTS_i = 0.1 \cdot \left[\Pi_i(\widehat{X}_i) + \widehat{\Pi}_j(\widehat{X}_j)\right] \tag{3}$$

Thus, the manager earned 10% of his division's actual profit, $\Pi_i(\widehat{X}_i)$, and the other division's reported profit, $\widehat{\Pi}_j(\widehat{X}_j)$, in every round. As described in section 2, truthful reporting is a dominant strategy equilibrium under this compensation function. Nevertheless, it would have been beneficial for the participants to make binding agreements about overstatements of the productivity parameters if this had been possible. For example, if both managers always reported the maximum productivity of 2.1 this would yield an ex ante expected compensation (in points) of 9.9 per round, compared to an ex ante expected value of 8.45 for truth-telling. However, as in reality, it was not possible for the participants to make binding agreements in the experiment. Furthermore, we excluded the possibility of side payments.

In the profit sharing treatments, the compensation was given by

$$POINTS_i = 0.1 \cdot \left[\Pi_i(\widehat{X}_i) + \Pi_j(\widehat{X}_j)\right] \tag{4}$$

Thus, compensation in these treatments equaled 10% of the actual firm profit. We introduced an ex ante information asymmetry of $\Delta = 0.1$ under profit sharing. Thus, participants could report productivities between 1.3 and 2.2 by steps of 0.1 in the profit sharing treatments and between 1.4 and 2.1 in the Groves treatments. Consequently, there are always three pareto efficient pure strategy Nash equilibria under profit sharing: one in which both managers always report truthfully, one in which they always slightly understate their productivities by 0.1, and one in which they always slightly overstate their their productivities by 0.1. Additional equilibria emerge in the communication treatment if both players truthfully communicate their actual productivities during the communication phase. In this treatment, not only do the three reporting strategies just described form equilibria, but also all other pairs of reported productivities which do not affect optimal resource allocation. Due to the discrete model structure of the experiment, this can also be the case when the deviations from the actual productivities of the two managers are not identical but the optimal resource allocation is left unchanged.

3.3 Procedure

The experiments were computerized, and subjects were anonymously matched via a computer network. Moreover, they were separated from each other by blinders, and they never learned the identity of their counterpart.

The participants of the experiment took over the role of the division managers, whereas the role of headquarters was played by a computer. The instructions informed the participants about the profit functions of their divisions, the resource allocation, and their compensation.[6]

All sessions proceeded as follows: After participants had arrived and chosen a computer terminal, the instructions appeared on the screens and were simultaneously read aloud to them. After the instructions, subjects received a summary of all functions. In the communication treatments, they further received communication rules. Before the 10 payoff rounds started, the participants completed 12 training rounds to learn how their compensation scheme worked. During these training rounds, the participants had no real partner, but a computer simulated the decisions of the other player. The points earned during the training rounds had no effect on the income from the experiment. After having completed the training, every participant was randomly assigned a partner for all following 10 payoff rounds. This was all known to the participants.

In the communication treatments, the participants were allowed to communicate with their partners after they had learned their actual productivity parameters for the current round but before they had to report their productivities to headquarters. Communication was possible via a chat program, and partners remained completely anonymous to each other during the whole experiment.[7] The communication time was three and a half minutes in the first round and was reduced to one and a half minutes in the course of the experiment.

At the beginning of every round, the participants were informed about their division's actual productivity for the current round. At the end of every round, they were informed about the resource allocation, the reported productivity of their partner, and their compensation for that round. In the profit sharing treatments, they were also informed of the actual productivity parameter of their partner, as they could have easily calculated it themselves from their compensation. In the Groves treatments, the actual productivity remained the private information of every player during the whole experiment. To facilitate comparisons between different rounds, the participants were also shown the data of all previous rounds. All sessions lasted between 80 and 150 minutes.

3.4 Measures

Truthful reporting behavior is measured as the frequencies of truthfully reported productivities, $f(DEV_i = 0)$. In accordance with Waller and Bishop (1990), deviations from truth-telling are operationalized by the following measures of misrepresentation[8]:

$$ABSDEV_i = \widehat{P}_i - P_i \tag{6}$$

$$RELDEV_i = \begin{cases} \frac{\widehat{P}_i - P_i}{P_i - 1.4} & \text{for } \widehat{P}_i < P_i \\ 0 & \text{for } \widehat{P}_i = P_i \\ \frac{\widehat{P}_i - P_i}{2.1 - P_i} & \text{for } \widehat{P}_i > P_i \end{cases} \tag{7}$$

where P_i and $\widehat{P}_i$ are manager i's actual and reported productivity parameter, respectively.

Coordination in the profit sharing treatments is measured as $f(HIT)$ which is the total frequency of equilibrium 'hits', i.e. the play of equilibrium strategies ex post.

Finally, in order to measure the effects on headquarters' earnings net of compensation costs, we calculated the efficiency loss resulting from non-truthful reporting behavior in every treatment as follows:

$$LOSS = \Pi_{HQ}(P_i, P_j) - \Pi_{HQ}(\widehat{P}_i, \widehat{P}_j) \tag{8}$$

where $\Pi_{HQ}(\widehat{P}_i, \widehat{P}_j) = \Pi_i(\widehat{X}_i) + \Pi_j(\widehat{X}_j) - POINTS_i - POINTS_j$ is headquarters' earnings net of compensation costs. Thus, $LOSS$ measures the difference between headquarters' net earnings in case both managers had truthfully reported their productivity parameters, and headquarters' net earnings under the actually reported productivity parameters.[9]

4 Experimental results

4.1 Descriptive statistics

Descriptive statistics for all treatments and all measures are reported in Table 1.[10] As can be seen, the data provide strong evidence against the truth-inducing property of the Groves mechanism. In the treatment without communication, $f(DEV_i = 0)$ amounts to only 44%, whereas in the communication treatment, the frequency of truth-telling even declines to 22% and the frequency of overstatements rises to 73%. The results of the non-communication treatment are very close to those of Waller and Bishop (1990), who find 48% truthful reports, 33% overstatements, and 19% understatements in their comparable Groves treatment.

(*Insert Table 1 about here.*)

Figure 1 displays the average relative misrepresentations in all treatments for every round t. It shows that $RELDEV_t$ is positive in all rounds in both Groves treatments, i.e. both Groves treatments lead to overstatements of productivities on average. Moreover, the figure reveals that in every round, $RELDEV_t$ is much larger in the treatment with communication than in the treatment without. This is confirmed by the data in Table 1.

(*Insert Figure 1 about here.*)

For the profit sharing treatments, the last two columns of Table 1 show that there are also strong deviations from truth-telling in the treatment without communication, as $f(DEV_i = 0)$ only amounts to 49%. Nevertheless, as explained in section 2, this does not necessarily imply coordination problems between the managers. In the treatment with communication, the frequency of truth-telling increases to 73% which points to the result that truth-telling might have served as a focal point during the communication. Figure 1 shows that $RELDEV_t$ is always positive in the treatment without communication, and positive in all but one round in the treatment with communication, and that it remains quite stable in both treatments during the experiment.

Mean efficiency losses in all treatments are positive and are in line with what could be expected from the data about misrepresentation. In both Groves treatments, overstatements of the productivities are frequent, and thus, the efficiency losses in these treatments are larger than in both profit sharing treatments. The descriptive statistics on the efficiency losses already point to one of the key results of the experiment: communication has different effects under the two incentive schemes as it increases the efficiency loss under the Groves mechanism but decreases it under profit sharing.

4.2 Tests of hypotheses

Tests of the hypotheses are based on nonparametric statistics as, for every measure, we have to reject that it is normally distributed in every treatment. Whenever we compare the misrepresentation measures between the different treatments, we use individual averages across rounds as the unit of observation in order to avoid problems of statistical dependence.[11] For the efficiency loss, we use averages across rounds for every pair of players. The levels of significance reported always refer to two-tailed tests.

H1a refers to the truth-inducing property of the Groves mechanism. As Table 1 clearly indicates, the Groves mechanism does not induce truth-telling of the participants. Moreover, even if we test whether the participants randomly decided to either tell the truth or to misrepresent the productivity, $f(DEV_i = 0)$ turns out to be significantly lower than 50% both in the treatment without communication ($\chi^2 = 4.64$, $p = 0.031$) and the treatment with communication ($\chi^2 = 129.96$, $p < 0.001$). Thus, we reject H1a.

H1b considers deviations from truth-telling but predicts that these deviations decrease over trials. However, as can be seen from Figure 1, neither Groves treatment exhibits a negative time trend. We further examine this question in a regression analysis where we regress $RELDEV_t$ on the round index t. As $RELDEV_t$ is censored ($1 \leq RELDEV_t \leq -1$), we use Tobit regressions. Moreover, we include group dummies to capture group fixed effects (e.g. Fehr and Gächter (2000)). Table 2 presents the regression results for both treatments. It shows that the coefficient of the round variable t is insignificantly negative in the treatment without communication, whereas it is even significantly *positive* in the treatment with communication. Consequently, we also reject H1b. Obviously, standard theoretical predictions do not capture actual division managers' reports of productivities to headquarters under the Groves mechanism. In contrast, the positive slope of the regression line in the communication treatment rather indicates that collusion among the division managers emerges during the experiment and persists even in the last rounds. We will explore this in more detail in the supplementary analysis.

(*Insert Table 2 about here.*)

Similarly, standard theoretical prediction do not capture the effects of introducing communication under this incentive scheme. While H2 predicts no effect of the communication implemented in the experiment, as it is cheap talk in the game-theoretical sense, Mann-Whitney U-tests reveal that both $ABSDEV$ ($z = 10.62$, $p < 0.001$) and $RELDEV$ ($z = 9.57$, $p < 0.001$) are significantly larger in the treatment with communication than in the treatment without. Moreover, $f(DEV_i = 0)$ is much smaller in the communication treatment than in the treatment without communication (22% vs. 44%), and this difference is highly significant ($\chi^2 = 85.49$, $p < 0.001$). Furthermore, Mann-Whitney U-tests show that the effect of the increased misrepresentation in the treatment with communication is detrimental to headquarters, as $LOSS$ is significantly larger in the communication treatment than in the treatment without communication ($z = 2.33$, $p = 0.020$). Thus, we reject both parts of H2.

Turning to the profit sharing scheme, H3 predicts coordination problems of the division managers between multiple equilibria in the treatment without communication. In order to examine the participants' ability to coordinate on an equilibrium that yields optimal resource allocation, Table 3 displays the total frequency of equilibrium 'hits', $f(HIT)$, in both profit sharing treatments.

Panel 1 of Table 3 reveals that $f(HIT)$ only amounts to 30% in the non-communication treatment. It further shows that the truth-telling equilibrium is hit more often than the two other equilibria in which both manager either over- or understate their productivities by 0.1.[12] Truth-telling thus seems to represent a focal point for the participants. However, it is not strong enough to coordinate all reported productivities. *In addition* to the coordinated reports, 47% of all reported productivities are either truthful or have $ABSDEV$ of 0.1 or -0.1. That means, these reported productivities could lead to an equilibrium, but do not due to the partner's differing report. Moreover, it is somewhat surprising that in rounds 6 through 10, $f(HIT)$ is as large as in rounds 1 through 5. Obviously, repeated interaction does not improve coordination in the profit sharing treatment without communication. Together, the data is consistent with the prediction of H3.

(*Insert Table 3 about here.*)

With respect to the effects of communication, panel 2 of Table 3 shows that the possibility of preplay communication strongly increases the frequency of truth-telling equilibria ($ABSDEV_i = ABSDEV_j = 0$), while the frequency of equilibria with $ABSDEV_i = ABSDEV_j \neq 0$ remains nearly stable. Thus, truth-telling obviously serves as a focal point during the communication. This is inconsistent with H4 which predicts a decrease in the frequency of truth-telling. Moreover, if we consider all reported productivities, $f(DEV_i = 0)$ is significantly larger in the treatment with communication than in the treatment without (73% vs. 49%, $\chi^2 = 96.10$, $p < 0.001$). Thus, H4 is rejected.

However, Table 3 shows that under the condition that both managers deviate by the same amount ($ABSDEV_i = ABSDEV_j$), $f(HIT)$ more than doubles, from 30% to 63%, which is highly significant ($\chi^2 = 93.44$, $p < 0.001$) and supports H5i. Moreover, this is a very conservative measure of $f(HIT)$ as we described in section 3 that, due to the discrete model structure, equal deviations from the actual productivities are not a necessary condition for an equilibrium in the communication treatment as long as the reported productivities induce efficient resource allocation. Pairs of reported productivities with unequal deviations but efficient resource allocation occur in 12% of the cases.[13] Thus, in 75% of the cases in the communication treatment, the reporting strategies represent pareto efficient equilibrium play which again supports H5i.

Consistent with this increase in coordinated reports is the decrease in $LOSS$ displayed in Table 1. In the profit sharing treatment with communication, the mean efficiency loss amounts to only 50% of the loss in the treatment without communication and Mann-Whitney U-tests reveal that this difference is highly significant ($z = 2.69$, $p = 0.007$). Together, the results are consistent with both parts of H5.

Finally, H6 and H7 compare the Groves mechanism and the profit sharing scheme. H6 predicts that, due to truth-telling as a dominant strategy under the Groves mechanism and multiple equilibria under the profit sharing scheme, $f(DEV_i = 0)$ will be larger under the former incentive scheme. However, the data in Table 1 reveal that the opposite is the case. χ^2-tests confirm that in the Groves treatment without communication, the frequency of truth-telling (44%) is significantly lower than in both the profit sharing treatment without communication (49%, $\chi^2 = 2.78$, $p = 0.095$) and with communication (73%, $\chi^2 = 160.59$, $p < 0.001$). This also holds for the comparison of the Groves treatment with communication (22%) and both the profit sharing treatment without ($\chi^2 = 118.88$, $p < 0.001$) and with communication ($\chi^2 = 546.70$, $p < 0.001$). Thus, both parts of H6 have to be rejected.

H7 predicts that headquarters' earnings net of compensation costs will be equal under both incentive schemes if communication is possible under profit sharing, but that headquarters' earnings will be lower under profit sharing than under the Groves mechanism if there is no communication possibility. However, Mann-Whitney U-tests indicate that in the Groves treatment without communication, $LOSS$ is insignificantly different from the corresponding loss in the profit sharing treatment without communication ($z = 1.43$, $p = 0.152$), but significantly *larger* than under profit sharing with communication ($z = 3.42$, $p = 0.001$). Moreover, the efficiency loss in the Groves treatment with communication is significantly larger than in both the profit sharing treatment without communication ($z = 4.66$, $p < 0.001$) and with communication ($z = 4.98$, $p < 0.001$). These findings reject both parts of H7.

4.3 Supplementary analysis

Non-truthful reporting behavior under the Groves mechanism

As we described in the introduction, prior experimental studies find significant deviations from truth-telling in the Groves mechanism but only weak evidence for tacit collusion. Similar to prior studies, the evidence for collusive behavior in our Groves treatment without communication is not very strong. Pairwise analysis of the reported productivities reveals that simultaneous overstatements occur in only 33 of the 190 cases. While the behavior of one pair can be attributed to tacit collusion, simultaneous overstatements of the other pairs seem to be the outcome of individual strategies and do not occur systematically. As Waller and Bishop (1990) attribute part of their results to difficulties in understanding the Groves mechanism, two post-experiment questions examined whether subjects understood how their own reported productivities and the reported productivities of their partner affected their compensation. In the treatment without communication, the two questions are answered correctly by only 63% and 55% of the participants. Thus, there is some evidence that incomplete understanding of the Groves mechanism contributes to the observed reporting behavior in the treatment without communication.[14]

However, our conclusion about the causes of deviations from truth-telling is completely reversed in the communication treatment, as can be seen from Table 4 that analyzes the communication in this treatment. Panel 1 of the table shows that participants inform their partner in 271 cases about their productivity in the current round and that over 95% of these messages are truthful, although they cannot be verified ex post.

(*Insert Table 4 about here.*)

Even more important, panel 2 displays subjects' behavior after they have agreed upon a reporting strategy that deviates from the dominant strategy of truth-telling. The panel shows that during the whole experiment, over 95% of the agreements are met. Moreover, the frequency of agreements met is not significantly different between the two halves of the experiment ($\chi^2 = 1.11$, $p = 0.291$). In an overwhelming number of cases, the cooperation between the participants does not break down in the last rounds, and we observe *stable* collusion strategies in the Groves treatment with communication. These results are in stark contrast to prior experimental research on the Groves mechanism, particularly with respect to the stability of the collusion strategies. Our results show that anonymous communication is sufficient to override the collusion-proofness of this mechanism.

Finally, we examine misrepresentation contingent on the participants' answers to the post-experiment question about their individually optimal strategy (given the partner's report). We report results on $RELDEV$, but results on $ABSDEV$ are virtually identical. Without communication, $RELDEV$ is larger when participants consider overstatements to be individually optimal (0.42) than for truthful reporting behavior (0.21) or understatements (-0.08). All differences are significant (Mann-Whitney U, $p \leq 0.06$ in all cases). In contrast, in the communication treatment, the differences in $RELDEV$ for the three groups (0.58 for overstatements, 0.53 for truth-telling, and 0.44 for understatements) are smaller and no longer significant (Kruskal-Wallis, $\chi^2 = 0.45$, $p = 0.799$). This further confirms that misrepresentations in this treatment are essentially driven by subjects' collusion strategies. In contrast to the treatment without communication, participants in the communication treatment choose reporting strategies that are beneficial for both partners, irrespective of their considerations about the individually optimal strategy.

The robustness of collusion under audits

We then conducted a Groves treatment with communication and audits in order to further study the stability of collusion strategies and to decrease the probability that the results of the communication treatment are mainly driven by incomplete understanding of the Groves mechanism or weak incentives to deviate from agreements with the partner. This treatment is identical to the Groves treatment with communication except for a 10%-probability of being audited for every participant in every round. If a subject is audited and $\widehat{P}_i$ is different from P_i he loses his entire variable compensation from this round.

The results of this treatment show that, relative to the communication treatment, the introduction of audits significantly increases $f(DEV_i = 0)$ to 64% ($\chi^2 = 433.14$,

$p < 0.001$) and decreases $ABSDEV$ to 0.088 (Mann-Whitney U, $z = 4.60$, $p < 0.001$) and $RELDEV$ to 0.203 ($z = 5.16$, $p < 0.001$). However, a comparison with Table 1 reveals that $ABSDEV$ and $RELDEV$ remain larger than in the Groves treatment without communication, and this difference is significant for $ABSDEV$ ($z = 1.84$, $p = 0.065$). Moreover, the mean efficiency loss in this treatment amounts to 2.04, which is larger than in both profit sharing treatments, and the difference is significant for the profit sharing treatment with communication ($z = 2.38$, $p = 0.017$). The analysis of the communication reveals that the auditing treatment leads to either coordinated truth-telling or coordinated misrepresentations, as more than 94% of the agreements deviating from truth-telling are met. Together, these results again underline the stability of collusion under the Groves mechanism with communication.

5 Conclusion and discussion

This paper experimentally explores the efficiency of the Groves mechanism versus a profit sharing scheme in a corporate budgeting context, as well as the effects of anonymous communication on both incentive schemes. In the Groves treatment without communication, our study shows significant deviations from truth-telling but only weak evidence for collusive behavior of the participants. In contrast, when anonymous preplay communication is introduced we observe *stable* collusion strategies from the vast majority of participants. Thus, our paper identifies conditions under which stable collusion emerges under the Groves mechanism. Under the profit sharing scheme, we find coordination failures between multiple equilibria and inefficient resource allocation in the treatment without communication. However, this time, communication strongly increases equilibrium play and headquarters' earnings. Moreover, our analysis shows that profit sharing leads to larger earnings for headquarters than the Groves mechanism. Thus, in contrast to prior experimental studies, our paper provides an experimentally superior alternative to the Groves mechanism in the context of resource allocation.

With respect to corporate reality with its various communication possibilities, these results are bad news for the Groves mechanism and support the use of profit sharing schemes. While the Groves mechanism is collusion-proof from a theoretical perspective, our experimental analysis has shown that it is not when implemented in practice.

In the following, we will discuss three points with respect to the generalizability of our results. First, as described in section 2, the general class of evaluation measures derived in Groves (1976) and Groves and Loeb (1979) is $C_i = G_i(\widehat{P}_j) \cdot (\Pi_i + \widehat{\Pi}_j) + H_i(\widehat{P}_j)$. In our experiment, we set $G_i(\widehat{P}_j) = 1$ and $H_i(\widehat{P}_j) = 0$ as this evaluation measure is the natural counterpart of a profit sharing scheme and enables us to compare our results with prior Groves experiments. However, the question arises whether our results can be generalized to other forms of the measure, particularly with respect to participants' collusion.

Although, under this class of evaluation measures, truth-telling is always the dominant strategy, a manager's compensation will generally be affected by the other division manager's reported productivity (Groves and Loeb (1979), p. 227). Thus, in general we have $\frac{\partial C_i}{\partial \widehat{P}_j} \neq 0$. Simultaneously, truth-telling is the dominant strategy for manager j, i.e. $\frac{\partial C_j}{\partial \widehat{P}_j} = 0$ for $\widehat{P}_j = P_j$. That means that the increase in C_i for a marginal increase in $\widehat{P}_j$ (if $\frac{\partial C_i}{\partial \widehat{P}_j} > 0$), or for a decrease in $\widehat{P}_j$ (if $\frac{\partial C_i}{\partial \widehat{P}_j} < 0$), will be larger than the corresponding decrease in C_j. Thus, manager i will generally have an incentive to bribe manager j to deviate from P_j, or, alternatively, there will be an incentive to collude for both managers if also $\frac{\partial C_j}{\partial \widehat{P}_i} \neq 0$.

For example, consider the so-called Pivot mechanism proposed in Groves (1976) and Groves and Loeb (1979), which sets $G_i(\widehat{P}_j) = 1$ and $H_i(\widehat{P}_j) = -\widehat{\Pi}_j(X_{-i})$. $\widehat{\Pi}_j(X_{-i})$ is the maximum of the reported profit of division j given that division i does not exist. As $\frac{\partial(\Pi_i + \widehat{\Pi}_j)}{\partial \widehat{P}_j}$ will generally be smaller than $\frac{\partial \widehat{\Pi}_j(X_{-i})}{\partial \widehat{P}_j}$ if the resource is scarce, $\frac{\partial C_i}{\partial \widehat{P}_j}$ will generally be negative under this evaluation measure. Consequently, the managers would now benefit from coordinating their reports and *understating* their productivities. Thus, although variations in C_i can change the *manipulation direction* in the setting of our experiment, it will generally not eliminate the *existence* of a collusion possibility.[15]

Whether people would collude under such modified versions of the Groves mechanism in the experiment is an open question. However, in our opinion, the main obstacle to collusion would only be the understanding of the compensation function and the collusion possibility, not the fact that collusion is not individually rational.

Second, in our experiment, the 'firm' only consists of two division managers whereas, in reality, the number of divisions may well be larger than two. Prior studies indicate that, in experiments without preplay interaction of the participants, increasing the number of group members reduces tacit collusion (e.g. Kamarei and Morrison (1990) and Abbink and Brandts (2002)). However, Brosig et al. (2003) and Bochet et al. (2006) find, in experimental studies of the voluntary contribution mechanism, that even groups of four participants are able to maintain very high levels of cooperation over the whole experiment when their preplay interaction is face-to-face. Consequently, although there might be a negative effect of an increasing number of group members on collusion, it might be smaller in settings with increased social contact.

Finally, in the setting of our experiment and all other Groves experiments described in section 1, the need for a truth-inducing pay scheme is not endogenously derived from the model but exogenously determined, as we do not consider a hidden action problem for the division managers. Thus, if the managers received a fixed wage, they would have no incentive to lie (Harris et al. (1982)). Moreover, using the standard version of the Groves mechanism is not optimal for combined hidden action and hidden information problems, as it does not allow to trade off information rents and efficient resource allocation (Kanodia (1993), Hofmann and Pfeiffer (2003)). In this context, Baldenius et al. (2005) show that the Groves mechanisms, derived as incentive compatible in their resource allocation settings without explicit hidden action problem, retain their truth-inducing property and are part of the optimal solution in the same settings with hidden action if the managers' reports maximize headquarters' net present value *after information rents*. Nevertheless, the mechanisms remain susceptible to collusion. However, it is an open question how an additional hidden action problem would affect the experimental results. To our best knowledge, the study of Fisher et al. (2002) is the only experiment combining resource allocation and the provision of effort incentives in a budgeting context. This underlines the need for further experimental research of combined hidden action and hidden information problems in order to gain further insights into real budgeting processes.

Notes

[1]In fact, the literature about centralization and delegation of decision authority usually relies upon the assumption of self-enforcing contracts when analyzing coalitions (Mookherjee (2006)).

[2]In general, the more direct the contact is between the players during the communication, the better the cooperation (Frohlich and Oppenheimer (1998) and Brosig et al. (2003)). Bochet et al. (2006) find that communication in a chat room is nearly as efficient in inducing cooperation as face-to-face interaction. For the effects of communication in social dilemma experiments, see also e.g. Sally (1995).

[3]For coordination through communication, see e.g. Farrell (1987) and Farrell and Rabin (1996) for a theoretical perspective and Cooper et al. (1989, 1994) for experimental results.

[4]Another important issue with respect to the Groves mechanism is its effectiveness for combined hidden information and hidden action problems (Kanodia (1993); Hofmann and Pfeiffer (2003)). We abstract from this problem in our experiment and will discuss it in more detail in section 5. See also Cohen and Loeb (1984) for the profit sharing scheme under hidden action.

[5]Technically, this assumption is necessary to induce multiple pareto efficient Nash equilibria in the profit sharing treatments. With $\Delta = 0$ the only pareto efficient equilibrium in pure strategies would be truth-telling. The ex ante information asymmetry thus prevents participants' focussing on this equilibrium during the experiment. For pareto efficiency as a natural focal point see e.g. Schelling (1966), Appendix C, Harsanyi and Selten (1988), chap. 3, also Cooper et al. (1990) and VanHuyck et al. (1990) for experimental results.

[6]However, the players were never told that the resource allocation scheme represents the optimal allocation given truthful reporting.

[7]The players were forbidden from revealing their identity or making arrangements beyond the game in the laboratory. If so, they would have lost their entire variable compensation from the experiment. In the analysis of the communication, no evidence could be found for rule breaking.

[8]As the range for $\widehat{P}_i$ is 1.3-2.2 under profit sharing, $RELDEV_i$ is correspondingly adjusted in these treatments.

[9]We did not directly compare $\Pi_{HQ}(\widehat{P}_i, \widehat{P}_j)$ in the different treatments, as due to the randomization of the productivity parameters, headquarters' net earnings for truth-telling were slightly larger in the profit sharing treatments than in the Groves treatments. Thus, using actual net earnings would favor profit sharing even if the efficiency losses under Groves and profit sharing were equal.

[10]The experimental data presented here were gathered in two studies. In the first study, we implemented the Groves treatments with and without communication, and in the second study we performed the profit sharing treatments with and without communication. However, as we had different participants in these two studies and did not change the instructions or the procedure (except for the adjustments necessary to account for the special characteristics of every treatment), there is no relevant difference between these two studies, and thus, we will not differentiate between them in the following. The data from the two Groves treatments are also used in Arnold and Ponick (2006).

[11]E.g., for the absolute misrepresentation, we use $\overline{ABSDEV_i} = \sum_{t=1}^{10} ABSDEV_{i,t}/10$.

[12]There are also 3 cases in the non-communication treatment where $ABSDEV_i$ equals $ABSDEV_j$ and is larger than 0.1 or lower than -0.1. However, we do not include them into Table 3 as deviations from truth-telling with absolute values larger than 0.1 do not lead to an equilibrium with certainty (i.e. for all P_i) in the non-communication treatment. In the communication treatment however, the corresponding cases are included into Table 3 if participants agreed upon these reports during the communication.

[13]When analyzing the communication, we found strong evidence that participants are indeed aware of the fact that only the resource allocation influences their compensation but not the exact magnitude of the deviations from truth-telling. For example, after two participants have truthfully exchanged their actual productivity parameters of $P_i = 1.6$ and $P_j = 1.7$ and player j has proposed to report $\widehat{P}_i = 1.6$ and $\widehat{P}_j = 1.9$, player i notes (translated from German): 'As long as you report a larger productivity you get more resource units. Thus, we can report 1.6:1.7 or 1.6:1.9, that makes no difference.'

[14]See also Güth et al. (1983), Kawagoe and Mori (2001) and Attiyeh et al. (2000) for difficulties of experiment participants with other forms of this mechanism.

[15]Note that setting $G_i(\widehat{P}_j)$ larger than 1 in order to make manager i's evaluation measure independent of a variation of $\widehat{P}_j$ is not possible, as $\frac{\partial(\Pi_i + \widehat{\Pi}_j)}{\partial \widehat{P}_j}$ will generally depend on P_i which is not known to headquarters. See also Green and Laffont (1979) and Crémer (1996) for lacking coalition robustness of the Pivot mechanism for binary public good decisions.

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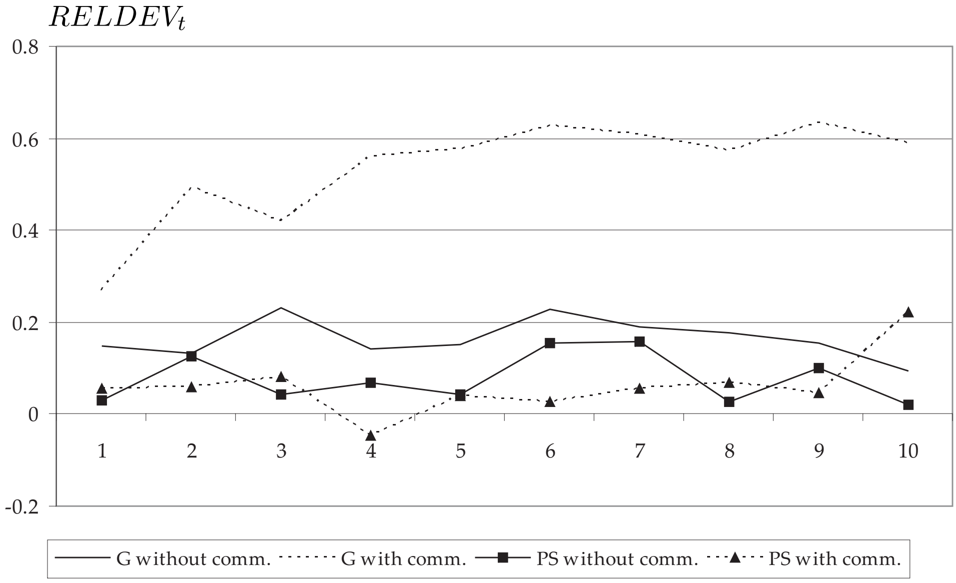

Figure 1: Mean relative misrepresentation in the Groves (G) and profit sharing (PS) treatments.

	Groves without communication	Groves with communication	PS without communication	PS with communication
Panel 1: Frequencies (absolute numbers) of reports[a]				
$f(DEV_i < 0)$	18.95%	5.75%	19.25%	8.00%
	(72)	(23)	(77)	(32)
$f(DEV_i = 0)$	44.47%	21.50%	48.75%	73.25%
	(169)	(86)	(195)	(293)
$f(DEV_i > 0)$	36.58%	72.75%	32.00%	18.75%
	(139)	(291)	(128)	(75)
Total	100%	100%	100%	100%
	(380)	(400)	(400)	(400)
Panel 2: Mean absolute misrepresentation ($ABSDEV$)[b]				
Rounds 1-5	0.0547	0.1945	0.0310	0.0315
Rounds 6-10	0.0605	0.2350	0.0365	0.0335
Total	0.0576	0.2148	0.0338	0.0325
Panel 3: Mean relative misrepresentation ($RELDEV$)[c]				
Rounds 1-5	0.1604	0.4643	0.0619	0.0374
Rounds 6-10	0.1683	0.6057	0.0924	0.0834
Total	0.1644	0.5350	0.0772	0.0604
Panel 4: Mean efficiency loss for headquarters ($LOSS$)[d]				
Rounds 1-5	3.17	3.76	1.39	0.75
Rounds 6-10	2.88	4.54	1.12	0.51
Total	3.03	4.15	1.26	0.63

[a] $f(DEV_i{<}0)$ is the relative frequency of understatements for a given treatment, $f(DEV_i{=}0)$ represents the relative frequency of truth-telling, and $f(DEV_i{>}0)$ is the relative frequency of overstatements.

[b] $ABSDEV$ is calculated by subtracting the actual productivity (P) from the reported productivity ($\widehat{P}$).

[c] $RELDEV$ is $ABSDEV$ divided by the maximum possible overstatement (if $ABSDEV{>}0$) or the maximum possible understatement (if $ABSDEV{<}0$). For example, in the case of an overstatement in one of the Groves treatments, $RELDEV$ is calculated as $(\widehat{P}{-}P)/(2.1{-}P)$.

[d] $LOSS$ is headquarters' efficiency loss due to non-truthful reporting behavior. It is calculated by subtracting the headquarters' actual earnings net of compensation costs from the headquarters' earnings net of compensation costs in case both managers had truthfully reported their productivities.

Table 1: Descriptive statistics for the Groves and the profit sharing (PS) treatments.

Treatment	Groves without communication	Groves with communication
Dependent var.	relative misrepresentation ($RELDEV_t$)	relative misrepresentation ($RELDEV_t$)
Independent var.	Coefficient (std. error)	Coefficient (std. error)
Constant	0.2678*	0.4431**
	(0.1517)	(0.1600)
t	-0.0061	0.0465**
	(0.0113)	(0.0117)
Group dummies	*yes*	*yes*
Left censored obs.	26	7
Right censored obs.	72	151
Total obs.	380	400
R^2	0.2606	0.2638
$Adj.\ R^2$	0.2194	0.2229

Tobit regressions of the relative misrepresentation ($RELDEV_t$) on the round variable t in the two Groves treatments. The coefficients of t reveal whether $RELDEV_t$ increases or decreases over time. Regressions include group dummies for group fixed effects. **, and * denote significance at the 1% and 10% levels.

Table 2: The variation of the relative misrepresentation over time.

Panel 1: $f(HIT)$ in the profit sharing treatment without communication

	Truth-telling equilibrium ($ABSDEV_i$ = $ABSDEV_j = 0$)	Other equilibria ($ABSDEV_i$ = $ABSDEV_j = \pm 0.1$)	Total $f(HIT)$
Rounds 1-5	26%	4%	30%
Rounds 6-10	24%	6%	30%
Total	25%	5%	30%

Panel 2: $f(HIT)$ in the profit sharing treatment with communication

	Truth-telling equilibrium ($ABSDEV_i$ = $ABSDEV_j = 0$)	Other equilibria ($ABSDEV_i$ = $ABSDEV_j \neq 0.1$)	Total $f(HIT)$
Rounds 1-5	56%	4%	60%
Rounds 6-10	61%	5%	66%
Total	58.5%	4.5%	63%

Within each panel of Table 3, the frequencies of equilibrium 'hits', $f(HIT)$, are displayed, i.e. the frequencies of equilibrium strategies play ex post. The columns distinguish between the truth-telling equilibrium where $ABSDEV_i$=$ABSDEV_j$=0 and all other equilibria. The percentage for total $f(HIT)$ in panel 2 is conservative as it only includes the cases with $ABSDEV_i$= $ABSDEV_j$. It does not include cases with $ABSDEV_i \neq ABSDEV_j$ but efficient resource allocation.

Table 3: Ex post equilibrium play in the profit sharing treatments.

Panel 1: Messages about P_i during communication[a]

Frequencies (absolute no.)	Truthful	Under-/overstatements
Rounds 1-5	95.20% (119)	4.80% (6)
Rounds 6-10	95.89% (140)	4.11% (6)
Total	95.57% (259)	4.43% (12)

Panel 2: Behavior after agreement upon deviation from truth -telling[b]

Frequencies (absolute no.)	According to agreem.	Deviation
Rounds 1-5	96.46% (109)	3.54% (4)
Rounds 6-10	94.78% (127)	5.22% (7)
Total	95.55% (236)	4.45% (11)

[a] Panel 1 displays the relative frequencies (the absolute numbers) of truthful and non-truthful messages sent to the partner about the own productivity during the communication phase.
[b] Panel 2 displays how often players reported their productivity to headquarters according to the agreement they had concluded with their partner during the communication and how often they deviated from this agreement when reporting their productivity. The panel only contains those cases in which participants agreed on deviating from the dominant strategy of truth-telling.

Table 4: Analysis of communication under the Groves mechanism.