The pivotal mechanism revisited: Some evidence on group manipulation

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Working Papers in Economics and Statistics

2011-15

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The Pivotal Mechanism Revisited: Some Evidence on Group Manipulation

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July 26, 2011

Abstract

This paper studies the vulnerability of the pivotal mechanism with respect to manipulation by groups. In a lab experiment, groups decide on the implementation of various alternatives, some of which imply opposite interests for the two subgroups. We investigate the occurrence of tacit and explicit collusion by allowing for communication within subgroups in one treatment and prohibiting it in another. Even though all agents' preferences are common knowledge and there exists a simple symmetric collusive strategy for one subgroup, we find little evidence for tacit collusion, not even with increasing experience. Only when explicit communication is allowed, collusion is established, and it becomes even more pronounced over time.

Keywords: Collective Decision Making, Pivotal Mechanism, Collusion

JEL Classification: D71, D61, C92

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1 Introduction

The pivotal mechanism (Clarke 1971) is a demand revealing mechanism developed for public goods decisions which proposes an efficient solution to the question of whether or not a public good of a given size should be provided. It uses a transfer system such that each individual takes into account the marginal social impact on the rest of society made by this individual's vote or report. In environments with quasi-linear preferences revelation of true preferences is then a dominant strategy.[1] The pivotal mechanism has a remarkable standing in the literature: It is one of the most well-known mechanisms in social choice theory, present in each textbook of public choice since decades. Despite being a nice theoretical construct, it has experienced a less successful history with respect to its applications in the context of public goods provision.

This paper reports the results of an experiment that studies how the lack of coalition-proofness affects the performance of the pivotal mechanism. Already in the 70s, Groves and Ledyard (1977a, 1977b) pointed out some shortcomings of demand revealing mechanisms that may affect the desired efficient allocation in a public goods context. Besides the failure to produce a budget balance they also noted that the mechanisms are vulnerability to strategic manipulation by coalitions of agents which would move the outcome away from Pareto optimality. Tideman and Tullock (1977), on the other hand, considered this a characteristic of all group processes including markets and majority rules, thus defending the applicability of demand-revealing processes. Green and Laffont (1979) later provided a formal proof for the impossibility of finding coalition incentive compatible Groves mechanisms, even if only a single coalition with two or more agents can be formed.

Whether and when groups can successfully manipulate the pivotal mechanism is an empirical question, which will be studied in this paper. The possibility of manipulation is relevant in a situation which allows a (sub)group of decision makers to coordinate their actions in order to obtain an outcome that is preferred by this group. We shall also refer to such actions as collusive behavior. One setting in which a collusive outcome may be expected is when communication amongst agents is possible. But from a theoretical perspective, collusion may also occur *tacitly* in the absence of explicit communication, in particular in a setting with rational and selfish agents who have complete information about other agents' preferences. Empirically, it is far from clear *a priori* whether and when collusion will actually occur in a given setup. There are at least three immediate motives for which

[1]Groves (1973), as well as Groves and Loeb (1975), and much earlier Vickrey (1961) independently also discovered such incentive compatible demand revealing mechanisms for environments with separable utility functions. Green and Laffont (1977) showed that the class of mechanisms proposed by Groves includes all these mechanisms, and furthermore that any efficient and strategy-proof direct revelation mechanism is isomorphic to a Groves mechanism.

such behavior may not be observed: First, a misrepresentation of preferences that leads to higher payoffs for a coalition requires that agents are able to identify such manipulation possibilities, thus limitations in cognitive abilities may prevent agents from collusive behavior. Second, agents may not be sufficiently confident about collusive behavior of other agents, thus complete information about other agents' preferences might not be sufficient to predict the occurrence of collusion as long as there is uncertainty about others' choices. And third, if one departs from the assumption of purely self-interested agents, it is possible that social preferences prevent agents from collusive behavior if the consequences are harsh for others. Expressed differently, the mechanism might work despite the theoretical prediction of collusion.

Experimental methods seem to be a useful tool to identify properties of this mechanism that are responsible for the difficulties in application. So far, experimental literature on the pivotal mechanism focussed on the (serious) problem that people do not seem to choose dominant strategies, that is, truth-telling is actually not implemented in the pivotal mechanism.[2] It was always suspected that this mechanism is too complex to be well-understood for applications and it therefore may not fulfill its intended purpose of revealing true preferences. This view was supported by the study of Attiyeh, Franciosi and Isaac (2000), who found that less than 10% of subjects revealed their true valuation for the public good, and moreover, no tendency toward the dominant strategy prediction was observed over time. The results suggested that due to its complexity the mechanism is inadequate for applications in the demand for public goods.[3] On the other hand, Kawagoe and Mori (2001) showed that there is a remedy to subjects' confusion caused by the complexity of the mechanism. When subjects were presented detailed payoff tables in addition to the abstract rule that maps bids to outcomes, nearly one half of the subjects played the dominant strategy. Kawagoe and Mori further argue that the bad performance of the pivotal mechanism in Attiyeh et el. (2000) may be due to the lack of *strict* incentive compatibility, i.e., since there exists a large number of strategies that leave subjects as well off as truth-telling for a wide range of strategies chosen by others, it is difficult for subjects to see why truth-telling is the unique dominant strategy. Finally, Cason et al. (2006) study the effect of secure implementation, which refers to mechanisms that ensure dominant strategy implementation with the additional requirement that there be no Nash equilibrium outcome other than the dominant strategy equilibrium outcome. This is not given in the pivotal mechanism, as there exist multiple Nash equilibria, in particular

[2]One of the early experiments by Tideman (1983) already suggested this possibility. However, this experiment was a kind of field experiment with little control over the factors that impact decisions, thus misrevelation could not be quantified.

[3]Note that in in computer science applications, the class of Vickrey-Groves-Clarke mechanisms is widely used, e.g. in resolving task and resource allocation problems that occur in multi-agent systems (see e.g. Dash, Rogers and Jennings 2003, or Dash, Park and Jennings 2004).

bad Nash equilibria which are Pareto inferior to the dominant strategy outcome. Cason et al. (2006) found that the proportion of dominant strategy equilibrium outcomes increases from 50% for a pivotal mechanism, where implementation is not secure, to 81% for a securely implementable Groves-Clarke mechanism with single peaked preferences. As in Kawagoe and Mori (2001), the instructions contained detailed payoff tables. After the disappointing results of Attiyeh et al. (2000), these findings shed a much more positive light on the pivotal mechanism.

In this paper, we study the open question of the mechanism's vulnerability with respect to manipulation by groups. The existence of a simple misrepresentation of preferences that leads to an increase in payoffs does not necessarily imply that strategic manipulation is actually observed: This is the result of an experimental study on the Borda mechanism by Kube and Puppe (2009). They showed that the lack of strategy-proofness, which is a well-known flaw of this mechanism, does not have the effect one may expect: Manipulations rates were found to be surprisingly low even when the voter who had complete information about the other agent's preferences knew about his superior position. Only when the agent with superior information was also informed about the other agent's actual vote, manipulation rates went up significantly. This suggests that behavior in their context is affected by uncertainty, while distributional concerns, in particular inequality aversion, do not seem to play an important role. The authors conclude that the fear of strategic manipulation is not always justified in an applied framework.

To investigate the effect from the lack of collusion-proofness, we consider a simple setting in which all agents are informed about others' preferences in order to facilitate the occurrence of collusion. In addition, we will vary the possibility to communicate: In one treatment, agents make individual decisions without communication, and thus only tacit collusion is possible. In the other treatment, a particular communication network exists, which allows agents to communicate and co-ordinate their decisions within their subgroup. This setup shall give some insight into the question whether collusion can occur tacitly, i.e. without explicit communication, but simply from learning or observing others' behavior over time, or whether other motives, such as distributional concerns, prevent subjects from colluding when some subjects would suffer significantly from the collusive outcome.

2 Experimental Design

Consider a group of five members, who all have given preferences over four different alternatives Alpha (A), Beta (B), Gamma (C), and Delta (D). Each alternative a represents a non-excludable public good, and agents face the decision whether or not each public good should be provided. The group consists of two subgroups: the "majority" of 3 voters, referred to as M-type agents (indexed as $m = M_1, M_2, M_3$), and the "minority" of 2 voters, referred to as N-type agents (indexed as $n = N_1, N_2$. All members within a subgroup have identical (induced) preferences, but preferences across the two subgroups differ. The true valuation v_i^a of agent i for each alternative a is represented in Table 1. All agents have full information about the valuations of the other agents and the structure of the group.

Table 1: Net valuations for the four alternatives

agent	Alpha	Beta	Gamma	Delta
M-type	30	-20	-30	10
N-type	10	40	-20	-40
group	110	20	-130	-50

The outcome is determined as follows: Each agent i submits a report r_i^a for each alternative a, which may or may not correspond to this agent's true valuation v_i^a. We shall allow for reported values between -60 and 60 in steps of 10. An alternative a is selected (the public good is implemented) if and only if the sum of all reported valuations for a is strictly positive ($\sum_i r_i^a > 0$). The number of selected alternatives is thus endogenously determined. Furthermore, if an agent is pivotal in the decision, he has to pay the Clarke tax, which corresponds to the total amount reported by all other agents, i.e. it reflects the cost that this agent imposes on the rest of society by changing the decision. Let r_{-i}^a be the vector of reports for alternative a omitting the report of agent i. Then the Clarke tax t_i^a, which agent i has to pay for alternative a, is calculated as follows:

$$t_i^a = \begin{cases} 0 & \text{if } r_i^a \leq 0 \text{ and } \sum_{j \neq i} r_j^a \leq 0 \text{ or } r_i^a > 0 \text{ and } \sum_{j \neq i} r_j^a > 0 \\ \sum_{j \neq i} |r_j^a| & \text{if } \sum_i r_i^a > 0 \text{ and } \sum_{j \neq i} r_j^a \leq 0, \text{ or} \\ & \text{if } \sum_i r_i^a \leq 0 \text{ and } \sum_{j \neq i} r_j^a > 0 \end{cases}$$

Each subject in the experiment thus had to submit four reports, one for each alternative. The simultaneous reports then determined which of the four alternatives would be selected. The total payoff of a player is the sum of the payoffs from the selected (winner) alternatives minus the respective tax he has to pay. Subjects were explained on the instruction sheets how payoffs are calculated. In addition, we prepared detailed payoff tables that include the Clarke tax (see Figures 9-12 in the Appendix), so that subjects could also read off the tables what their payoff for each possible combination of chosen values would be.[4]

[4]From the payoff tables one can see that agents are indifferent between stating their true valuation and the next higher valuation for all alternatives, e.g. for M-types, the same payoff is reached for Alpha by reporting 30 or 40, for Beta with -20 and -10, etc. This is simply an artifact of the discrete space of reports, which implies that each agent has two weakly dominant

The valuations for each type are chosen such that there should be consensus regarding the provision of alternatives Alpha (positive valuation for both types) and Gamma (negative valuation for both types). A major conflict of interest between the two subgroups is expected for alternatives Beta and Delta. Since our research question regards susceptibility of the pivotal mechanism to collusion, we used a complete information setup that enhances the occurrence of collusion and gives simple and precise theoretical predictions. All subjects played 10 rounds of this game. They were paid out 5 cents for each point earned in the experiment. Since N-types were likely to make losses, they received a bonus of 15 Euros at the beginning of the experiment; losses were then subtracted from this bonus. Subjects were not informed at any time about the actual reports of any other subject. Feedback only included the total sum of reported values for each alternative and own payoffs from all four alternatives. We used communication as a control variable to differentiate between tacit and explicit collusion. In the *No Communication* treatment, subjects had no possibility of communication, while in the *Communication* treatment we allowed for communication within a subgroup but not between subgroups. This is sufficient in order for subgroups with identical preferences to coordinate their reports.[5] Communication was possible by using a chat program via computers, which closed after five minutes. Chatting was anonymous, and any sort of agreement made via chat is non-binding. The experiment was run on computers using the software *z-tree* (Fischbacher 2007). Average earnings were 10.30 Euros, and the duration of a session was about 45 minutes. A total of 80 subjects participated in this experiment at the University of Innsbruck, they were equally distributed between the two treatments.

3 Predictions

Agents in our game have to submit one report for each of the four alternatives. The total payoff of a player is the sum of the payoffs resulting from the decisions on each alternative. As a theoretical benchmark, we assume additively separable utility functions, and we may thus consider the decision for each alternative separately.[6] The pivotal mechanism is designed such that individual agents have an incentive to report their true valuation for an alternative. In the absence of collusion possibilities, with a discrete strategy space and a binary decision regarding the selection of an alternative each agent has two weakly dominant strategies for

strategies in the pivotal mechanism. For the choice of the socially efficient outcome it does not matter which of these two strategies is selected.

[5]Agents of different type have no incentive to collude by virtue of their opposed preferences for alternatives Beta and Delta.

[6]This shall serve as main benchmark. In the section describing the experimental results, we will also discuss the case where agents bundle the alternatives.

each alternative: reporting the true valuation or its next-highest level (see footnote 4). Reporting a dominant strategy would then ensure that the social optimum is achieved. In our experiment this means that only Alpha and Beta should be selected, since only for these two alternatives the sum of the valuations for all group members is strictly positive.

In games where collusion is beneficial for a subset of players, coordination of individual behavior is crucial to achieve the collusive outcome. The concept of strong equilibrium by Aumann (1959) requires that such a collusive agreement is not subject to an improving deviation by any coalition of players. A deviation is self-enforcing when there are no further profitable deviations for a subset of players. Auman's (1959) strong equilibrium does not require deviations to be self-enforcing, i.e. an agreement has to be resistent to any deviation which itself is not required to be resistent to further deviations. This is a strong requirement for non-cooperative games like ours where pre-play communication is allowed, but agreements on coordinated actions are non-binding. Bernheim, Peleg and Whinston (1987) suggested that such agreements should be self-enforcing. Thus, they require for their notion of coalition-proof Nash equilibrium (CPNE) that an agreement is a Nash equilibrium and immune to improving deviations which are self-enforcing. We will use this equilibrium notion as a theoretical benchmark for the collusion case.[7] As Peleg (1998) showed for a two-person example, the profile of true preferences in the pivotal mechanism is not a CPNE, as other Nash equilibrium profiles exist that Pareto dominate truth-telling.

As for CPNE in our setup, note that Alpha and Gamma do not impose any conflicts of interest upon the two types, since Alpha offers a positive and Gamma a negative payoff for all. Thus, in a CPNE we must have that Alpha is selected and no player has to pay the Clarke tax, while Gamma is not selected and no player pays a tax. If one or more players would have to pay a tax, they would prefer to revise their report such that they do not need to pay the tax. Such a deviation would be self-enforcing, as there exist profiles of reports for Alpha and Gamma such that no player has to pay a tax. For Alpha, a CPNE is thus a profile of reports such that $\sum_i r_i^A - \max_i\{r_i^A\} > 0$, while for Gamma, a CPNE is a profile of reports such that $\sum_i r_i^C - \min_i\{r_i^C\} \leq 0$. There is a large set of CPNE for Alpha and Gamma, but the *CPNE outcome* is unique. Due to the lack of conflict, these two alternatives are less interesting and shall serve mostly as a reference regarding

[7]Moreno and Wooders (1996) pointed out that in a game with pre-play communication, however, players may correlate their actions, thus the set of all correlated strategies should be taken as the space of feasible agreements. They then define a coalition-proof equilibrium as an agreement for which no coalition (including the grand coalition) has a self-enforcing deviation that makes all its members better off. We will focus on pure strategies for our experiment, as the number of pure strategy equilibria is large, and equilibria using mixed or correlated strategies require even more sophistication by players.

subjects' understanding of simple decisions compared to the more complex ones for Beta and Delta.

Regarding the CPNE for alternatives Beta and Delta, note that by coordinating behavior the majority can ensure that their preferred outcome is implemented. For Beta, a symmetric strategy for all M-types of reporting -60 ("maximally underreporting") leads to a CPNE outcome, since, irrespective of the N-types' reports, Beta is not selected and no M-type pays a tax, thus no coalition of M-types can improve upon this outcome. A similar reasoning applies to Delta when the coalition of M-types maximally overreports. However, there are many other CPNE, which shall be characterized in the following.

(i) *In a CPNE Beta must not be selected and Delta must be selected.* Suppose otherwise, i.e. suppose Beta is selected (Delta is not selected). This implies a payoff of -20 (0) for M-types. But the coalition of all M-types can guarantee a payoff of 0 (10) for each M-type by maximally underreporting (maximally overreporting).

(ii) *In a CPNE only coalitions consisting of agents of the same type need to be considered.* To see this, consider a profile of reports that induces a given outcome regarding Beta. Suppose now that there exists a coalition including an M-type and an N-type who deviate in order to improve upon this outcome. If Beta is selected after the deviation, this deviation cannot be self-enforcing, since the coalition of all M-types can always ensure their preferred outcome in which Beta is not selected and no M-type pays a tax. If Beta is not selected after the deviation, then an N-type would only participate in this coalition if he would have to pay a tax of more than 40 before. This means that the original outcome must have selected Beta (otherwise the N-type would not pay a tax). But then it is again sufficient to consider only the coalition of all three M-types who can ensure to avoid the selection of Beta. A similar argument applies to Delta.

(iii) *In a CPNE no N-type pays a tax.* Since N-types do not get their preferred outcome with regard to Beta and Delta in a CPNE, they cannot be pivotal since that would mean that they submitted a report that goes against their preferred outcome.

(iv) *A CPNE in which all three M-types pay a tax does not exist.* Suppose otherwise, then the coalition of all M-types could improve by maximally underreporting for Beta and maximally overreporting for Delta, in which case no M-types pays a tax.

(v) *In a CPNE we must have for Beta $\sum_m r_m^B \leq -100$ and for Delta $\sum_m r_m^D \geq 100$, for $m = M_1, M_2, M_3$.* Recall that in a CPNE Beta must not be implemented. To achieve this, it is sufficient for M-types to submit reports such that the tax for N-types would be higher than the benefit of having Beta selected. When $\sum_m r_m^B \leq -100$, at least one N-types would have to pay a tax of more than 40 and thus prefer not to have Beta implemented. A similar argument applies to Delta.

In a CPNE, M-types thus submit reports such that either one, or two, or none of the M-types pays a tax. Furthermore, if two M-types pay a tax, at least one of them must report -60. Otherwise they could decrease their tax by reporting -60 and would thus both be strictly better off. This characterization of CPNE for Beta and Delta helps to identify all CPNE (by computer programming); there are 26195 CPNE for Beta and 25484 CPNE for Delta.

Amongst the large set of CPNE, those with symmetric reports on the boundary of the strategy space for each M-type, i.e. maximally underreporting for Beta and maximally overreporting for Delta, seem particularly appealing. These extreme reports avoid tax payments and ensure the preferred outcome of the coalition of M-types *independent* of the reports of N-types. Therefore, they are weakly dominant for the coalition of M-types and should be of particular appeal in an experimental setup. We are interested in observing whether collusion can be established, and this seems a particularly simple way to achieve such collusive outcome, as it avoids difficulties in coordination. Furthermore, we know from experimental evidence in Charness et al. (2007) that salient group membership induces individual behavior towards more favorable outcomes for other group members, therefore, by the design of two subgroups with partly opposed interests, belonging to the majority would imply that M-types prefer the symmetric extreme reports to any other CPNE profile where some agent risks to pay a tax. And if our design of majority versus minority does create a feeling of competition towards the other subgroup, it would also lead us to expect better coordination, as Bornstein et al. (2002) have shown in their intergroup competition in a coordination game. While one may expect that this CPNE with extreme reports for M-types can also occur in the treatment without communication due to its simplicity and symmetry, it seems rather unlikely that any other (asymmetric) CPNE strategy profile can be achieved without explicit communication. Therefore, we take CPNE with symmetric reports for the M-types as a benchmark for identification of possible tacit collusion in the treatment without communication. Since any report of N-types is a best response to this weakly dominant strategy for the coalition of M-types, we have $13^2 = 169$ of these equilibria for both Beta and Delta, in which the strategies of all M-types are identical.

4 Experimental Results

4.1 No Communication Treatment

Outcomes: Selected alternatives. Recall that an alternative a is selected if the sum of all reports is strictly positive: $\sum_i r_i^a > 0$. Table 2 shows the observed frequencies of the various combinations of alternatives over all rounds in the treatment without communication. First, notice that Alpha, which is the only alternative that gives both types a positive payoff, was always selected. Gamma, the only alternative that gives both types a negative payoff, was selected in less than 5%, which is in the range of typical errors of subjects in experiments. Regarding the two alternatives where preferences are opposite, Delta, the majority's preferred outcome, was selected in 63%, while Beta, implementing the preferred outcome of the minority, was selected in 70%. Interestingly, Beta and Delta were selected simultaneously in a significant number of games. It is easily seen that three combinations of outcomes are predominant in this treatment: the social optimum {Alpha, Beta} occurred in 35%, the best possible collusive outcome for M-types {Alpha, Delta} in 27.5%, and then we observe the combination {Alpha, Beta, Delta} in 31% of all outcomes in this treatment. The first important results are thus that (i) tacit collusion does not easily emerge when communication between agents is not possible, despite full information and a seemingly easy-to-achieve, symmetric collusive outcome, and (ii) the social optimum still plays an important role. Furthermore, we have a third prominent outcome, {Alpha, Beta, Delta}, which needs further investigation. It shall be checked whether this was due to unsuccessful attempts of tacit collusion or whether subjects possibly considered it a desirable outcome for reasons other than selfish profit maximization.

Table 2: No Communication: Frequencies of Selected Bundles

1 winner	2 winners	3 winners	4 winners
A: 1 (1.25%)	AB: 28 (35%) AC: 0 (0.0%) AD: 22 (27.5%)	ABC: 1 (1.25%) ABD: 25 (31.25%) ACD:1 (1.25%)	ABCD: 2(2.5%)

(A=Alpha, B=Beta, C=Gamma, D=Delta)

If the triple {Alpha, Beta, Delta} is regarded as a bundle, this bundle offers a total payoff of 20 for M-types and 10 for N-types. Assuming that there are subjects with distributional concerns such as a self-centered inequality aversion as introduced by Fehr and Schmidt (1999) and further extended by Charness and Rabin (2002), these subjects may consider {Alpha, Beta, Delta} as the bundle offering the least unequal positive payoff for the two types of players. In particular, this bundle still favors the majority and may thus be more easily supported by M-types. Compared to this bundle, the collusive outcome {Alpha, Delta} implies a negative payoff of -30 for the minority; the social optimum {Alpha, Beta} would imply positive payoffs for both types, but they are highly unequal and favor the minority. The only other possible outcome which implies positive payoffs to both types is to select only Alpha, but the payoffs of 30 to M-types and 10 to N-types would again emphasize the inequality of payoffs for the two types of agents. The bundle {Alpha, Beta, Delta} is implementing payoffs that are as close as possible to equal positive payoffs for all agents. If there are subjects with distributional preferences, this may well represent their preferred choice.[8]

	Round									
Group	1	2	3	4	5	6	7	8	9	10
1	AB	ABD	ABD	ABD	ABD	AD	ABD	AB	ABD	ABD
2	AD	AD	AD	AD	AD	ABD	AD	AD	AD	AD
3	ABD	AD	ABD	AD	AD	AD	ABD	AB	A	ABD
4	AD	ABD	ABD	ABD	ACD	ABD	AB	ABC	AD	AD
5	AB	AB	AB	AB	AB	ABD	ABD	AB	AB	AB
6	AB	ABD	AB	AB	AB	ABCD	AD	AB	AB	AB
7	AD	ABD	AD	ABD	AB	AB	AD	ABD	AB	AB
8	AD	ABD	ABD	ABCD	ABD	AB	AB	AB	AB	AB

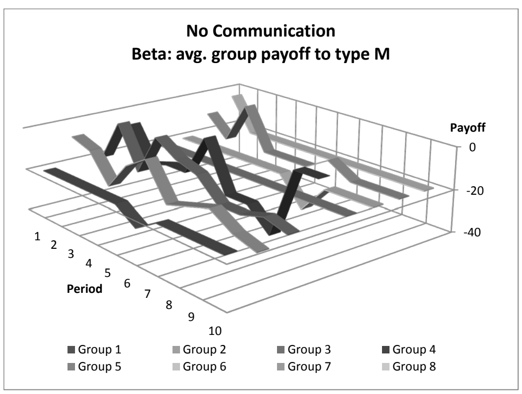
(A=Alpha, B=Beta, C=Gamma, D=Delta)

Figure 1: No Communication: All Outcomes over time

To answer the question whether this choice, which occurred in over 30% of all outcomes for the treatment without communication, came about as a purposeful choice or if it happened due to insufficient coordination, we first look at decisions over time. Figure 1, which displays all selected alternatives for each group and each period, offers a first impression of how possible learning of coordinating reports through repeated interaction affects outcomes. We define the first three rounds as "early" rounds and the last three as "late" rounds in the experiment. Then the choice of selecting bundle {Alpha, Beta, Delta} occurs significantly more often in earlier rounds than in later rounds (two-sample Wilcoxon rank sum test (MWU): $p = 0.05$), which points towards an unintended outcome, since experience leads away from selecting this bundle. This would be in line with the findings of Puppe and Kube (2009), where no evidence for behavior that could be interpreted as a preference for inequality aversion was found. Our results below for the treatment with communication will confirm this result.

[8]For example, in the Fehr-Schmidt (1999) model of inequality aversion this would be the preferred choice of an N-type agent if the parameter β, which measures the weight the agent puts on others' monetary payoffs when he is behind, is sufficiently high.

A comparison of the frequency of selected outcomes over time further confirms that M-types did not succeed in establishing tacit collusion on {Alpha, Delta}. There is no significant difference in the occurrence of {Alpha, Delta} in early and late rounds (MWU: $p = 0.33$), i.e. collusion does not become more prevalent even though subjects gain experience and learn about other agents' reporting behavior in their own group. Learning or experience alone was thus not sufficient to establish collusion amongst M-types. The social optimum, on the other hand, gains importance with subjects' experience. {Alpha, Beta} is selected significantly more often in later rounds compared to earlier rounds (MWU: $p < 0.05$). In late rounds, {Alpha, Beta} was selected in 54% of all group decisions, which corresponds to the implementation of the first-best outcome through the pivotal mechanism in other experiments where collusion was not possible (e.g. Cason et al. 2006). This result might, however, not be due to the pivotal mechanism's incentive to submit truthful reports (or at least to select a dominant strategy), but rather due to unsuccessful attempts of M-types to tacitly collude and the time needed for N-types to understand how to co-ordinate on the reports of Beta. This shall be further investigated in subjects' reports below.



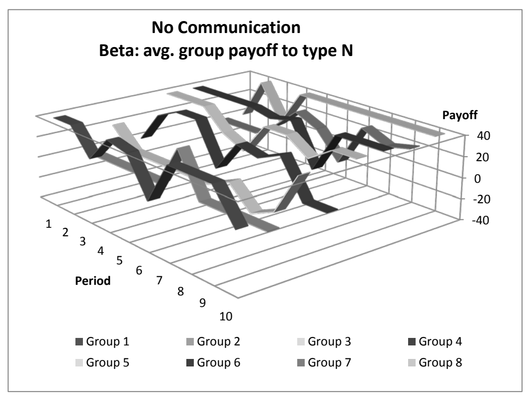


Figure 2: No Communication: Average group payoffs for Beta by type

Outcomes: Tax payments and Payoffs. Describing outcomes only in terms of selected alternatives is not sufficient in order to evaluate the performance of the pivotal mechanism and the occurrence of collusion. Since tax payments may be considerable, overall payoffs have to be considered. Furthermore, payoffs over time should give information about subjects' possible adjustments after observing outcomes and payoffs in previous rounds. For Alpha and Gamma, there were overall few tax payments (less than 5%). Figures 2 and 3 separately display the average payoffs (including taxes) M-types and N-types achieved in each group for alternatives Beta and Delta over the 10 rounds. Since Beta was selected in over 70%, it is important to understand at which cost for N-types this outcome came about. Of 160 decisions of N-types, in almost 20% a tax was paid to have Beta implemented, and the average tax paid was 28.7. However, these subjects are significantly better off despite the tax payment (Sign test: $p < 0.01$; Wilcoxon signed rank (WSR): $p < 0.01$) compared to the case where Beta is not selected. Similarly, we have 15% of N-types paid an average tax of 23.7 in order to avoid Delta, and they are better off than if Delta had been selected (WSR: $p = 0.07$, Sign test: $p = 0.08$, one-sided). Thus, while one would normally expect that subjects learn to avoid tax payments over time since they decrease payoffs, the feedback here gives tax-paying N-types a positive reinforcement for both Beta and Delta. Despite being part of the minority who cannot enforce an outcome with certainty, past payoffs encourage N-types to overreport for Beta and underreport for Delta. It is then not surprising that the frequency of tax payments for Beta does not change over time. For Delta, N-types pay less tax in later rounds (Pearson χ^2: $p < 0.03$), while Delta is then selected less frequently. This implies that in both cases, the success of the N-types is also due to the insufficient coordination of M-types.

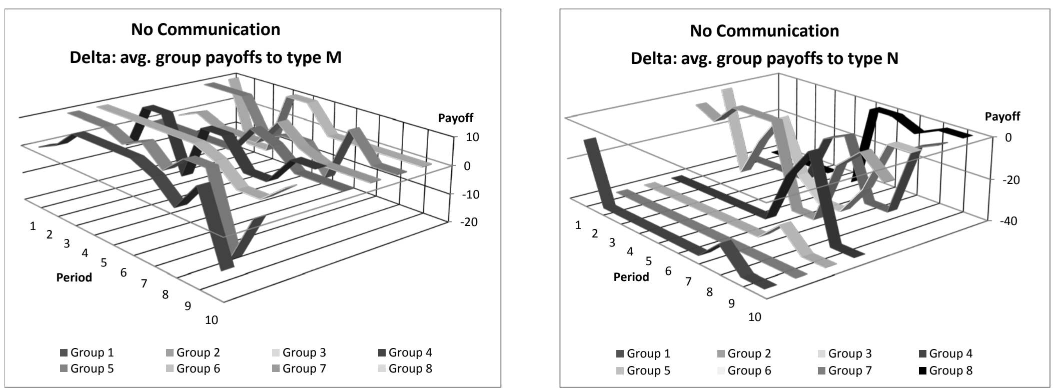


Figure 3: No Communication: Average group payoffs for Delta by type

In 15% of the 240 reports of M-types for Beta a tax was paid in order to avoid Beta, and it was 22.4 on average. These subjects are no better off than if Beta had been selected. For Delta, we have 14% of tax-paying M-types to have Delta selected, with an average tax of 20. These subjects are significantly worse off than if it had not been selected (WSR: $p < 0.01$, Sign test: $p < 0.01$). Neither for Beta nor for Delta the frequency of tax payments changes significantly over the rounds played. M-types thus do not seem to learn to avoid tax payments, even though it was never profitable for them to pay a tax, and as majority they could have avoided tax payments all together with a simple coordination on extreme reports. A closer look at their reports will help understand in which way this result is due to attempted but insufficient coordination of M-types and why N-type were more successful in achieving their preferred outcomes despite being in the minority.

Behavior: Reports, dominant strategies and collusion. Analyzing subjects' reports should reveal why tacit collusion by M-types on the outcome {Alpha,

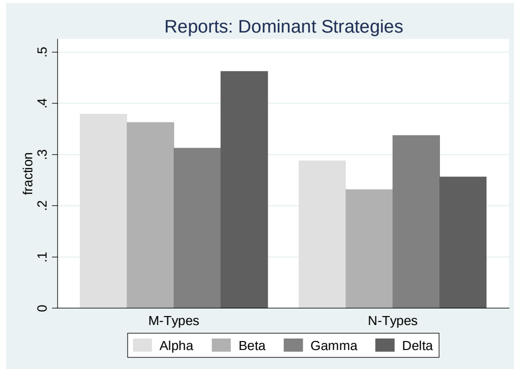


Figure 4: No Communication: Dominant Strategy Choices

Delta} was not observed in the NoCommunication treatment when it was clearly a desirable outcome for a selfish M-type, and whether the pivotal mechanism was successful in eliciting truthful behavior. Figure 4 shows the fraction of dominant strategies for both types for each alternative.[9] For M-types, the fraction of reports that are consistent with a dominant strategy of the non-collusive game is between one third and one half for all alternatives. Notice, in particular, that the dominant strategy choices for Beta and Delta, where more strategic reports might be expected, are not lower than those for Alpha and Gamma. For N-types, the proportion of dominant strategy reports is overall lower. In fact, we found significant differences between the fraction of dominant strategy reports of the two types for all alternatives except Gamma (MWU: $p < 0.05$ for Alpha, $p < 0.01$ for Beta, $p = 0.60$ for Gamma, and $p < 0.01$ for Delta). For subjects who do not use dominant strategies, the question is then whether they report strategically instead.

Table 3 shows in which direction subjects deviate from the truthful report.[10] Overall, subjects tend to overreport for all alternatives. Even for the alternatives with negative valuations, they seem hesitant to underreport, and strategic reports do not seem to play an important role. More specifically, all reports for M-types are above the truthful valuation; this is highly significant (WSR: $p < 0.01$) for all alternatives except Beta. In the case of Beta, strategic reporting would imply that we observe a significant number of underreports, which is not the case. And while 70% of M-types did overreport for Delta, the low number of collusive outcomes implies that the amount by which they overreported was not sufficient. It also implies that N-types must have behaved strategically. Looking at N-types'

[9]Recall that the pivotal mechanism provides two weakly dominant strategies for an individual in this experiment if we consider only non-collusive behavior: reporting the true valuation and reporting its next-highest value.

[10]Note that this is different from the analysis of dominant strategy choices. Here we refer to deviations from the truthful report, since we are interested in the direction of the misreport. It gives a less optimistic picture of the mechanism regarding truthful revelation.

behavior, we find, however, that they also overreported (WSR: $p < 0.01$) for all alternatives except for Gamma. Strategic behavior would have required overreporting for Beta and underreporting for Delta. N-types are thus not overall more strategic, however, since we observe a significant number of outcomes where the minority's preferred alternatives were implemented, those N-types who under- or overreported must have chosen more extreme values than M-types.

Table 3: No Communication: Truthful Reports and Deviations

	M-Types			N-Types		
Altern.	truthful	overreport	underreport	truthful	overreport	underreport
Alpha	.212	.488	.3	.113	.556	.331
Beta	.204	.421	.375	.131	.525	.344
Gamma	.087	.696	.217	.138	.425	.437
Delta	.137	.7	.163	.100	.556	.344
	# obs = 240			# obs = 180		

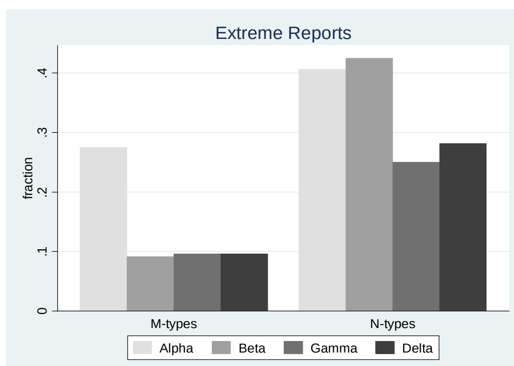


Figure 5: No Communication: Extreme Reports

Figure 5 displays the proportion of extreme reports, i.e. the proportion of subjects that reported the highest possible value for an alternative with a positive valuation and the lowest possible value for an alternative with a negative valuation. As we have argued previously, the extreme reports for Beta and Delta shall be considered a measure for collusive behavior. In the case of M-types, such extreme reports would imply a favorable and certain outcome of the corresponding alternative at no tax, while in the case of N-types there is no profile of reports that leads to a certain outcome. Thus, on the one hand, M-types are in the better position, since being the majority they can enforce their preferred outcome if they all collude. On the other hand, it might just be easier to coordinate two N-type reports as opposed to three M-types when collusion can only occur tacitly.[11] Figure 5 shows that the

[11] In a survey paper on collusion in experiments in the field of industrial organization, Haan

proportion of extreme reports differs significantly between the two types: While about 28% of M-types maximally overreport for Alpha, where strategic behavior does not seem necessary (but is also less risky in terms of expected tax payments) as there is consensus over this alternative, they do not attempt collusion for any other alternative. N-types, on the other hand, seem to understand immediately that they can only have Beta selected if they sufficiently overreport, as we see that over 40% choose the extreme report here. Interestingly, this strategy is not used to the same extent for Delta: only about 30% maximally underreport here. Note that selecting Beta gives a payoff of 40, while selecting Delta gives −40, thus while these two situations are symmetric, successful strategic behavior involves positive payoffs for Beta and at best a zero payoff for Delta. N-types treat these two situations differently. They seem to be less risk-seeking in the loss-context (Delta), i.e. they do not take as much risk in paying a tax to implement their preferred outcome when the best possible outcome is merely to avoid a loss, compared to the gain-context (Beta). This stands in contrast to what would be expected from Kahnemann and Tversky's (1992) cumulative prospect theory.[12]

Since coordinating reports might require some rounds of learning, we check whether the rate of extreme reports changes over time. Table 4 shows that for M-types there is no significant difference in extreme reports for Beta between early and late rounds; note that the number of M-types who maximally underreport in NoCommunication is overall very small: only 8% in early rounds and 11% in late rounds.

Table 4: No Communication: Extreme reports over time

	M-types			N-types		
Altern.	early rounds	late rounds	all rounds	early rounds	late rounds	all rounds
Beta	.083	.111	.092	.375	.479	.425
Delta	.097	.111	.095	.250	.354	.281

Allowing for learning is not sufficient for M-types to behave strategically despite the complete information context. For N-types, extreme reports are somewhat higher in late rounds, but the difference is not significant. Furthermore, the

et al. (2009) pointed out that without communication firms have little success in establishing collusion, but collusion is found to some extent for industries with only two firms. The possibility to communicate yielded collusive outcomes.

[12]In an experiment on social comparison in decision making under risk, Linde and Sonnemans (2009) also found that decision makers are more risk-averse in the loss context than in the gain context, however, in their experiment, the gain or loss context was defined by whether one's own potential payoffs were above or below a reference person's payoffs.

difference in collusive behavior regarding Beta and Delta persists in later rounds (MWU: $p = 0.05$). Overall, there are no significant learning effects for either type in the treatment without communication; allowing subjects to gain experience does not alter their behavior towards more collusion, in particular not that of M-types.

4.2 Communication Treatment

	Round									
Group	1	2	3	4	5	6	7	8	9	10
1	A	AB	AD	AD	AD	AD	AD	AD	AD	AD
2	AB	AD	AD	AD	AD	AD	AD	AD	AD	AD
3	AD	AD	AD	AD	AD	AD	AD	AD	AD	AD
4	AD	AD	AD	AD	AD	AD	AD	AD	AD	AD
5	AB	AD	AD	AD	AD	AD	AD	AD	AD	AD
6	ABD	AC	AB	AB	AB	AD	AD	ACD	AD	AD
7	ABD	A	AD	AD	A	AD	AD	AD	AD	ABD
8	AD	AD	AD	AD	A	AD	AD	AD	AD	AD

(A=Alpha, B=Beta, C=Gamma, D=Delta)

Figure 6: With Communication: All Outcomes over time

So far we found no evidence for tacit collusion of the majority, despite the simple and symmetric collusive strategies. When communication among same-type subjects is introduced, results change dramatically, and the pivotal mechanism breaks down completely. Figure 6 shows that collusion amongst M-types is successfully established. The occurrence of the majority's payoff-maximizing outcome {Alpha, Delta} increases significantly from 63% in early rounds to 92% in late rounds (Pearson χ^2: $p < 0.02$). Behavior is best illustrated by the choice of extreme reports as shown in Table 5: over one half of all M-types now report -60 for Beta and 60 for Delta in early rounds, and this proportion significantly increases to 72% for Beta and 86% for Delta in late rounds (Pearson χ^2: $p < 0.03$ for Beta and $p < 0.01$ for Delta). This learning effect implies that it is not only the lack of communication that prevents M-types to collude, but that probably also cognitive limits constraint subjects from choosing their collusive best response in this situation. Again, we observe the particularity that subjects are more hesitant with extreme reports for an alternative with a negative valuation. N-types, on the other hand, do not use extreme reports more extensively than in the treatment without communication, and there is also no change over time for extreme reports of Beta and Delta. This is easily explained: as the collusive behavior of M-types now determines the outcome, the reports of N-types become irrelevant. With an increase in collusive behavior, the rate of dominant strategy choices collapses: while we had about 50% dominant strategy choices by M-types for Delta in early and late rounds, they decrease from

23% in early rounds to almost zero in late rounds. Interestingly, introducing communication does not change the proportion of dominant strategy reports for Alpha and Gamma for N-types (still about 30%), while for M-types they drop from 38% to 17% for Alpha and from 31% to 17% for Gamma.

Table 5: With Communication: Extreme reports over time

Altern.	M-types early rounds	M-types late rounds	M-types all rounds	N-types early rounds	N-types late rounds	N-types all rounds
Beta	.556	.722	.642	.479	.500	.544
Delta	.528	.861	.733	.479	.458	.456

Comparing the two treatments with regard to tax payments, fewer agents paid taxes overall in the treatment with communication. This is shown in Figures 7 and 8. Communication thus improved the efficiency regarding tax payments: for M-types in the Communication-treatment, there were significantly less tax payments for both Beta (Pearson χ^2: $p = 0.02$) and Delta (Pearson χ^2: $p < 0.01$). For N-types, the number of subjects who paid a tax for Beta also decreased significantly in the Communication-treatment (Pearson χ^2: $p < .01$), only for Delta the decrease is not significant (Pearson χ^2: $p = 0.12$).

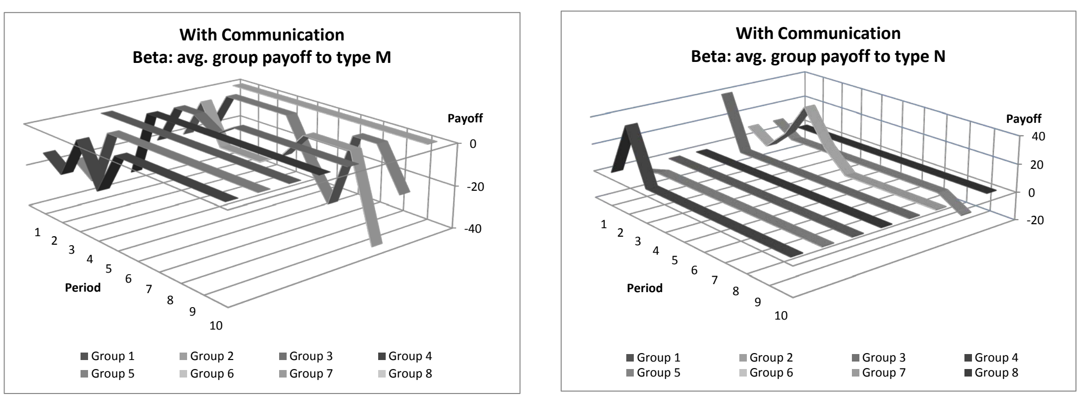
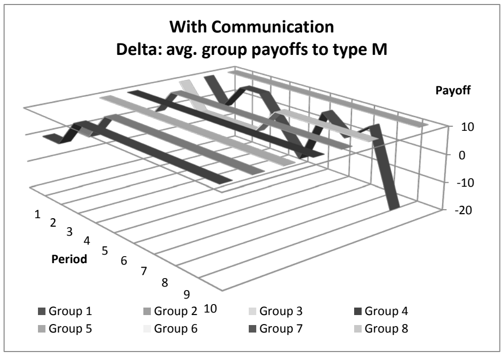


Figure 7: With Communication: Average group payoffs for Beta by type

Regarding bundle {Alpha, Beta, Delta}, which was frequently selected in the treatment without communication, we can finally conclude that it must have occurred unintentionally. It disappeared completely in this treatment where subjects could have explicitly decided to vote for it. This leads us to the conclusion that social preferences, which could have influenced outcomes, have no importance in this context. One may argue that allowing for communication only among subgroups may have emphasized competition between groups and selfish behavior.

This is possible, and it might be interesting to investigate this effect in further experiments. Our main goal, however, was to understand whether collusion is easily established in a pivotal mechanism context, and we thus chose a design with two treatments on the extremes regarding communication possibilities.



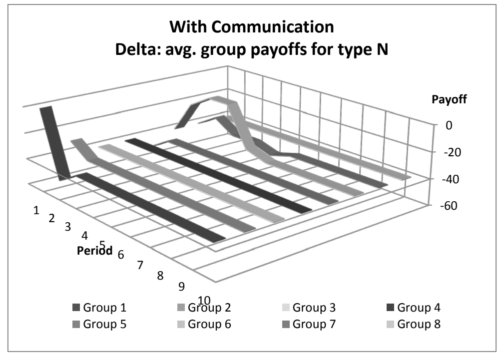


Figure 8: With Communication: Average group payoffs for Delta by type

We gained some additional insight regarding selfishness and fairness concerns by analyzing the chat protocols. Only in 3 out of 8 subgroups of M-types unfairness towards N-types was mentioned by single subjects. Subjects who brought up the fairness topic did not insist much and the issue was discarded rather quickly. This is in line with the findings of Bosman et al. (2006), who analyzed video taped discussions preceding group decision making in a power-to-take experiment. In their context, fairness is also discussed very little and fairness standards are prone to the self-serving bias. As hypothesized earlier, we can also see from the chat protocols that not all M-types subjects are able to understand strategic behavior here. This is why learning is significant only in the communication treatment, i.e. only with the explicit help of others can some subjects follow the collusive strategy. Communication thus helps subjects to understand a complex problem and it helps coordinate strategies towards a collusive outcome.

5 Conclusion

This paper studies the susceptibility of the pivotal mechanism with respect to manipulation by groups. Knowing that this mechanism is not collusion-proof, it seems important to understand under which circumstances this property is responsible for the failure of the mechanism in implementing the social optimum. In a lab experiment where a group decides on the implementation of various alternatives, we investigate the occurrence of tacit and explicit collusion by allowing for communication in one treatment and prohibiting it in another. While we found a strong treatment effect, i.e., explicit communication helps to coordinate actions such that strategic reports implement the preferred outcome of the majority, there is little evidence that tacit collusion works in the treatment without communication, despite the fact that all agents' preferences are common knowledge and there exists a simple symmetric collusive strategy for the majority. Individual dominant strategies are chosen by a proportion of one third (Gamma) to almost one half (Delta) of subjects in the majority, when extreme reports on the boundary of the strategy space could have ensured the majority's preferred outcome for Beta and Delta without tax payments. Overall, when communication is absent, the social optimum is chosen in over 50% of all late rounds.

Learning has no effect on the selection of a collusive outcome for the majority when explicit communication is not allowed. Only the introduction of communication has a strong effect on the outcomes: we observe over 60% of collusive outcomes in early rounds, and gaining experience further enhances collusion, so that in over 90% of late rounds the majority attains their payoff-maximizing outcome. M-type subjects learn to submit extreme reports which ensure this outcome at no risk of paying taxes only in the treatment with communication. Outcomes that would have implemented more equal total payoffs to all subjects have no importance here. While we chose the communication structure in this experiment such that it enhances collusion, it may be true that we also created an inter-group competition between majority and minority, which lead to such little concern for the payoffs of the other subgroup. Future work could involve the question whether the information structure matters, e.g. whether the results would differ if we allow for communication among all group members, or if subjects can choose with whom to communicate.

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7 Appendix: Payoff Tables

Alternative Alpha

sum of reports of other 4 agents \ your report for Alpha	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
-240	0	0	0	0	0	0	0	0	0	0	0	0	0
-230	0	0	0	0	0	0	0	0	0	0	0	0	0
-220	0	0	0	0	0	0	0	0	0	0	0	0	0
-210	0	0	0	0	0	0	0	0	0	0	0	0	0
-200	0	0	0	0	0	0	0	0	0	0	0	0	0
-190	0	0	0	0	0	0	0	0	0	0	0	0	0
-180	0	0	0	0	0	0	0	0	0	0	0	0	0
-170	0	0	0	0	0	0	0	0	0	0	0	0	0
-160	0	0	0	0	0	0	0	0	0	0	0	0	0
-150	0	0	0	0	0	0	0	0	0	0	0	0	0
-140	0	0	0	0	0	0	0	0	0	0	0	0	0
-130	0	0	0	0	0	0	0	0	0	0	0	0	0
-120	0	0	0	0	0	0	0	0	0	0	0	0	0
-110	0	0	0	0	0	0	0	0	0	0	0	0	0
-100	0	0	0	0	0	0	0	0	0	0	0	0	0
-90	0	0	0	0	0	0	0	0	0	0	0	0	0
-80	0	0	0	0	0	0	0	0	0	0	0	0	0
-70	0	0	0	0	0	0	0	0	0	0	0	0	0
-60	0	0	0	0	0	0	0	0	0	0	0	0	0
-50	0	0	0	0	0	0	0	0	0	0	0	0	-20
-40	0	0	0	0	0	0	0	0	0	0	0	-10	-10
-30	0	0	0	0	0	0	0	0	0	0	0	0	0
-20	0	0	0	0	0	0	0	0	0	10	10	10	10
-10	0	0	0	0	0	0	0	0	20	20	20	20	20
0	0	0	0	0	0	0	0	30	30	30	30	30	30
10	-10	-10	-10	-10	-10	-10	30	30	30	30	30	30	30
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70	30	30	30	30	30	30	30	30	30	30	30	30	30
80	30	30	30	30	30	30	30	30	30	30	30	30	30
90	30	30	30	30	30	30	30	30	30	30	30	30	30
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200	30	30	30	30	30	30	30	30	30	30	30	30	30
210	30	30	30	30	30	30	30	30	30	30	30	30	30
220	30	30	30	30	30	30	30	30	30	30	30	30	30
230	30	30	30	30	30	30	30	30	30	30	30	30	30
240	30	30	30	30	30	30	30	30	30	30	30	30	30

Alternative Beta

sum of reports of other 4 agents \ your report for Beta	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
-240	0	0	0	0	0	0	0	0	0	0	0	0	0
-230	0	0	0	0	0	0	0	0	0	0	0	0	0
-220	0	0	0	0	0	0	0	0	0	0	0	0	0
-210	0	0	0	0	0	0	0	0	0	0	0	0	0
-200	0	0	0	0	0	0	0	0	0	0	0	0	0
-190	0	0	0	0	0	0	0	0	0	0	0	0	0
-180	0	0	0	0	0	0	0	0	0	0	0	0	0
-170	0	0	0	0	0	0	0	0	0	0	0	0	0
-160	0	0	0	0	0	0	0	0	0	0	0	0	0
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-130	0	0	0	0	0	0	0	0	0	0	0	0	0
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-110	0	0	0	0	0	0	0	0	0	0	0	0	0
-100	0	0	0	0	0	0	0	0	0	0	0	0	0
-90	0	0	0	0	0	0	0	0	0	0	0	0	0
-80	0	0	0	0	0	0	0	0	0	0	0	0	0
-70	0	0	0	0	0	0	0	0	0	0	0	0	0
-60	0	0	0	0	0	0	0	0	0	0	0	0	0
-50	0	0	0	0	0	0	0	0	0	0	0	0	-70
-40	0	0	0	0	0	0	0	0	0	0	0	-60	-60
-30	0	0	0	0	0	0	0	0	0	0	-50	-50	-50
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70	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
80	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
90	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
100	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
110	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
120	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
130	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
140	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
150	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
160	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
170	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
180	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
190	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
200	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
210	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
220	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
230	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
240	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20

Figure 9: M's Payoff Tables for Alternatives Alpha and Beta

Alternative Gamma

your report for Gamma

sum of reports of other 4 agents	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
-240	0	0	0	0	0	0	0	0	0	0	0	0	0
-230	0	0	0	0	0	0	0	0	0	0	0	0	0
-220	0	0	0	0	0	0	0	0	0	0	0	0	0
-210	0	0	0	0	0	0	0	0	0	0	0	0	0
-200	0	0	0	0	0	0	0	0	0	0	0	0	0
-190	0	0	0	0	0	0	0	0	0	0	0	0	0
-180	0	0	0	0	0	0	0	0	0	0	0	0	0
-170	0	0	0	0	0	0	0	0	0	0	0	0	0
-160	0	0	0	0	0	0	0	0	0	0	0	0	0
-150	0	0	0	0	0	0	0	0	0	0	0	0	0
-140	0	0	0	0	0	0	0	0	0	0	0	0	0
-130	0	0	0	0	0	0	0	0	0	0	0	0	0
-120	0	0	0	0	0	0	0	0	0	0	0	0	0
-110	0	0	0	0	0	0	0	0	0	0	0	0	0
-100	0	0	0	0	0	0	0	0	0	0	0	0	0
-90	0	0	0	0	0	0	0	0	0	0	0	0	0
-80	0	0	0	0	0	0	0	0	0	0	0	0	0
-70	0	0	0	0	0	0	0	0	0	0	0	0	0
-60	0	0	0	0	0	0	0	0	0	0	0	0	0
-50	0	0	0	0	0	0	0	0	0	0	0	0	-80
-40	0	0	0	0	0	0	0	0	0	0	0	-70	-70
-30	0	0	0	0	0	0	0	0	0	0	-60	-60	-60
-20	0	0	0	0	0	0	0	0	0	-50	-50	-50	-50
-10	0	0	0	0	0	0	0	0	-40	-40	-40	-40	-40
0	0	0	0	0	0	0	0	-30	-30	-30	-30	-30	-30
10	-10	-10	-10	-10	-10	-10	-30	-30	-30	-30	-30	-30	-30
20	-20	-20	-20	-20	-20	-30	-30	-30	-30	-30	-30	-30	-30
30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
40	-40	-40	-40	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
50	-50	-50	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
60	-60	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
70	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
80	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
90	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
100	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
110	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
120	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
130	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
140	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
150	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
160	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
170	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
180	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
190	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
200	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
210	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
220	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
230	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
240	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30

Alternative Delta

your report for Delta

sum of reports of other 4 agents	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
-240	0	0	0	0	0	0	0	0	0	0	0	0	0
-230	0	0	0	0	0	0	0	0	0	0	0	0	0
-220	0	0	0	0	0	0	0	0	0	0	0	0	0
-210	0	0	0	0	0	0	0	0	0	0	0	0	0
-200	0	0	0	0	0	0	0	0	0	0	0	0	0
-190	0	0	0	0	0	0	0	0	0	0	0	0	0
-180	0	0	0	0	0	0	0	0	0	0	0	0	0
-170	0	0	0	0	0	0	0	0	0	0	0	0	0
-160	0	0	0	0	0	0	0	0	0	0	0	0	0
-150	0	0	0	0	0	0	0	0	0	0	0	0	0
-140	0	0	0	0	0	0	0	0	0	0	0	0	0
-130	0	0	0	0	0	0	0	0	0	0	0	0	0
-120	0	0	0	0	0	0	0	0	0	0	0	0	0
-110	0	0	0	0	0	0	0	0	0	0	0	0	0
-100	0	0	0	0	0	0	0	0	0	0	0	0	0
-90	0	0	0	0	0	0	0	0	0	0	0	0	0
-80	0	0	0	0	0	0	0	0	0	0	0	0	0
-70	0	0	0	0	0	0	0	0	0	0	0	0	0
-60	0	0	0	0	0	0	0	0	0	0	0	0	0
-50	0	0	0	0	0	0	0	0	0	0	0	0	-40
-40	0	0	0	0	0	0	0	0	0	0	0	-30	-30
-30	0	0	0	0	0	0	0	0	0	0	-20	-20	-20
-20	0	0	0	0	0	0	0	0	0	-10	-10	-10	-10
-10	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	10	10	10	10	10	10
10	-10	-10	-10	-10	-10	-10	10	10	10	10	10	10	10
20	-20	-20	-20	-20	-20	10	10	10	10	10	10	10	10
30	-30	-30	-30	-30	10	10	10	10	10	10	10	10	10
40	-40	-40	-40	10	10	10	10	10	10	10	10	10	10
50	-50	-50	10	10	10	10	10	10	10	10	10	10	10
60	-60	10	10	10	10	10	10	10	10	10	10	10	10
70	10	10	10	10	10	10	10	10	10	10	10	10	10
80	10	10	10	10	10	10	10	10	10	10	10	10	10
90	10	10	10	10	10	10	10	10	10	10	10	10	10
100	10	10	10	10	10	10	10	10	10	10	10	10	10
110	10	10	10	10	10	10	10	10	10	10	10	10	10
120	10	10	10	10	10	10	10	10	10	10	10	10	10
130	10	10	10	10	10	10	10	10	10	10	10	10	10
140	10	10	10	10	10	10	10	10	10	10	10	10	10
150	10	10	10	10	10	10	10	10	10	10	10	10	10
160	10	10	10	10	10	10	10	10	10	10	10	10	10
170	10	10	10	10	10	10	10	10	10	10	10	10	10
180	10	10	10	10	10	10	10	10	10	10	10	10	10
190	10	10	10	10	10	10	10	10	10	10	10	10	10
200	10	10	10	10	10	10	10	10	10	10	10	10	10
210	10	10	10	10	10	10	10	10	10	10	10	10	10
220	10	10	10	10	10	10	10	10	10	10	10	10	10
230	10	10	10	10	10	10	10	10	10	10	10	10	10
240	10	10	10	10	10	10	10	10	10	10	10	10	10

Figure 10: M's Payoff Tables for Alternatives Gamma and Delta

Alternative Alpha

sum of reports of other 4 agents \ your report for Alpha	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
-240	0	0	0	0	0	0	0	0	0	0	0	0	0
-230	0	0	0	0	0	0	0	0	0	0	0	0	0
-220	0	0	0	0	0	0	0	0	0	0	0	0	0
-210	0	0	0	0	0	0	0	0	0	0	0	0	0
-200	0	0	0	0	0	0	0	0	0	0	0	0	0
-190	0	0	0	0	0	0	0	0	0	0	0	0	0
-180	0	0	0	0	0	0	0	0	0	0	0	0	0
-170	0	0	0	0	0	0	0	0	0	0	0	0	0
-160	0	0	0	0	0	0	0	0	0	0	0	0	0
-150	0	0	0	0	0	0	0	0	0	0	0	0	0
-140	0	0	0	0	0	0	0	0	0	0	0	0	0
-130	0	0	0	0	0	0	0	0	0	0	0	0	0
-120	0	0	0	0	0	0	0	0	0	0	0	0	0
-110	0	0	0	0	0	0	0	0	0	0	0	0	0
-100	0	0	0	0	0	0	0	0	0	0	0	0	0
-90	0	0	0	0	0	0	0	0	0	0	0	0	0
-80	0	0	0	0	0	0	0	0	0	0	0	0	0
-70	0	0	0	0	0	0	0	0	0	0	0	0	0
-60	0	0	0	0	0	0	0	0	0	0	0	0	0
-50	0	0	0	0	0	0	0	0	0	0	0	0	-40
-40	0	0	0	0	0	0	0	0	0	0	0	-30	-30
-30	0	0	0	0	0	0	0	0	0	0	-20	-20	-20
-20	0	0	0	0	0	0	0	0	0	-10	-10	-10	-10
-10	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	10	10	10	10	10	10
10	-10	-10	-10	-10	-10	-10	10	10	10	10	10	10	10
20	-20	-20	-20	-20	-20	10	10	10	10	10	10	10	10
30	-30	-30	-30	-30	10	10	10	10	10	10	10	10	10
40	-40	-40	-40	10	10	10	10	10	10	10	10	10	10
50	-50	-50	10	10	10	10	10	10	10	10	10	10	10
60	-60	10	10	10	10	10	10	10	10	10	10	10	10
70	10	10	10	10	10	10	10	10	10	10	10	10	10
80	10	10	10	10	10	10	10	10	10	10	10	10	10
90	10	10	10	10	10	10	10	10	10	10	10	10	10
100	10	10	10	10	10	10	10	10	10	10	10	10	10
110	10	10	10	10	10	10	10	10	10	10	10	10	10
120	10	10	10	10	10	10	10	10	10	10	10	10	10
130	10	10	10	10	10	10	10	10	10	10	10	10	10
140	10	10	10	10	10	10	10	10	10	10	10	10	10
150	10	10	10	10	10	10	10	10	10	10	10	10	10
160	10	10	10	10	10	10	10	10	10	10	10	10	10
170	10	10	10	10	10	10	10	10	10	10	10	10	10
180	10	10	10	10	10	10	10	10	10	10	10	10	10
190	10	10	10	10	10	10	10	10	10	10	10	10	10
200	10	10	10	10	10	10	10	10	10	10	10	10	10
210	10	10	10	10	10	10	10	10	10	10	10	10	10
220	10	10	10	10	10	10	10	10	10	10	10	10	10
230	10	10	10	10	10	10	10	10	10	10	10	10	10
240	10	10	10	10	10	10	10	10	10	10	10	10	10

Alternative Beta

sum of reports of other 4 agents \ your report for Beta	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
-240	0	0	0	0	0	0	0	0	0	0	0	0	0
-230	0	0	0	0	0	0	0	0	0	0	0	0	0
-220	0	0	0	0	0	0	0	0	0	0	0	0	0
-210	0	0	0	0	0	0	0	0	0	0	0	0	0
-200	0	0	0	0	0	0	0	0	0	0	0	0	0
-190	0	0	0	0	0	0	0	0	0	0	0	0	0
-180	0	0	0	0	0	0	0	0	0	0	0	0	0
-170	0	0	0	0	0	0	0	0	0	0	0	0	0
-160	0	0	0	0	0	0	0	0	0	0	0	0	0
-150	0	0	0	0	0	0	0	0	0	0	0	0	0
-140	0	0	0	0	0	0	0	0	0	0	0	0	0
-130	0	0	0	0	0	0	0	0	0	0	0	0	0
-120	0	0	0	0	0	0	0	0	0	0	0	0	0
-110	0	0	0	0	0	0	0	0	0	0	0	0	0
-100	0	0	0	0	0	0	0	0	0	0	0	0	0
-90	0	0	0	0	0	0	0	0	0	0	0	0	0
-80	0	0	0	0	0	0	0	0	0	0	0	0	0
-70	0	0	0	0	0	0	0	0	0	0	0	0	0
-60	0	0	0	0	0	0	0	0	0	0	0	0	0
-50	0	0	0	0	0	0	0	0	0	0	0	0	-10
-40	0	0	0	0	0	0	0	0	0	0	0	0	0
-30	0	0	0	0	0	0	0	0	0	0	10	10	10
-20	0	0	0	0	0	0	0	0	0	20	20	20	20
-10	0	0	0	0	0	0	0	0	30	30	30	30	30
0	0	0	0	0	0	0	0	40	40	40	40	40	40
10	-10	-10	-10	-10	-10	-10	40	40	40	40	40	40	40
20	-20	-20	-20	-20	-20	40	40	40	40	40	40	40	40
30	-30	-30	-30	-30	40	40	40	40	40	40	40	40	40
40	-40	-40	-40	40	40	40	40	40	40	40	40	40	40
50	-50	-50	40	40	40	40	40	40	40	40	40	40	40
60	-60	40	40	40	40	40	40	40	40	40	40	40	40
70	40	40	40	40	40	40	40	40	40	40	40	40	40
80	40	40	40	40	40	40	40	40	40	40	40	40	40
90	40	40	40	40	40	40	40	40	40	40	40	40	40
100	40	40	40	40	40	40	40	40	40	40	40	40	40
110	40	40	40	40	40	40	40	40	40	40	40	40	40
120	40	40	40	40	40	40	40	40	40	40	40	40	40
130	40	40	40	40	40	40	40	40	40	40	40	40	40
140	40	40	40	40	40	40	40	40	40	40	40	40	40
150	40	40	40	40	40	40	40	40	40	40	40	40	40
160	40	40	40	40	40	40	40	40	40	40	40	40	40
170	40	40	40	40	40	40	40	40	40	40	40	40	40
180	40	40	40	40	40	40	40	40	40	40	40	40	40
190	40	40	40	40	40	40	40	40	40	40	40	40	40
200	40	40	40	40	40	40	40	40	40	40	40	40	40
210	40	40	40	40	40	40	40	40	40	40	40	40	40
220	40	40	40	40	40	40	40	40	40	40	40	40	40
230	40	40	40	40	40	40	40	40	40	40	40	40	40
240	40	40	40	40	40	40	40	40	40	40	40	40	40

Figure 11: N's Payoff Tables for Alternatives Alpha and Beta

Alternative Gamma

your report for Gamma (columns); sum of reports of other 4 agents (rows)

sum of reports of other 4 agents	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
-240	0	0	0	0	0	0	0	0	0	0	0	0	0
-230	0	0	0	0	0	0	0	0	0	0	0	0	0
-220	0	0	0	0	0	0	0	0	0	0	0	0	0
-210	0	0	0	0	0	0	0	0	0	0	0	0	0
-200	0	0	0	0	0	0	0	0	0	0	0	0	0
-190	0	0	0	0	0	0	0	0	0	0	0	0	0
-180	0	0	0	0	0	0	0	0	0	0	0	0	0
-170	0	0	0	0	0	0	0	0	0	0	0	0	0
-160	0	0	0	0	0	0	0	0	0	0	0	0	0
-150	0	0	0	0	0	0	0	0	0	0	0	0	0
-140	0	0	0	0	0	0	0	0	0	0	0	0	0
-130	0	0	0	0	0	0	0	0	0	0	0	0	0
-120	0	0	0	0	0	0	0	0	0	0	0	0	0
-110	0	0	0	0	0	0	0	0	0	0	0	0	0
-100	0	0	0	0	0	0	0	0	0	0	0	0	0
-90	0	0	0	0	0	0	0	0	0	0	0	0	0
-80	0	0	0	0	0	0	0	0	0	0	0	0	0
-70	0	0	0	0	0	0	0	0	0	0	0	0	0
-60	0	0	0	0	0	0	0	0	0	0	0	0	0
-50	0	0	0	0	0	0	0	0	0	0	0	0	-70
-40	0	0	0	0	0	0	0	0	0	0	0	-60	-60
-30	0	0	0	0	0	0	0	0	0	0	-50	-50	-50
-20	0	0	0	0	0	0	0	0	0	-40	-40	-40	-40
-10	0	0	0	0	0	0	0	0	-30	-30	-30	-30	-30
0	0	0	0	0	0	0	0	-20	-20	-20	-20	-20	-20
10	-10	-10	-10	-10	-10	-10	-20	-20	-20	-20	-20	-20	-20
20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
30	-30	-30	-30	-30	-20	-20	-20	-20	-20	-20	-20	-20	-20
40	-40	-40	-40	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
50	-50	-50	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
60	-60	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
70	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
80	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
90	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
100	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
110	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
120	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
130	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
140	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
150	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
160	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
170	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
180	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
190	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
200	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
210	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
220	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
230	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
240	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20

Alternative Delta

your report for Delta (columns); sum of reports of other 4 agents (rows)

sum of reports of other 4 agents	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60
-240	0	0	0	0	0	0	0	0	0	0	0	0	0
-230	0	0	0	0	0	0	0	0	0	0	0	0	0
-220	0	0	0	0	0	0	0	0	0	0	0	0	0
-210	0	0	0	0	0	0	0	0	0	0	0	0	0
-200	0	0	0	0	0	0	0	0	0	0	0	0	0
-190	0	0	0	0	0	0	0	0	0	0	0	0	0
-180	0	0	0	0	0	0	0	0	0	0	0	0	0
-170	0	0	0	0	0	0	0	0	0	0	0	0	0
-160	0	0	0	0	0	0	0	0	0	0	0	0	0
-150	0	0	0	0	0	0	0	0	0	0	0	0	0
-140	0	0	0	0	0	0	0	0	0	0	0	0	0
-130	0	0	0	0	0	0	0	0	0	0	0	0	0
-120	0	0	0	0	0	0	0	0	0	0	0	0	0
-110	0	0	0	0	0	0	0	0	0	0	0	0	0
-100	0	0	0	0	0	0	0	0	0	0	0	0	0
-90	0	0	0	0	0	0	0	0	0	0	0	0	0
-80	0	0	0	0	0	0	0	0	0	0	0	0	0
-70	0	0	0	0	0	0	0	0	0	0	0	0	0
-60	0	0	0	0	0	0	0	0	0	0	0	0	0
-50	0	0	0	0	0	0	0	0	0	0	0	0	-90
-40	0	0	0	0	0	0	0	0	0	0	0	-80	-80
-30	0	0	0	0	0	0	0	0	0	0	-70	-70	-70
-20	0	0	0	0	0	0	0	0	0	-60	-60	-60	-60
-10	0	0	0	0	0	0	0	0	-50	-50	-50	-50	-50
0	0	0	0	0	0	0	0	-40	-40	-40	-40	-40	-40
10	-10	-10	-10	-10	-10	-10	-40	-40	-40	-40	-40	-40	-40
20	-20	-20	-20	-20	-20	-40	-40	-40	-40	-40	-40	-40	-40
30	-30	-30	-30	-30	-40	-40	-40	-40	-40	-40	-40	-40	-40
40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
50	-50	-50	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
60	-60	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
70	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
80	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
90	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
100	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
110	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
120	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
130	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
140	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
150	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
160	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
170	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
180	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
190	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
200	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
210	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
220	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
230	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
240	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40

Figure 12: N's Payoff Tables for Alternatives Gamma and Delta

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The pivotal mechanism revisited: Some evidence on group manipulation

Abstract
This paper studies the vulnerability of the pivotal mechanism with respect to manipulation by groups. In a lab experiment, groups decide on the implementation of various alternatives, some of which imply opposite interests for the two subgroups. We investigate the occurrence of tacit and explicit collusion by allowing for communication within subgroups in one treatment and prohibiting it in another. Even though all agents' preferences are common knowledge and there exists a simple symmetric collusive strategy for one subgroup, we find little evidence for tacit collusion, not even with increasing experience. Only when explicit communication is allowed, collusion is established, and it becomes even more pronounced over time.

ISSN 1993-4378 (Print)
ISSN 1993-6885 (Online)