

Monitoring in Teams

A Model and Experiment on the Central Monitor Hypothesis

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Abstract. An influential hypothesis about why workers are not major profit claimants in most firms argues that there is need for a concentrated residual claim in the hands of a central agent, to motivate the monitoring of workers. We model monitoring as a way to transform team production from a collective action dilemma with strong free riding incentives to a productivity-enhancing opportunity with strong private marginal incentives to contribute effort. In an experiment, we have subjects experience team production without monitoring, team production with a central monitor, and team production with peer monitoring, then vote on whether to employ the central monitor, who gets to keep 25% of the team output, or to rely on peer monitoring, which entails a severe coordination problem. Our subjects usually prefer peer monitoring and are more successful at it than predicted by standard theory, perhaps because the desire to avoid sharing output with a specialist monitor mitigates free riding incentives.

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1. Introduction

In an influential paper about the theory of the firm, Alchian and Demsetz (1972) defined team production as a situation in which there exist several input providers, the combined output is larger than the sum of the outputs that the individual input providers can achieve by working alone, there is an observable team output but no observable output of the individual input provider, and it is possible but costly to measure the amount of input contributed by each individual provider. The central dilemma of team production, they argued, is that the benefits of working as a team, benefits from economies of scale or of specialization, may be undercut by the incentive that each team member has to free ride if compensated according to team output rather than personal input. To mitigate this problem, team members' rewards must be tied to their contributions, but that requires another costly input—monitoring—and this in turn gives rise to another collective action problem if monitoring is to be supplied by the team members themselves. The classical capitalist firm solves this problem, they argue, by making one specialized agent the monitor of the other team members who pays them according to their observed inputs. The central agent is motivated to monitor by the fact that he keeps all team revenue above his contractual obligations to the input providers.

We understand Alchian and Demsetz's depiction of team production in the absence of monitoring to be an example of the familiar problem of collective action or incentives in teams that has been studied by experimental economists in recent decades under the heading Voluntary Contribution Mechanism (VCM) or Public Goods Game (PGG). In a VCM or PGG, subjects are grouped with others and each decides how much of a certain endowment to contribute to a group project and how much to hold for herself. Contributions to the project are scaled up by the experimenter, as a result of which there is a social optimum of contributing, but the resulting revenues are divided equally among team members, making the individual optimum that of contributing nothing. We interpret Alchian and Demsetz as saying that if a sufficient investment is made in monitoring individuals' contributions, then they can be paid according to their contributions, rather than an equal per capita share, as a result of which there will be an incentive to contribute and not to free ride.

We present a simple theoretical model corresponding to this structure, and we investigate how real decision-makers respond to the structure by having subjects make potentially rewarding/costly decisions under it in a laboratory experiment. In the model and experiment, monitoring can either be done by a specialized agent, who is assigned a fraction of the team's joint output, or by the team members themselves, who are then compensated for their contributions to production but not for their monitoring itself. Suppose that agents care only about increasing their own earnings, know one another to be of the same type, and are rational. Then if the only monitoring were to be that done by the team members themselves, there would be a considerable possibility that monitoring would not suffice and hence that the production stage of the model would be a simple VCM, for which there is a straightforward prediction of zero contributions. If, instead, a specialist were offered a sufficient fraction of team output and permitted to monitor, it would be in the specialist's interest to monitor enough to make contributing to team production rational for each team member. With appropriate specifications of returns to team production and of the share claimed by the specialist, team members earn more producing together with a specialist monitor than having no monitor and producing individually. If allowed to vote at no cost—a proxy for workers' choice among organizational forms in a market economy—the model predicts that team members will vote to hire the specialist unless they manage to successfully monitor themselves.

We carry out experimental play of such a model. We vary the conditions under which team members and specialists can learn about their tasks by varying the order in which play occurs (a) with no monitoring, (b) with monitoring (if any) by team members, and (c) with monitoring (if any) by a specialist, before having several opportunities to vote on which kind of monitoring to use, more periods of play, and opportunities to vote again. We also vary the costliness of monitoring for team members versus specialists.

Ours is the first experiment we are aware of in which a public goods game with its well-known free rider problem can be converted into a payment for effort environment without free rider problem by the free choices of subjects. It extends the recent innovation of studying institutional evolution in the laboratory, applying it to a key issue in the theory of economic organization that has not previously been addressed by such methods.

Our results are striking. In four of the five treatments with which we experiment, almost all teams are successful at self-monitoring and thus choose not to hire a specialist. Only when we make monitoring by team members more costly than that by the specialist (in a sense to be made precise below) do some groups choose the specialist, and even then some groups succeed with peer monitoring despite its costs and don't hire the specialist.

In view of the difficulty of the coordination problem in self-monitoring facing the subjects and their inability to solve it through communication, subjects' success in solving the peer monitoring problem seems likely to stem in part from a preference for cooperating rather than sharing earnings with an outside party. In this respect, our results appear to be consistent with experimental findings that a large number of subjects typically attempt cooperation in the lab, a finding that a growing body of re-search attributes to a preference structure of "conditional cooperation."¹ Like real-world findings of enhanced incentives and mutual monitoring when teams work under profit-sharing arrangements, our results suggest that the explanation adduced by Alchian and Demsetz may not be a major reason why most workers are employed in firms in which those who exercise control and are the main residual claimants are not themselves production workers.

The structure of the paper is as follows. Section 2 briefly discusses the theory and literature on the organizational form of production in a market economy. Section 3 presents our theoretical model, and Section 4 lays out its implementation in our experimental design. Section 5 presents the experiment's results. Section 6 summarizes and provides additional discussion.

¹ On the presence of cooperation, see inter alia Ledyard (1995). On the conditional cooperation hypothesis, see Fehr and Gächter (2000a), Fischbacher et al. (2001), and Camerer and Fehr (2004).

2. Literature

Why most firms in market economies exhibit certain common features, and in particular why control rights usually reside in a group of investor/residual claimants, with employees working under the supervision of their employers, has long been a central question of the economics of organization and comparative institutional analysis. Knight (1921) argued that the more confident and less risk-averse individuals become entrepreneurs while others become workers who demand insurance against risk and who accordingly must be supervised, since their fixed wages give rise to moral hazard (see also Kihlstrom and Laffont (1979)). Alchian and Demsetz's explanation of why workers are supervised by a residual-claiming central monitor was summarized in the introduction. Marglin (1974) argued that capitalists carved out the role of imposing discipline on workers at the expense of workers' welfare, by developing technologies that undercut the positions of independent workers. Holmström (1982) suggested that the monitoring of inputs could be rendered unnecessary by a forcing contract, but the contract envisioned is largely hypothetical and has been argued to suffer from serious moral hazard problems (Eswaran and Kotwal (1984), MacLeod (1988)). Eswaran and Kotwal (1989) and Banerjee and Newman (1993) explain the assignment of control rights to financiers by reference to unequal wealth and imperfections in credit markets associated with the limited liability of borrowers. Kremer (1997) argued that workers usually don't run firms because control by workers leads to a tendency to redistribute earnings among members, which distorts incentives.

Dow and Putterman (2000) and Dow (2003) view Alchian-Demsetz's monitoring hypothesis as one of the leading candidates to explain the conventional employment relationship,² alongside theories of worker liquidity constraints and risk aversion, additional financing problems associated with missing membership markets, and potential decision-making problems due to heterogeneity of worker preferences. However, they point out that contrary to the theories' implication that work incentives would be weak without a residual-claiming central monitor, most evidence on worker-owned and

² See also the references to Alchian and Demsetz's hypothesis in many of the papers cited in the previous paragraph.

profit-sharing firms, as well as that on self-managing teams, suggests that they achieve higher-than-average effort levels with less-than-average numbers of supervisors (Estrin et al. (1987); Weitzman and Kruse (1990); Craig and Pencavel (1995)). Incentives appear to be a strength, rather than a weakness, of profit-sharing, with a frequently mentioned theme being its encouragement of mutual monitoring.

In a recent experimental study of work organization and incentives Potters et al. (2005) compare laboratory manager-less teams that play a standard public goods game with teams having managers who can decide how much to pay the other members. They find that managers are able to elicit higher effort from team members than is forthcoming in the PGG, by linking pay to effort somewhat in the manner suggested by Alchian and Demsetz. While the performance of their “managerial” firms is remarkable, their manager-less firms may be a poor representation of self-managing teams, since linkage of pay to effort is ruled out in such teams under their experimental design.

Another attempt to experimentally compare self-managed teams and centrally managed teams has been undertaken by Frohlich et al. (1998). They designed a real-effort experiment wherein they observed higher productivity, greater perceived fairness in pay and lower need of supervisory efforts for employee owned firms compared to the “conventionally owned” firms. Another experimental study incorporating different group incentive mechanisms is Nalbantian and Schotter (1997). They compared revenue sharing, forcing contracts, competition between teams, profit sharing and monitoring. Monitoring in their context was a probability of being observed and getting fired when one’s effort is too low. This kind of monitoring was successful but only if the probability is high enough; thus, successful monitoring is expensive.³

³ The numerous social dilemma experiments beginning with Fehr and Gächter (2000a) or Carpenter et al. (2006), in which subjects can punish those who contribute too little to a public good, can also be viewed as studying alternative incentive mechanisms for group production. In these experiments, the public good always remains public, whereas we allow its public character to be eliminated by monitoring.

3. A model of team production with monitoring

We model a team consisting of N members who play a finitely repeated game for T periods. In each period, a team member receives an endowment e , which we'll assume to be identical for all members. Team member i chooses an amount c_i with $0 \leq c_i \leq e$ to contribute to a team production process, leaving $e - c_i$ for private production. The sum of the team members' contributions (denoted by $C = \sum_{i=1}^N c_i$) generates a team profit of $R \cdot C$ with $1 < R < N$. The division of the team profit among the team members depends on the monitoring technology applied to identify the individual team contributions, which is a result of a simultaneous investment process prior to the contribution decision. Each team member invests $m_i \in [0, \dots, 1]$ into the monitoring technology at a linear cost $\kappa \cdot m_i$ (with the marginal monitoring cost $\kappa \geq 1$). The total investment in monitoring $M = \sum_{i=1}^N m_i$ determines the "accuracy" of the monitoring technology and thus the proportion of the team profit which is divided according to the individual contribution: allows no identification of the individual contributions and hence the team profit is divided equally among the team members. The higher M is the higher is the proportion of the team profit which is allocated according to the individual contributions. $M = N$ allows a perfect identification of the team members' contributions and hence the team profit is allocated according to the individual contributions. The general rule for team member i 's profit is:

$$\Pi_i = e - \kappa \cdot m_i - c_i + \frac{N - M}{N} \cdot \frac{R}{N} \cdot C + \frac{M}{N} \cdot R \cdot c_i \quad (1)$$

The monitoring technology changes the nature of the team problem. Without any monitoring ($M = 0$) team production is a classical linear public good provision problem with free-rider incentives due to $\Pi_i = e - c_i + R \cdot C / N$. However, if each team member fully invests in the monitoring technology ($M = N$), team production is a private investment task with $\Pi_i = e - \kappa - c_i + R \cdot c_i$. The positive interest rate $R - 1$ provides incentives for full contributions. Intermediate values of M lead to linear combinations of the

public and the private good provision. If, for example, half of all team members fully invest in monitoring, i.e. $M = N/2$, then half of the team output is allocated according to the private contribution and the other half is distributed equally among the team members, i.e. $\Pi_i = e - \kappa \cdot m_i - c_i + \frac{1}{2} \cdot \frac{R}{N} \cdot C + \frac{1}{2} \cdot R \cdot c_i$. Thus, the model reflects Alchian and Demsetz's idea that without monitoring team production is a pure public good problem in which the team output is shared equally, however if a sufficient investment is made in monitoring individuals' contributions, then they can be paid according to their contributions as a result of which there will be an incentive to contribute and not to free ride.

For the analysis of the subgame perfect equilibria of the game it is convenient to restructure (1) as:

$$\Pi_i = e - \kappa \cdot m_i - c_i + \beta \cdot c_i + \gamma \cdot C_{-i} \quad (2)$$

where $C_{-i} = \sum_{\substack{j=1 \\ j \neq i}}^N c_j$ denotes the sum of the others' contributions, the weight

$\beta = \frac{R}{N^2} \cdot (N - M + N \cdot M)$ denotes the team member's marginal return from his/her own investment and the weight $\gamma = \frac{R}{N^2} \cdot (N - M)$ denotes the team member's marginal return from the investment of the others.

With no monitoring $\beta = \gamma = \frac{R}{N}$, meaning that all team members profit equally from each unit of contribution, while with perfect monitoring $\beta = R$ and $\gamma = 0$, meaning that only the contributor profits from his or her own contribution. Obviously, it is individually rational to contribute the entire endowment when $\beta \geq 1$, because each token invested has an individual return of at least 1. $\beta \geq 1$ is satisfied if and only if

$$M \geq \frac{N}{N-1} \cdot \left(\frac{N}{R} - 1 \right) =: \tilde{M}.$$

Equilibrium investment in monitoring and contributions to the team project

The game consists of two stages. In the first stage players simultaneously invest in monitoring. After having learned the total investment M the players decide on their contribution to the team project. Suppose that the team members are solely motivated by the maximization of their monetary payoff. We will analyze the game by backward induction to identify the subgame perfect equilibria. Consider the subgames of the contribution to the team project (after the amount M was made public). Obviously, it suffices to distinguish three classes of subgames: those with $\beta < 1$, those with $\beta > 1$, and those with $\beta = 1$. For $\beta < 1$ the individual return from the individual contribution is lower than the cost of contributing and hence in the equilibria of these subgames all team members choose $c_i = 0$. If, however, $\beta > 1$ each team member individually gains from contributing and hence will choose $c_i = e$ in equilibrium. For $\beta = 1$ players are indifferent between contributing and keeping the entire endowment or parts of it and hence each contribution $0 \leq c_i \leq e$ may be part of a subgame perfect equilibrium. Now turn to the investment in monitoring. The subgame has multiple equilibria. There are two symmetric Nash equilibria in pure strategies: one in which each player does not invest in monitoring ($m_i = 0$) and the other one in which each player invests the N -th part of the amount necessary to make full contribution to the public good individually rational ($m_i = \frac{\tilde{M}}{N}$). In addition, there is an infinite number of asymmetric pure strategy equilibria of the subgame which are all characterized by investments m_i satisfying $M = \tilde{M}$.

Hence the public good dilemma of team production may be “resolved” in the monitoring phase prior to it. However, the investment in monitoring is a coordination problem with multiple equilibria, thus vulnerable to severe coordination failures.⁴ If decision maker i believes that other group members will invest little in monitoring such that her investment m_i does not suffice to achieve \tilde{M} , her best reply is not to invest. Similarly, if i believes that other group members will invest enough in monitoring to achieve \tilde{M} , then her best reply is to abstain from monitoring—a situation resembling the incentive to free ride on monitoring that Alchian and Demsetz appear to have had in mind. Only if

⁴ Marx and Matthews (2000)

i believes that her investment is needed to exactly meet \tilde{M} is it rational for her to invest in monitoring.

Specialist monitoring

To overcome the coordination problem in the monitoring phase, team members may hire a specialist to take the monitoring decision. The substitution of peer monitoring by specialist monitoring has the advantage that the specialist is a single decision maker who (in equilibrium) chooses an incentive compatible level of monitoring without any coordination problems. The drawback obviously is that she has to be paid a share of the team output in order to have the proper incentives.⁵

Let the specialist be entitled to a share $S \leq 1$ of the team profit $R \cdot C$. Suppose that the specialist has an endowment e_s which enables her to invest at least \tilde{M} units of monitoring. Thus, the payoff functions under specialist monitoring are as follows:

$$\Pi_s = e_s - \kappa_s m_s + S \cdot C \cdot R \quad \text{for the specialist} \quad (3)$$

$$\Pi_i^s = e - c_i + \beta^s \cdot c_i + \gamma^s \cdot C_{-i} \quad \text{for the team member } i \quad (4)$$

with the adjusted weight $\beta^s = (1-S) \cdot \beta$ denoting a team members' marginal return from his/her investment after deduction of the specialist's share and the adjusted weight $\gamma^s = (1-S) \cdot \gamma$ denoting a team member's marginal return from the investment of the others after deduction of the specialist's share.

Full contribution of the team members is individually rational if and only if

⁵ Alchian and Demsetz never spell out where the residual earnings of the central monitor come from, simply asserting that the monitor pays team members the estimated value of their marginal products and keeps the residual. Our model assigns to the monitor a fraction of the output because with average and marginal product equal, there is no residual above the sum of marginal products. We implement the model with sufficiently large R so that both monitor and team members can profit from centrally monitored team production.

$$\beta^s \geq 1 \Leftrightarrow M \geq \frac{N}{N-1} \cdot \left(\frac{N}{(1-S) \cdot R} - 1 \right) =: \tilde{M}^s.$$

If the specialist invests less than \tilde{M}^s , team members in equilibrium contribute a total of 0 units of effort to team production, so the specialist's earnings from team production will be $S \cdot 0 = 0$. If the specialist invests at least \tilde{M}^s in monitoring, each team member in equilibrium contributes his/her full endowment of e to team production, so the specialist's earnings from team production will be $S \cdot N \cdot e \cdot R$. Hence, for reasonable costs κ_s the specialist will in equilibrium choose the lowest monitoring level for which it is individually rational for the team members to fully contribute their endowment, that is \tilde{M}^s , and gain a total profit of $\pi_s = e_s - \kappa_s \cdot \tilde{M}^s + S \cdot N \cdot e \cdot R$.

To recap, we presented a formal model of team production in the spirit of Alchian and Demsetz. The elegance of the model is that it allows a continuous transformation of the team problem with free-riding incentives into a profitable private investment problem through the actions of the team members and/or the decision of the specialist monitor. It is not impossible, although very hard, that team members manage the transformation, while the specialist may do the transformation by a single individual decision. The drawback of hiring the monitor is its cost, albeit it is – in equilibrium – more than compensated compared to full free-riding.

A discrete version of the model

For the experimental implementation of the game we chose a discrete version of the payoff function and a binary choice in the investment in peer monitoring $m_i \in \{0,1\}$ to facilitate comprehension by subjects. We exogenously introduce two different thresholds of monitoring T_1 and T_2 with $T_1 < T_2 \leq N$. If $M < T_1$ all team members equally profit from all contributions, for $T_1 \leq M < T_2$ half of the team profit is allocated equally and the other half according to individual contributions, and finally, for $T_2 \leq M \leq N$ each team member solely profits from his/her own contribution. Hence, the payoff function under peer monitoring is:

$$\Pi_i = \begin{cases} e - \kappa \cdot m_i - c_i + \frac{1}{N} \cdot R \cdot C, & 0 \leq M < T_1 \\ e - \kappa \cdot m_i - c_i + \frac{1}{2} \cdot \frac{1}{N} \cdot R \cdot C + \frac{1}{2} \cdot R \cdot c_i, & T_1 \leq M < T_2 \\ e - \kappa \cdot m_i - c_i + R \cdot c_i, & T_2 \leq M \leq N \end{cases} \quad (5)$$

In terms of β and γ this means:

$$\begin{cases} \beta = R/N, \quad \gamma = R/N & 0 \leq M < T_1 \\ \beta = \frac{R(N+1)}{2N}, \quad \gamma = \frac{R}{2N} & T_1 \leq M < T_2 \\ \beta = R, \quad \gamma = 0 & T_2 \leq M \leq N \end{cases}$$

Example:

The following example illustrates the model and uses functional forms and parameters that will also be used in our experiment. Let $N = 5$ be the number of team members with an endowment $e = 10$, a multiplier $R = 3$, the specialist's endowment $e_S = 5$ and the specialist's share $S = 0.25$. Then

$$\begin{cases} \beta = 0.6, \quad \gamma = 0.6 & 0 \leq M < T_1 \\ \beta = 1.8, \quad \gamma = 1.5 & T_1 \leq M < T_2 \\ \beta = 3.0, \quad \gamma = 0 & T_2 \leq M \leq N \end{cases}$$

$$\begin{cases} \beta^S = 0.45, \quad \gamma^S = 0.45 & 0 \leq M < T_1 \\ \beta^S = 1.35, \quad \gamma^S = 1.125 & T_1 \leq M < T_2 \\ \beta^S = 2.25, \quad \gamma^S = 0 & T_2 \leq M \leq N \end{cases}$$

Hence for $M \geq T_1$ full contribution to the team project is individually rational, because the individual return from investment β is greater than 1. In the subgame perfect equilibrium without peer monitoring ($m_i^* = 0$), contributions to the team project are 0

($c_i^* = 0$), leading to team members' payoffs of 10. However, there are also equilibria in which monitoring takes place. The simplification of the model by choosing discrete values of monitoring and thresholds restricts the number of these equilibria. Nevertheless, there are still $\binom{N}{T_1}$ subgame perfect pure strategy equilibria, characterized by exactly T_1 team members investing in monitoring.

In the experiment we used two treatments in which $T_1 = 2$ and three in which $T_1 = 4$. Because team members are restricted to integer investments, a symmetric equilibrium with monitoring is not achievable. This means that the only symmetric equilibrium prescribes no investment in peer monitoring. All the equilibria with monitoring are asymmetric and hence very vulnerable to coordination failure. In case of $N = 5$ and $T_1 = 2$, the game has 10 pure strategy equilibria in which exactly 2 out of the 5 players have to invest in monitoring and in case of $N = 5$ and $T_1 = 4$, the game has 5 pure strategy equilibria in which exactly 4 out of the 5 players have to invest in monitoring. If team members are able to self-organize (i.e. achieve $M \geq T_1$) each team member earns 30 minus the investment in monitoring (if individually applicable).⁶ In the equilibrium of specialist monitoring the specialist invests T_1 in monitoring and the team members contribute their entire endowment. Hence, the team members earn $22.5 = 0.75 \cdot 30$ and the observer earns her endowment (of 5) minus the monitoring investment plus $37.5 = 0.25 \cdot 150$.

Obviously, it would be most profitable for the team members to play one of the equilibria with positive peer-monitoring. Then each member earns 29 or 30, dependent on whether he/she invested in monitoring or not. However, there is a high risk of coordination failure. Failing to reach the sufficient level of monitoring leads to drastically lower individual payoffs of 9 and 10, dependent on whether the individual invested in monitoring or not.⁷ Facing this risk, team members may decide to hire a specialist to make

⁶ Notice that the monitoring cost is paid out of end-of-round earnings; thus, contributing to monitoring doesn't prevent a subject from still contributing a full 10 units to team production.

⁷ The other form of coordination failure in the form of over-provision of monitoring is "less disastrous" because it just leads to more players earning 29 instead of 30, than in equilibrium.

the monitoring decision and achieve a payoff 7.5 lower than the highest equilibrium payoff, but 13.5 higher than the worst payoff in case of coordination failure without sufficient monitoring.

4. Experimental Design

We conducted an experiment consisting of five treatments corresponding closely to the model above. In each session of the experiment, subjects were randomly and anonymously assigned to groups of six, with one subject randomly assigned the role dubbed “observer” and the other five the role “team member”. We implemented the discrete version of the game described above with the parameters of the example above. Subjects were told at the outset that they would engage in thirty rounds of decisions in the same roles and with the same anonymous group members. The two *step structures* 2-5 ($T_1 = 2$ and $T_2 = 5$) and 4-5 ($T_1 = 4$ and $T_2 = 5$) specify two sets of parameters for the thresholds T_1 and T_2 , which in turn generate three possible incentive regimes for team production henceforth referred to as EQUAL, HALF/HALF, and ATIC (“according to individual contribution”) (see Table 1).

Table 1 Step Structures

Division rule	Step Structure 2-5	Step Structure 4-5
equal division (“EQUAL”)	$0 \leq M < 2$	$0 \leq M < 4$
half divided equally, half according to contributions (“HALF/HALF”)	$2 \leq M < 5$	$4 \leq M < 5$
division according to individual contributions (“ATIC”)	$M = 5$	$M = 5$

In step structure 2-5 at least two units have to be invested in monitoring to make contributions to the team project individually rational, while in step structure 4-5 at least 4

units have to be invested. Each group of subjects was assigned to either one structure or the other throughout their session, with no knowledge of the other structure.

The 30 rounds of a session were divided into six phases, with 5 rounds each. In every session, Phase I consisted of 5 rounds with no monitoring—i.e., a standard 5 round VCM condition. Phases II and III consisted of 5 rounds with monitoring (if any) by the observer and 5 rounds of monitoring (if any) by peers, with the order in which observer and peer monitoring occurred varying among sessions (see Table 2). In OP sessions, the observer made the monitoring decisions in Phase II and the team members made the monitoring decisions in Phase III; in PO sessions, the order was reversed.

To avoid boredom and unnecessary inequalities and to motivate the observer to learn about incentives in team production, we assigned the observer a task to perform in those periods in which he or she was not permitted to monitor and earn a 25 percent share of team project revenue. The observer’s task was to estimate the period’s sum of contributions C in his/her group. As an incentive for accuracy, the observer earned more the closer was his/her guess to the actual C , which was revealed to him/her at the end of the period.⁸ Note that the observer might learn something about how team members’ contributions respond to monitoring by observing peer monitoring phases, and accordingly sessions using the PO ordering might be expected to be more conducive than those with ordering OP to successful decision-making by the observer when in the monitoring role.

In each session, each of the last three phases could have either observer or peer monitoring, depending on how the members of the team in question voted. Before rounds 16, 21, and 26, each team member was asked to vote for either observer or peer monitoring. The group was informed of the majority vote (without a breakdown of the number of votes) and began to play five rounds according to the chosen institution. A schematic representation of the course of the interaction in the PO ordering is given in Figure 1. Phases I to III form the first half of the experiment, and phases IV to VI the second half.

⁸ The formula for the observers’ profit during the Phase I was: $\pi = \frac{30}{1 + 0.05|C - \text{Guess of } C|}$

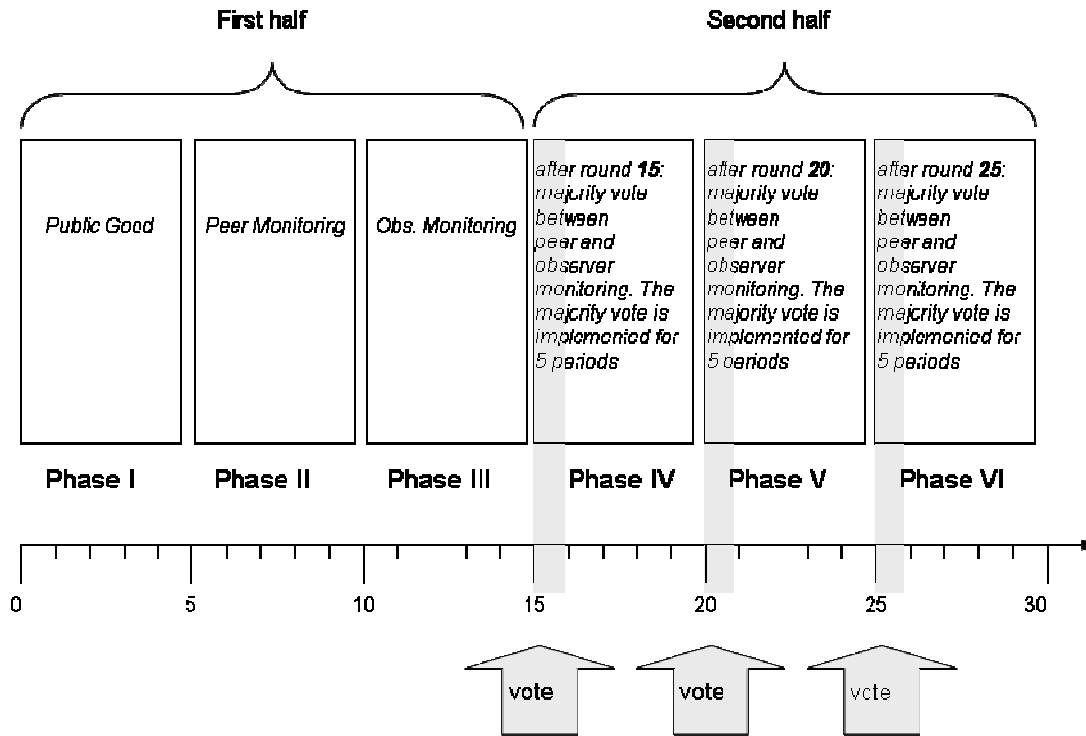


Figure 1 Schematic representation of the course of the interaction for PO

The alternatives of the PO or OP ordering and of the 2-5 or 4-5 monitoring structure give rise to a 2x2 design with four treatments: PO25, OP25, PO45, OP45. Due to the unexpected nature of the results of those treatments, which are discussed in the next section, we conducted sessions with an additional treatment that is otherwise like the OP45 treatment but in which the cost of a unit of monitoring was made three times higher for a team member than in the other four treatments, while the cost of monitoring for the observer was left unchanged. We distinguish the two treatments by referring to them as OP45MC1 and OP45MC3, with the other three treatments also sharing the MC1 designation. Table 2 provides an overview of the five treatments.

Table 2 Treatment description

Treatment	Phase Sequence		Step structure	Cost per unit of monitoring	
	Phase II	Phase III		Peer κ	Observer κ_s
PO25MC1	Peer	Observer	Step Structure 2-5	1	1
OP25MC1	Observer	Peer		1	1
PO45MC1	Peer	Observer	Step Structure 4-5	1	1
OP45MC1	Observer	Peer		1	1
PO45MC3	Peer	Observer		3	1

In each treatment we have 6 groups (from two sessions of three groups each) each containing 6 subjects (5 team members and 1 observer). Hence we had 180 subjects in the experiment. Each subject sat in a separate compartment in the experiment lab at the University of Erfurt, did not know which other subjects were in his/her group, and had no communication with others apart from information about choices that was transmitted by computer. Subjects were first read aloud and followed on their screens instructions explaining the structure of the entire session, worked through examples, and asked the experimenter questions, if any. All subjects were students who were recruited at the University of Erfurt using the Orsee System⁹. The experiment was conducted with the z-tree Software package Fischbacher (2007). Subjects earned on average EUR 21.

5. Results

The evaluation of the data exhibited that there are no significant sequence effects in the order of peer and observer monitoring in the first phase of play, in particular the

⁹ <http://www.orsee.org/>

investments in monitoring and the contribution levels are not significantly different.¹⁰ Therefore, we analyze the pooled treatments PO25MC1 and OP25MC1 as 25MC1 and the pooled treatments PO45MC1 and OP45MC1 as 45MC1. In each of the pooled treatments we now have 12 independent observations. Discussion of treatment PO45MC3 is postponed until section 5.3.

5.1. Voting Results and consequences

One of our main research focuses is on the endogenous choice of whether the peers or the observer shall monitor. Therefore, we start off with the presentation of the result of the second half of play.

Did the voting process exhibit a preference for observer monitoring to avoid the coordination problem in peer monitoring? The answer is a surprisingly clear No! As Table 3 shows, the observer was never chosen by majority vote in the 36 voting rounds of treatment 45MC1 and chosen only once in the same number of votes in treatment 25MC1.

Table 3 Choice of Observer or Peer Monitoring in the second half

	Number of choices of	
	Observer monitoring	Peer monitoring
25 MC1	1 (3%)	35 (97%)
45 MC1	0 (0%)	36 (100%)

Result 1: *The observer is almost never chosen by the majority vote of the team members.*

How did the peer monitoring teams perform? In the majority of cases team members failed to reach an equilibrium level of monitoring. In 25MC1 an investment in monitor-

¹⁰ The difference in average contributions and monitoring regarding the sequence are not different at 10 % level (exact Mann-Whitney-U-Test) with one exception (OP25MC1 vs. PO25MC1 in the observer monitoring)

ing of 2 was reached in 37.7 percent of the cases, while in 45MC1 the equilibrium level of 4 units of monitoring was only reached in 18.3 percent of all cases. This demonstrated the high vulnerability of monitoring to coordination failure. Nevertheless, in the two MC1 treatments the peer monitored groups were very successful in implementing a division rule in which full contribution to the team project is individually rational (see Figure 2a). They implemented HALF/HALF or ATIC in 93 percent of the cases. Figures 2b and 2c additionally show that contributions as well as payoffs under both sharing rules are extremely high. However, we observe an interesting difference between HALF/HALF and ATIC. A payoff-maximizing subject should contribute her full endowment under both division rules, because in both cases one unit of contribution is repaid by more than one, for all possible actions of the other team members. Nevertheless we observe that contributions under ATIC are on average 9.9, whereas contributions under HALF/HALF are on average 8.7. The difference is significant ($p < 0.001$, two tailed exact Wilcoxon test). The explanation for this phenomenon may be attributed to social preferences. Under ATIC only the contributing team member profits from her contribution, whereas under HALF/HALF all other team members also profit (at least partly). Although it maximizes the individual payoff, a team member may (for example, due to fairness concerns) withhold contribution in order to reduce a potential free-rider's benefit from her contributions.

Result 2: *Peer monitoring performs extremely well: in 93 percent of the cases a rule capable of eliciting full contributions is reached; contributions are near 100 percent of endowments and payoffs are high.*

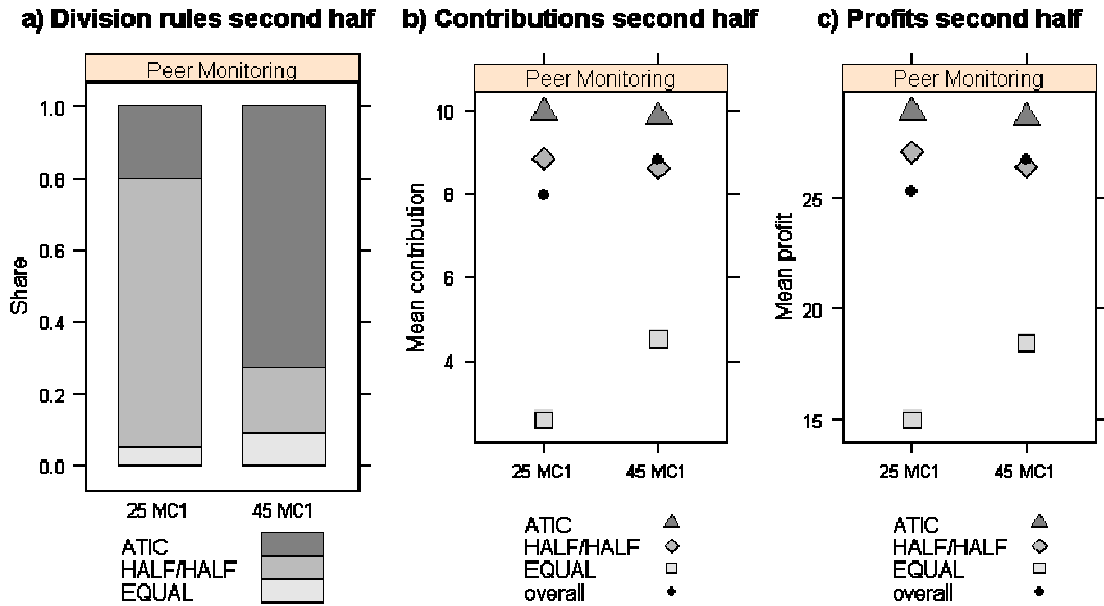


Figure 2: a) Frequency of implemented division rules; b) Contributions; c) Payoffs; displayed are averages over the observations in the second half

An interesting finding is that the average payoffs in 45MC1 are significantly higher than in 25MC1 ($p=0.043$ one sided Mann-Whitney U), although 4 instead of 2 units of monitoring are required to make full contribution individually rational. The reason is the extremely high number of implementations of ATIC in 45MC1 accompanied by high contributions in ATIC (see above). This means that subjects invest more in monitoring than would be necessary to make full contributions to the team project individually rational. How can we explain why subjects achieve ATIC more often in the treatments with 4-5 step, although this constitutes “overinvestment” in monitoring? A likely reason is that by “overinvestment” in monitoring, the risk of coordination failure is reduced at a low cost. Considering the impossibility of reaching and sharing a decision on which of the five team members will refrain from monitoring each period, most team members decide to monitor every period, for the sake of safety. Not only is the average cost of over-monitoring to each subject only one unit every five periods, but in practice that cost is not wasted, given that subjects respond to ATIC with more effort than to HALF/HALF. The histograms of the total investment M in Figure 3 show systematic “overinvestment” in monitoring, that is team members manage to “solve” the coordination problem by higher investments in monitoring, which is a cheaper way than hiring the observer.

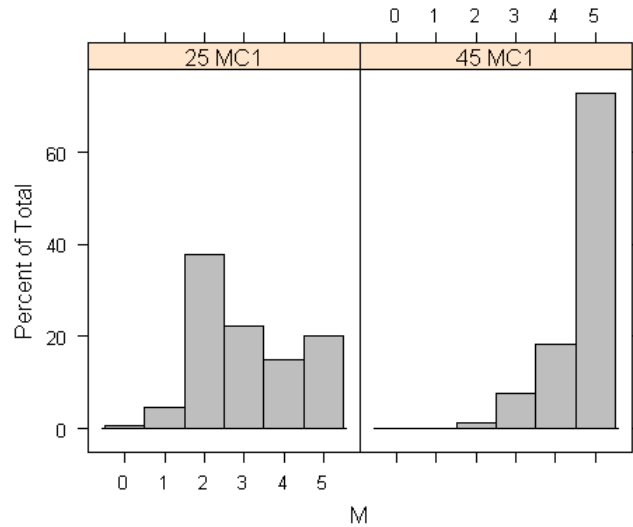


Figure 3: Histogram of the sum of investments in peer monitoring; displayed are averages over the observations in the second half.

4.2. Causes

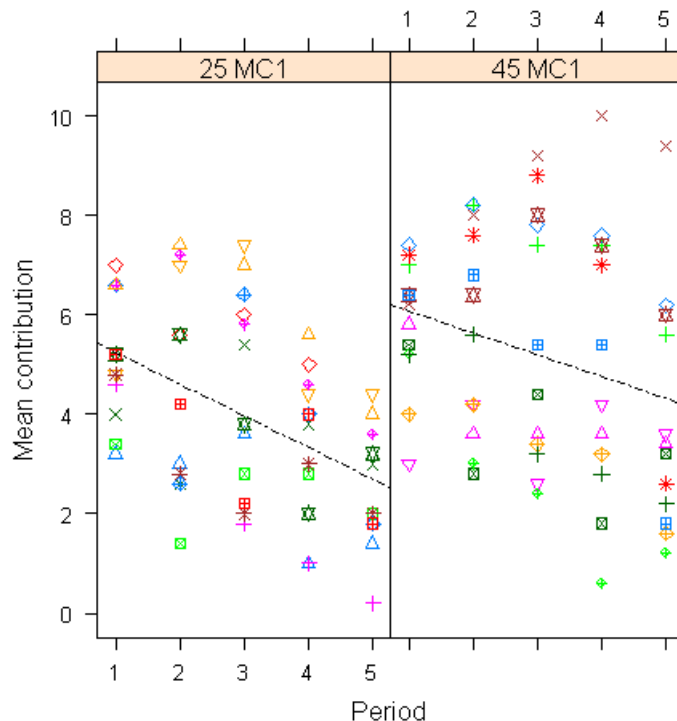
Why did subjects select peer monitoring from their first opportunity to vote on the matter, and how were they able to succeed with it despite a coordination problem exacerbated by inability to communicate and incomplete feedback about others' choices? We begin by analyzing behaviours in the first half of the experiment, with its exogenous phases of no monitoring, peer monitoring, and observer monitoring.

How did subjects respond to the various division rules? The results of the first phase of play, in which subjects interact in a classical prisoners' dilemma environment, are well in line with the observations from numerous previous experimental studies of VCMs. As Figure 4 shows, average contributions start off at about half of the endowment and decrease from there on. In all four treatments we observe a negative trend in contributions over time¹¹ which is in line with past experiments¹² and illustrates Alchian and Demsetz's intuition about free riding if monitoring is absent, yet departs (as is

¹¹ A linear regression for each treatment in the first phase with the average (per group) contributions as dependent variables show significance at 1% level for the period for all treatments except the PO 45 MC1 treatment. (robust, Huber White standard errors). Also the tobit regressions on the individual contribution decisions of the peers (for the whole experiment) did show a significant negative trend over the time.

¹² See Ledyard (1995), for a review of the VCM literature.

typical in VCMs) from the strict theoretical prediction of zero contributions assuming payoff-maximizing agents.¹³



Legend: The symbols correspond to the independent observations.

Figure 4: Average contributions of the separate groups by period and treatment.

During the observer and peer monitoring periods of Phases II and III, subjects responded to HALF/HALF and ATIC division rules with considerable increases in contributions. There were, however, two mild surprises. First, as already noted for the exogenous rule phases, subjects contributed moderately but significantly more under ATIC than under HALF/HALF, even though a payoff-maximizing agent is predicted to contribute the full endowment under either division rule. Second, subjects tended to contribute somewhat less when the observer monitored than when the team members did. (The difference in response depending on who is monitoring is statistically significant for the HALF/HALF rule only.) Notice that the private marginal return from contribut-

¹³ There is by now an immense literature attempting to explain this anomaly. Some of the explanations emphasize heterogeneity of agent preferences, a matter to which we return shortly.

ing effort is smaller under HALF/HALF and under observer monitoring than under ATIC and peer monitoring. Perhaps subjects responded to differences in marginal returns, even though full contribution is privately optimal (since β and $\beta_S > 1$) for both division rules and both assignments of the monitoring role.

Result 3: *Responses to EQUAL division are consistent with those in the experimental literature on the voluntary contribution mechanism and with presence of a free-riding problem, though there is less free riding than theory predicts. Subjects also respond to changes in marginal private return associated with the difference between ATIC and HALF/HALF rules and with that between observer and peer monitoring, although theory predicts full contributions regardless of these differences.*

The surprises observed thus far are mild ones compared to the one we take up next: the fact that peers managed to supply incentive-imparting monitoring at least as often as did specialist observers. The peers chose an incentive compatible mechanism in 95 percent of the cases, the observers in 82.5 percent (in the first half). This difference is significant ($p=0.044$, exact Wilcoxon signed rank test).

Result 4: *Failure to achieve a division rule providing incentives to contribute the full endowment occurred less often in the exogenous peer than in the exogenous observer monitoring phases.*

Recall that a rational payoff-maximizing subject would not invest in monitoring unless she believed there to be a sufficient chance that the others' monitoring choices were leaving the group one unit short of that required for HALF/HALF division, as would be the case were subjects able to coordinate on a monitoring strategy. Since subjects could not communicate and since their only feedback about others' monitoring choices was information about the rule achieved, they faced a severe co-ordination problem. No such problem was faced by the observer. Yet, as Figure 5a shows, observers failed to provide enough monitoring to reach HALF/HALF division more often than did peers in both 25MC1 and 45MC1.

How did the teams manage the coordination problem? One explanation could be as follows: because wasting a unit on monitoring is better than losing many units by ending up with equal division, and because the simultaneous avoidance of such waste and

assurance of HALF-HALF division is made impossible by lack of coordinating devices, subjects could adopt the strategy “invest in monitoring regardless of others’ choices”—or what can be called an “overprovision strategy”.¹⁴ “Non-standard” or social preferences could also play a part. Suppose, for example, that some subjects are conditional cooperators in the sense of Fehr and Gächter (2000) and Fischbacher, Gächter and Fehr (2001). For such individuals, the (subjective) payoffs in a VCM may resemble those of an assurance or stag hunt game more than those of a prisoners’ dilemma. Their presence could help to explain the higher-than-predicted contributions in Phase I, and likewise would account for propensities to contribute to monitoring even if coordination were impossible or if no equilibrium strategies existed, for payoff-maximizers.¹⁵

Evidence that subjects with preference-based inclinations to cooperate account both for some contributions and some monitoring could take the form of a significant correlation between contributions especially in the first period of Phase I, and average monitoring during a peer monitoring phase. We checked the correlation at individual subject level between monitoring investment during the exogenous peer monitoring phase and first period contribution in Phase I. Pooling the data for the four MC1 treatments, we found a significant correlation, with the asymptotic Spearman correlation test, stratified by treatment, having a p-value of 0.016. Statistical tests confirm that team member earnings were significantly higher under exogenous peer than under exogenous observer monitoring ($p < 0.01$ percent Mann-U).

Result 5: Team members’ earnings were lower under exogenous observer than under exogenous peer monitoring.

The fact that team members earned more in the first half under peer than under observer monitoring seems sufficient to explain why they voted to implement peer rather

¹⁴ Note that in the setting of our experiment a group could succeed in monitoring even if only two members adhered to an overprovision strategy, in 25MC1, or if four adhered to it in 45MC1.

¹⁵ Duffy, Ochs and Vesterlund (2006) find that subjects are not much more likely to complete a public project of fixed size when a final payoff jump causes equilibrium strategies in positive contributions to exist than when absence of such a jump makes a positive giving equilibrium theoretically non-existent. Their subjects’ contributions despite contrary equilibrium predictions for rational selfish agents resemble our team members’ provision of monitoring.

than observer monitoring in the second half of their sessions. Of course, if teams had then failed to achieve sufficient monitoring to sustain contributions in later phases, they might be expected to have switched to voting for observer monitoring. But no team experienced more than one period of incentive failure during phases IV and V, so their continued preference for peer monitoring is rational.¹⁶

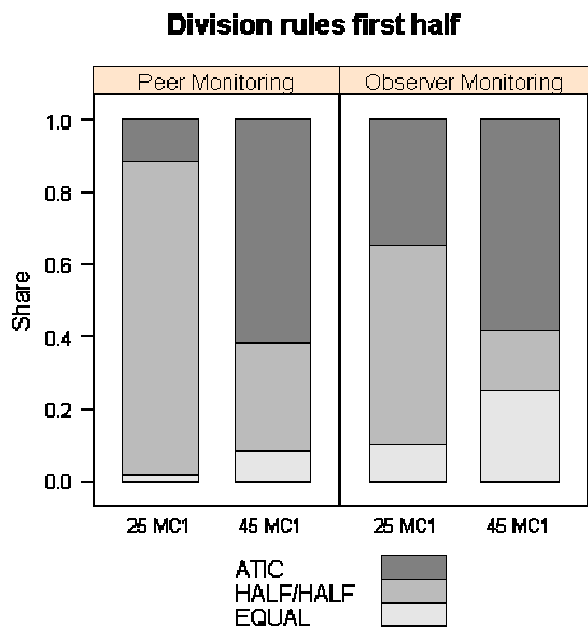


Figure 5a: Frequency of implemented division rules; displayed are averages over the observations in the first half in the 25MC1 and 45MC1 treatments

¹⁶ We can find no explanation for the one instance in which three of five team members voted for observer monitoring after Phase IV, occurring in OP25MC1. Although the team in question had achieved HALF/HALF monitoring in four of five periods of Phase II with a bare two subjects monitoring (achieving ATIC one time), team members have no way to know whether 2, 3 or 4 monitored, and their earnings were higher under peer (Phase II) than observer (Phase III) monitoring in every period. Non-parametric tests for differences between the antecedents of that vote and others in the MC1 treatments are impossible since the case in question is singular.

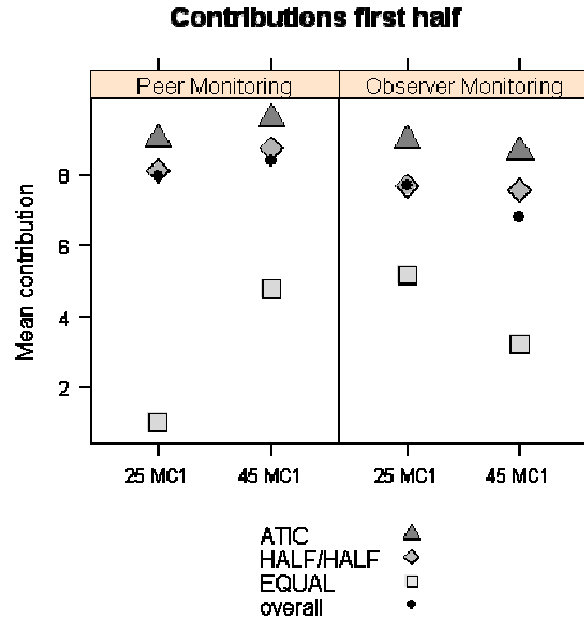


Figure 5b: Average contributions over the observations in the first half in the 25MC1 and 45MC1 treatments.

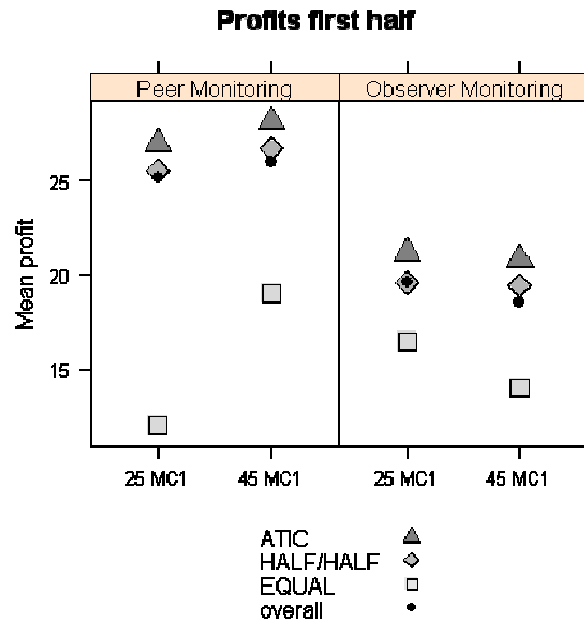


Figure 5c: Average profits over the observations in the first half in the 25MC1 and 45MC1 treatments.

5.3. Raising the bar – a further test

As we have seen, in sections 5.1 and 5.2 team members seem to reduce the risk of coordination failure by “overinvestment” in monitoring. Obviously, “overinvestment” in monitoring is not an equilibrium, since any individual has an incentive to deviate. But it

is a less costly way of achieving an incentive compatible division rule than “hiring” the observer to take the monitoring decision. In the light of these results we extended our analysis by conducting a new treatment PO45MC3 which is identical to PO45MC1, with the only exception that for the peers the cost of one unit of monitoring is raised to 3. This raises the bar for peer monitoring: it increases the cost of implementing the HALF/HALF rule from 4 to 12, triples the cost for implementing ATIC from 5 to 15, and it also triples the cost to the individual of adhering to an “overinvestment” strategy.¹⁷ Notice that the observer’s cost remains at 1 per unit of monitoring. We collected six independent observations in this treatment. Through this change monitoring by the observer should become more attractive because coordination and “overinvestment” in monitoring is more costly and hence can be expected to be more difficult to achieve.

Voting Results and Consequences

Indeed, we observe a sharp increase in voting results implementing observer monitoring. The observer was voted for by a majority in 61 percent of the 18 votes. Figure 7a shows that the observer implements ATIC in the majority of the cases. In response to this, team members make high contributions and receive payoffs which are diluted by the observer’s share of 25 percent. Interestingly, in those groups and phases in which peer monitoring was the voting choice, team members manage to achieve HALF/HALF or ATIC in almost 90 percent of periods. Hence, when peer monitoring is voted by the majority of the team, the team is quite successful in providing enough units of monitoring to provide incentives for making full contributions individually rational, despite the higher costs and continued, perhaps even exacerbated, coordination problem. Because of their success at monitoring and avoidance of the 25 percent observer charge, teams using peer monitoring earned significantly more than those with observer monitoring during the second half of the treatment.

Result 6: *If the unit cost of peer monitoring is raised to 3, the majority of teams vote for observer monitoring. However, almost 40 percent still vote for peer monitoring and perform well, out-earning those who hire the observer.*

¹⁷ As before, the monitoring charge is still paid out of end-of-round earnings, so it is possible to pay 3 to monitor, yet still contribute 10 to team production.

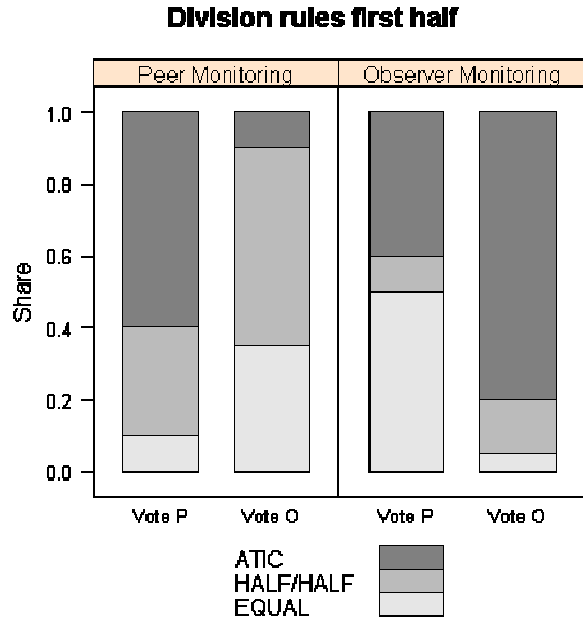


Figure 6a: Frequency of implemented division rules; displayed are averages over the observations in the first half of PO45MC3 comparing those groups voting for the observer (Vote O) with those who voted for peer monitoring (Vote P).

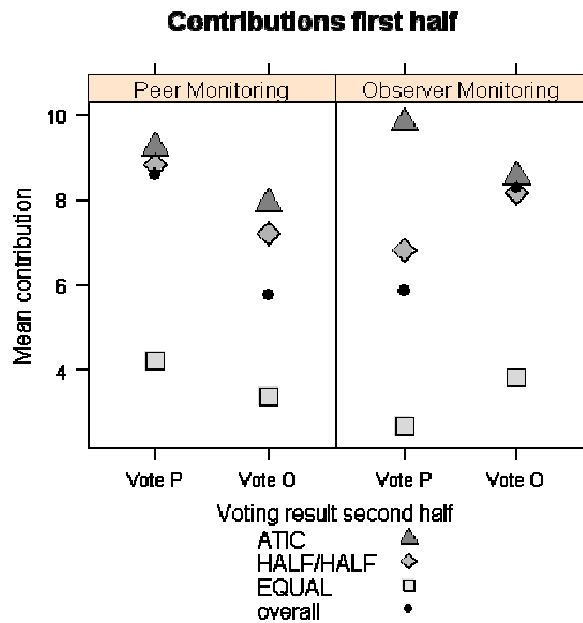


Figure 6b: Contributions; displayed are averages over the observations in the first half of PO45MC3 comparing those groups voting for the observer (Vote O) with those who voted for peer monitoring (Vote P).

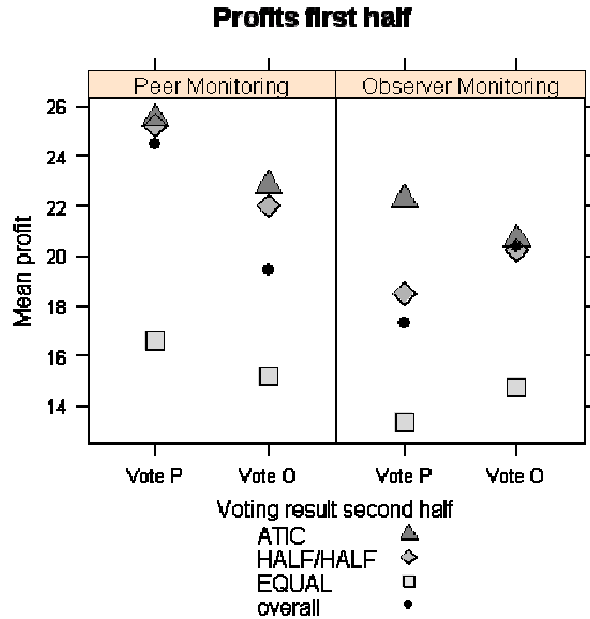


Figure 6c: Payoffs; displayed are averages over the independent observations in the first half of PO45MC3 comparing those groups voting for the observer (Vote O) with those who voted for peer monitoring (Vote P).

What is it that makes the observer model more appealing to subjects in PO45MC3? Figures 6a-c show the differences in the first half between those groups voting for the observer later on and those who did not. It is clear from Figure 6a that there were more failures to achieve HALF/HALF or ATIC under exogenous peer (observer) monitoring in groups that eventually voted for observer (peer) monitoring. Those groups which vote for peer monitoring experienced higher average contributions under peer monitoring in the first phase, while those who vote for observer monitoring experienced higher contributions under observer monitoring in the first phase (see Figure 6b). The same tendency is observed when looking at profits (see Figure 6c).

Figure 7 compares first half outcomes of all three treatments and reveals that the groups of the MC3 treatment achieved lower contributions on average, which is due to the mentioned failure to achieve appropriate payment systems. Figure 8 performs the corresponding comparison for the second half and shows that observers were more successful in achieving sustainable cooperation in that part of the experiment if they were voted in.

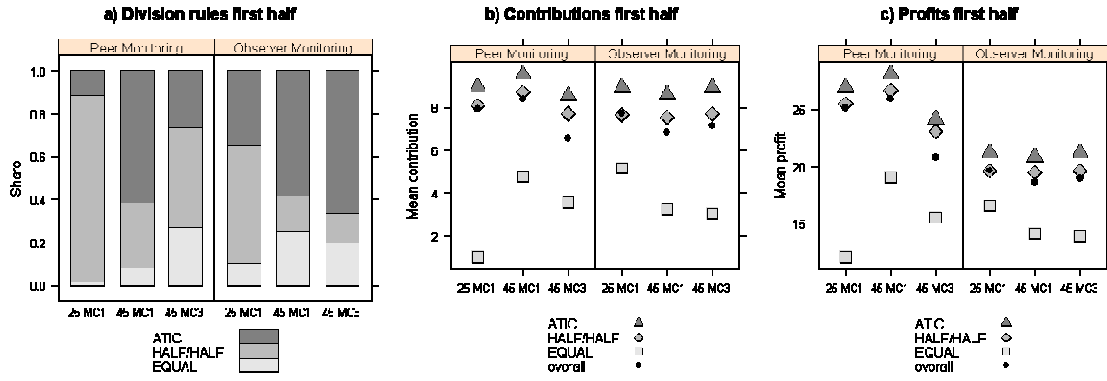


Figure 7: a) Frequency of implemented division rules; b) Contributions; c) Payoffs; displayed are averages over the independent observations in the first half all treatments.

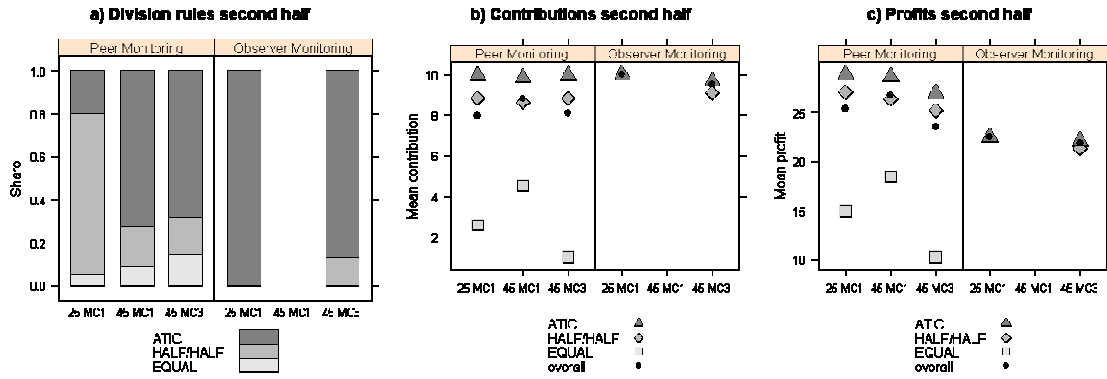


Figure 8: a) Frequency of implemented division rules; b) Contributions; c) Payoffs; displayed are averages over the independent observations in the second half all treatments.

6. Conclusions

We modelled team production as a process that varies in incentive features from a pure public goods game with free riding incentives to a privately profitable opportunity with payment in proportion to contribution, with intermediate options that we collapsed to a half/half incentive condition in our experiment. We made the incentive a function of costly investment in a process denoted monitoring. We compared two institutions, one in which monitoring is provided by a specialist who is compensated with a share of the team output, the other in which monitoring is provided by the production team members, who benefit from providing monitoring insofar as better incentives lead to more

contributions to production and hence to higher earnings. We investigated the claim that monitoring is usually provided by a residual-claiming specialist because team members have insufficient incentives and/or ability to coordinate on the provision of monitoring, and thus fail to provide adequate incentives to contribute effort to team production.

In our model and experiment, incentives for peer monitoring are potentially adequate, but there exists a severe coordination problem that makes success in peer monitoring improbable unless team members adopt an “over-provision” strategy with respect to which there are always incentives to free ride. Despite this, our experimental subjects were surprisingly successful in peer monitoring, eschewing the opportunity to use a specialist monitor almost every time they chose between the two options in treatments where monitoring was equally costly to both peers and observer. Only when monitoring costs of team members were raised dramatically were there a substantial number of peer monitoring failures and thus votes for a specialist monitor. Even so, some groups succeeded in peer monitoring and earned substantially more than those using a specialist, despite the higher cost.

Our experiment is the first to nest the VCM or public goods game within a set of team incentive conditions, and to make the choice of condition or incentive regime an endogenous one. Our subjects behaved rationally in that they usually voted for the institution that gave them the highest earnings. However, their success at peer monitoring is not likely to be attributable to the existence of strategies that make monitoring a dominant strategy. Given the severe difficulty of coordinating on such strategies, many subjects seemed to adopt an “over-provision” strategy which should in theory invite free riding but may not have done so in practice to the extent expected because of conditional willingness to cooperate. Conditional cooperation has been found among many subjects in recent VCM experiments¹⁸, and it may have been enhanced in the present experiment by the desire to avoid ceding a significant share of output to a specialist monitor.

¹⁸ Fehr and Gächter (2000b), Page et al. (2005), Gürer et al. (2006)

While our results cannot explain why mutual monitoring and profit-sharing is usually not relied upon as the main method of eliciting effort from workers in most actual firms, they are consistent with the fact that when profit-sharing is introduced, it is often successful at raising productivity (Weitzman and Kruse (1990), Craig and Pencavel (1995)). A typical claim of writers on the topic is that despite the free-riding incentives that some associate with profit-sharing (Baker, Jensen and Murphy, 1988), workers in many firms respond to it by mutually monitoring one another's effort and working harder (Kruse (1993)) either because of an identification with the firm's "bottom line," to avoid the reproach of fellow workers (Kandel and Lazear (1992)), or both. The upshot is that the facts that most residual claims are not held by workers and that firms employ substantial amounts of top-down monitoring may have to be explained by factors other than an inclination of workers to free ride in the provision of monitoring.

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