How Communication Links Influence Coalition Bargaining

A Laboratory Investigation

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The nature of multilateral negotiations depends in part on the communication routes or links by which bargainers send messages to one another. We investigate how the available communication links affect a three-person coalition negotiation. We compare the data to models representing both the cooperative and non-cooperative game literatures. The data indicates that the available communication links strongly influence which coalition forms, and how payoffs within a coalition are distributed. Unconstrained communication does not ensure maximum total payoff, nor does communication control always benefit the controlling bargainer. The non-cooperative extensive form model organizes the data best, although a substantially different model may be necessary to explain outcomes when all communication is public.

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1. Introduction: The role of communication links in coalition bargaining

It may seem rather apparent that the structure of communication plays an important role in coalition bargaining. One would not generally expect to see the same outcome when a single bargainer controls the flow of messages as when all bargainers can communicate freely. Yet only a few coalition models take explicit account of communication. Instead most assume, often implicitly, that communication is free and unconstrained. And whether this is in fact a necessary or sufficient condition, or what effect restrictions would have, is often left unstated.

We say a communication *link* exists between two bargainers if it is possible for them to directly exchange information. For a bilateral negotiation, there is but one possible link, and hence but one possible configuration. For more than two bargainers, the configuration depends on the particular circumstances. Multilateral trade treaty negotiations, for example, typically permit all private and public links between bargainers. In other cases, such as thin markets, establishing particular links may be prohibitively costly.[1] In still other cases, certain links are banned outright. For example, in labor contract negotiations, the union bargaining team provides the pivotal link: Employees and management can both communicate with the union team, but are barred from communicating directly with one another.

In this paper, we present an experiment designed to gauge the effect of varying the communication links on the outcome of a three-person coalition bargaining game with a strictly super-additive characteristic function. We compare five different link configurations, including one where communication is unconstrained, permitting public as well as private messages, another where all communication must be public, and three configurations where a single bargainer controls the flow of messages.

Myerson (1977) describes one of the few coalition models that take explicit account of communication.[2] A key innovation of the model is the modification of the coalition characteristic function so that coalitions without connected communication paths are effectively eliminated from consideration. Myerson then proposes a set of axioms that lead to the Shapley value of the modified characteristic function. We retain Myerson's method of modifying the

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[1] Kranton (1996) models a market in which bilateral links function as an alternative to search.
[2] Borm, Owen and Tijs (1992) take a similar approach.

characteristic function, and construct two more models by substituting alternative solution concepts: the core and subgame perfect equilibrium. Applying the latter requires an extensive form game. We use the sequential offer coalition bargaining model studied by Chatterjee, Dutta, Ray and Sengupta (1993). Each benchmark model, Myerson value, modified core, and sequential offer, provides a distinct account of what we can expect from manipulating the communication configuration.

Because two of the models are cooperative games, the bargaining in our experiment is free form: Beyond a time deadline, and the restrictions imposed by the communication configuration, bargainers are free to send messages pretty much as they please.[3] We interpret the non-cooperative game model as an extensive form approximation of the free form environment.

The experiment demonstrates that varying the communication links can cause sharp shifts in both the coalitions that form, and the profits that individual bargainers make. Neither of the models based on cooperative solution concepts explains these shifts particularly well. The sequential offer model, however, gets several important features of the data correct. Some are surprising. For example, the model accurately predicts that the two "weaker" bargainers can benefit from controlling the communication flow, but that the third bargainer cannot, even though he is in all respects in the strongest strategic position, and even though he receives less than his core payoff when communication is unconstrained. The model also accurately predicts that the two configurations in which the weaker bargainers control the communication flow will yield the most grand coalitions, counter to the usual intuition that the grand coalition is most likely when communication is unconstrained. Also, for each configuration except the fully public one, the model accurately predicts that high-payoff, two-party coalitions will tend to exhibit equal-division payoffs, and the distribution in lower-payoff two-party coalitions will look like a competitive response to the equal-division one.

The sequential offer model also has some shortcomings. It predicts that restricting to public communication will have no effect; but in fact it clearly does. Also, the predicted

[3] The imposition of a publicly announced deadline distinguishes our experiment from some earlier experiments on cooperative model and may explain some of the differences in results that we observe.

coalition frequencies are not particularly accurate; specifically, grand coalitions are systematically underpredicted, and the bargaining impasses we observe are not predicted at all.

In spite of these failings, the sequential offer model's successes are substantial, and difficult to write off to chance. It turns out that much of what the model gets right can be attributed to accurately predicting that certain equal-division as well as "competitive" coalitions will form with positive frequency.[4] Neither of the key theoretical factors behind this prediction – restricting moves to sequential proposals, and a slight amount of time discounting at a common rate – is explicitly present in the free form environment, so it is unlikely that bargainers are playing a perfect equilibrium from the sequential offers model in any literal sense. We go into details later, but based on our investigation of the data it appears that certain characteristics of the free form bargaining – a propensity for private offers, and the influence of the bargaining deadline – serve to approximate the strategic effect of the factors that drive the theoretical results. These same characteristics play out differently when all communication must be public, potentially explaining the failure of the model in this instance.

The results demonstrate that an extensive form model, even when it is not a literal transcription of the actual game, can provide significant strategic insight. The results also point to the important gains to be had from a better theoretical understanding of the strategic role of a bargaining deadline, and of the comparative influence of public versus private communication.

So far as we know, our experiment is the first to look at coalition bargaining models that explicitly consider the configuration of communication, although some previous multilateral bargaining experiments have dealt with communication issues.[5]

Two studies that touch directly on the influence of the communication configuration are Rapoport and Kahan (1976) and Murnighan and Roth (1977). Both investigate three-person coalition bargaining games, and both compare treatments that allow private and public

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[4] While standard subgame perfect arguments have not fared particularly well in the lab, they have done better when combined with an appropriate equity principle (ex., Bolton, 1991). The Chatterjee et al. model is exceptional in that its equity principle arises from purely strategic considerations. Still, there is a thematic consistency here that we return to explore later.

[5] Most of the work on coalition bargaining, much of it done during the 1970's, was directed at testing cooperative game theory concepts such as the core and the bargaining set, and did not deal explicitly with communication. Selten (1987) includes an overview of the literature. Some recent work has focused on the effect of pre-play communication; ex., Moreno and Wooders (1998)

communication to ones that allow only public (both studies manipulated other factors as well). Murnighan and Roth report an effect, whereas Rapoport and Kahan find that the manipulation makes no difference. (Our findings suggest a possible explanation for the differing results.)[6]

Valley, White, Neale and Bazerman (1992) studied a buyer-seller transaction in which all communication is passed through a middleman. They found that the type of information available to the middleman tends to influence the settlement, suggesting that communication control is susceptible to strategic manipulation. Rather than passing on all information unfiltered, the middlemen use the information to increase their own payoffs.

Several three-person coalition bargaining experiments suggest that communication can affect grand coalition formation. Raiffa (1982) reports an experiment of this kind that he performed with Elon Kohlberg. In a treatment in which bargainers negotiated face-to-face, over 90 percent of the negotiations concluded with the grand coalition. In a second treatment in which negotiations took place across a computer interface, over 90 percent concluded with a two-person coalition. In one treatment of Bolton and Chatterjee's (1995) study, bargainers negotiated according to a finite horizon version of Okada's (1996) model.[7] No other communication was allowed. In the second treatment, bargaining was free form. Both treatments were face-to-face. There were very few grand coalitions in the structured game, but mostly grand coalitions in the free form game. Paresh Patel (1997) repeated the free form game in an anonymous setting, allowing secret messages in one treatment and public messages in another. In both treatments, two-person coalitions formed approximately 75 percent of the time. These experiments indicate that grand coalition formation is sensitive to the communication medium. It is, however, difficult to say whether the effect is due to a change in communication patterns across treatments or to factors related to face-to-face bargaining.

Our experiment systematically manipulates the configuration of communication links, holding all other factors fixed.

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[6] In Murnighan and Roth's experiment, one bargainer, referred to as the monopolist, is much stronger than the other two in that he must be included in any coalition with positive value. They report that "the monopolist's payoffs were greatest when…the offers were [publicly] announced…His payoffs were least in the condition where secret [private] messages were allowed." p. 1341.

[7] The infinite horizon version of this model leads to conclusions that are similar to those derived from the Chatterjee et al. (1993) model.

2. A new experiment: The game, the communication configurations, and three models

We discuss the models in the context of the game used for the experiment. There are three bargainers, *S*, *C*, and *T*. The characteristic function is defined by

$$\upsilon(SCT) = 100,\ \upsilon(SC) = 90,\ \upsilon(ST) = 70,\ \upsilon(CT) = 40,\ \upsilon(S) = \upsilon(C) = \upsilon(T) = 0.$$

This function implies a unique core outcome, the grand coalition with payoffs (*S*,*C*,*T*) = (60,30,10). The Shapley value is (*S*,*C*,*T*) = (46.67, 31.67, 21.66).[8] By these measures, the *S* bargainer is in the strongest strategic position, and *T* in the weakest. This unequal distribution of strategic strength is a desirable feature given the model predictions we want to test.[9]

Bargainers conducted negotiations by electronic mail with an eight-minute time limit. Bargaining was essentially free form, a design choice that seems natural given that two of the models we test are from the cooperative literature. (A detailed description of the bargaining game is given in the next section). The five experimental treatments are distinguished by communication configuration.

> *Unconstrained*: Any bargainer can send a message or proposal to either one or both of the other bargainers.
>
> *Public*: Messages and proposals from one bargainer must go to both of the other bargainers.
>
> *S-controls*: All messages and proposals must originate or pass through *S*. *C* and *T* may send communication to *S*, but not directly to one another. *S* is under no obligation to pass a message from one bargainer on to another.
>
> *C-controls*: All communication must pass through *C*.

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8 The core is the set of all outcomes that are not dominated by another outcome. For our game, outcome *x* dominates outcome *y* if all members of the coalition necessary to realize *x* are weakly better off in *x* than they are in *y,* and at least one is strictly better off. The Shapley value is the grand coalition allocation in which each bargainer receives the marginal contribution he adds by joining the grand coalition, averaged over all orders of joining.

9 As we will see, one of the key predictions of the non-cooperative model is that some of the coalitions will exhibit equal-division payoffs even when strategic strength is distributed unequally. An affirmative finding in a design where bargainers were of symmetric strategic strength might be confounded with explanations that revolve around the symmetry rather than the reasoning behind the model.

T-controls: All communication must pass through *T*.

We consider three models.

The *Myerson value*, due to Myerson (1977), is the Shapley value for the characteristic function game in which the value of a coalition is set to 0 if the set of direct communication links between members fail to form a connected path. Consider, for example, the *S*-controls treatment: We modify the characteristic function υ by setting the value of coalition (*CT*) to 0 because there is no connected path between the members. (Intuitively, (*CT*) can form only if *S* agrees to act as a go-between; a service that *S* has a disincentive to perform, rendering (*CT*) practically infeasible.) We then take the Shapley value of the modified characteristic function: (*S*,*C*,*T*) = (60,25,15).

Table 1. Myerson value predictions

configuration/treatment	payoffs *S*	*C*	*T*
Unconstrained & Public	46.67	31.67	21.66
S-controls	60	25	15
C-controls	35	55	10
T-controls	31.67	16.67	51.66

Table 1 lists the Myerson value allocations for the treatments of the experiment. In all cases, there is a connected path linking the three bargainers, and so applying the Shapley value calculation, the only coalition we anticipate is the grand coalition. When moving from the Unconstrained to the Public configuration, the entire set of connected communication paths is unaffected, so no change is predicted. Giving a single bargainer control of communication leaves the two non-controlling bargainers without a connected communication path, eliminating the coalition of non-controlling bargainers from consideration. This raises the average marginal contribution to the grand coalition of the controlling bargainers, and thereby raises his predicted payoff.

It is difficult to challenge the reasoning behind disregarding coalitions without connected communication paths. (And our experiment turns up no empirical violations.) We retain this feature, and construct two alternative models by substituting alternative solution concepts; specifically, the core and subgame perfect equilibrium.

We refer to the model that results when we apply the core to the set of coalitions with connected communication paths as the *modified core*. The predictions are displayed in Table 2. For essentially the same reasons as with the Myerson value, the grand coalition is the only coalition predicted, and there is no difference in prediction between Unconstrained and Public. While giving a single bargainer control of communication effectively eliminates a competitive option of the non-controlling bargainers, the resulting predictions are not very precise: We can only say that the bargainer who controls communication should receive at least as much as they would in Unconstrained.

Table 2. Modified core predictions

Configuration/treatment	payoffs *S*	*C*	*T*
Unconstrained & Public	60	30	10
S-controls	≥ 60	≤ 30	≤ 10
C-controls	≤ 60	≥ 30	≤ 10
T-controls	≤ 60	≤ 30	≥ 10

The *sequential offer model* of Chatterjee, Dutta, Ray and Sengupta (1993) takes a wholly non-cooperative strategic approach to the coalition bargaining problem. It nevertheless produces predictions with an interesting equity characteristic. The three-person negotiation is modeled in the extensive form, as a sequence of proposals and counterproposals. A proposal consists of a coalition and a division of the coalition payoff. Once the proposal is on the table, members of the named coalition respond sequentially, indicating either acceptance or rejection. If everyone accepts, the proposal is adopted and the game ends; otherwise, the first rejecter makes a counterproposal. The model supposes that individual payoffs are discounted between a rejection and a counterproposal at a common rate of δ, and that utility is transferable. The game is solved by stationary subgame perfect equilibrium (stationary in the sense that bargainers make proposals and responses that are independent of play in past rounds).

Since the free-form environment does not designate any particular bargainer to propose first, we will suppose that the first proposer is chosen at random, each bargainer selected with equal probability. Since we have no reason to favor any specific number of rounds as the maximum possible, we work out the stationary perfect equilibrium of the infinite horizon version of the game, for the limiting case when $\delta \rightarrow 1$.

Table 3. Sequential offer predictions

	coalition	payoffs†		
Configur./treatment	freq.	*S*	*C*	*T*
Unconstrained, Public	2/3	45	45	
and *S*-controls	1/3	45		25
C-controls	2/3	45	45	
	1/3	45	45	10
T-controls	2/3	35		35
	1/3	35	30	35

†A blank indicates the bargainer is not a member of the coalition.

Table 3 summarizes the predictions. For each configuration, there is an equal-division coalition and a coalition that looks like a competitive response to the equal-division one. This is a general feature of the model (see Chatterjee et al., 1993). It is important to understand how these equal division and competitive tendencies interact. We get a glimpse at the intuition from a simple algorithm that can be used to compute the limiting equilibrium: Identify the coalition with the highest per capita payoff. Each member of this coalition, if chosen to be proposer, will name this coalition and the equal-division allocation. If a bargainer excluded from this coalition is chosen to be proposer, she will name the coalition that gives her the largest possible payoff, given that she must offer her coalition partner(s) what they would receive in the equal-division coalition. To illustrate, consider the unconstrained configuration, where the effective characteristic function is υ. In equilibrium, *S* and *C* will both propose the coalition with the highest per capita payoff, (*S*, *C*) = (45, 45). *T* will propose (*S*, *T*) = (45, 25). Since all bargainers are equally likely to be chosen proposer, (*SC*) forms two-thirds, and (*ST*) one-third, of the time.

In terms of the extensive form: When the common discount factor is close to 1, proposer and responders have more or less equal advantage, and this creates a tendency towards equal-divisions. On the other hand, pursuit of the best payoff implies that one should wait to form the coalition which will give him the highest equal share – unless he gets an offer just as good from elsewhere. But why doesn't competition undermine these coalitions as it would, for example, with the core? The answer is that the restriction to sequential proposals when coupled with the slight discounting at a common rate, rules out two competing offers being considered simultaneously, thereby ruling out the type of undercutting and overbidding that constitute the rationale for a solution like the core. The model tends to favor two-person coalitions over the grand coalition because successful proposals must compensate each responder for forgoing rejecting and obtaining the first-mover advantage. Proposing to one bargainer instead of two economizes on the compensation.

As with the Myerson value and the modified core, the sequential offer model predicts no difference between Unconstrained and Public configurations, but now the invariance extends to *S*-controls: Rendering (*CT*) infeasible, as the *S*-controls configuration does, is redundant in that the (*CT*) coalition was not large enough to have an influence on the solution anyway. The invariance implies there is no gain to *S* from controlling communication. But when *C* is given control, the coalition that excludes *C* is effectively eliminated, and this guarantees her best possible equal-division payoff – a clear gain. *T* likewise gains from controlling communication. The predicted pattern of grand coalition formation is in sharp contrast to the usual intuition that more communication promotes efficient coordination: Only when either *(ST)* or (*SC*) is rendered effectively infeasible does one of the bargainers have an incentive to propose the grand coalition.

As a result, efficiency, as measured by average total payoff per game, is predicted to be higher in *C* and *T*-controls than in Unconstrained, and highest in *C*-controls.

A summary of how the models' predictions compare:

> *Which constraints on communication do not matter?* All three models imply that removing the ability to communicate privately, as in Public, should make no difference. The sequential offer model further implies that giving *S* control of communication should make no difference.
>
> *Coalition formation and overall efficiency*. The Myerson value and the modified core predict that the grand coalition is the only coalition that should form, independent of communication configuration. The sequential offer model predicts that (*SC*) should be the modal coalition except in *T*-controls where (*ST*) should be modal; and the grand coalition should form only if *C* or *T* controls communication. As a consequence, the sequential offer model implies that efficiency should be higher in *C* and *T*-controls and highest in *C* controls.
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> *Payoffs*. The Myerson value (modified core) predicts that gaining control of communications increases (does not decrease) the controlling bargainer payoff relative to Unconstrained. The sequential offer model predicts that only *C* and *T* will benefit from controlling communication. Some coalition payoff allocations predicted by the sequential offer model are equal-division, while others appear to be competitive responses to the equal-division ones.

3. Laboratory protocol

Up to communication configuration, procedures for all five treatments were the same.

3.1 Treatment overview: The basic protocol

A complete copy of the instructions appears in Appendix A. The bargaining game was described in terms of a context intended to make the task transparent (the context is very similar to the one used in the Kohlberg and Raiffa experiment):

> Each negotiation involves representatives from three cement making companies: the Scandinavian Cement Company (*SC*) the Cement Corporation (*CC*) and the Thor Cement Company (*Thor*). The three companies are contemplating a formal merger. Each firm would bring value to the merger greater than its own individual profit, because of the synergies that would be realized, but how much extra value depends on the mergers that are formed. The following schedule shows the total profit value of all possible mergers, in a fictional currency called thalers:

Merging Parties	Total Profit of Merger (in thalers)
SC, *CC*, and *Thor*	100
SC and *CC*	90
SC and *Thor*	70
CC and *Thor*	40

The instructions then explained the communication links. In the *S*-controls treatment, for example, subjects were told

> The rules of communication are as follows: *SC* may send a message to either *Thor* or *CC* or to both. *CC* may send a message to *SC* but not to *Thor*. *Thor* may send a message to *SC* but not to *CC*. *The only way for Thor or CC to get a message to one another is to send it through SC.*

Each bargainer was given the e-mail addresses of only those bargainers the communication configuration allowed him to communicate with. (Bargaining transcripts verify that no one e-mailed anyone they were not permitted to). Negotiations lasted no longer than eight minutes, something that was public information. Subjects were free to write what they wished in their messages, save information that would identify them personally.[10] They were allowed to, and sometimes did, forward messages.

There were five rounds of negotiation in each session.[11] Each subject was assigned a role (*SC*, *CC*, or *Thor*) that remained fixed for all rounds.[12] Bargainers played games in the round robin format common to two-person bargaining experiments. The design provides experience to the bargainers. Reputation effects are a particular concern in a game where individuals fashion their own messages. The design controls for reputation effects by ensuring that no two

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[10] One might argue that from the perspective of the sequential offer model, allowing offers and the words 'accept' and 'reject' would be a sufficiently rich message space. But a solution like the core might well require a substantially richer message space. For example, the said restriction would rule out *S* telling *T* "If you don't agree to taking 10 in the next minute, *C* and I have agreed to form our own coalition with a 60-30 split."
[11] There were actually 6 rounds in the Public treatment. For reasons of comparability, we drop the 6th round data from the analysis we present here, although it makes no significant difference to include it. All outcome data collected is reported in Appendix B.
[12] If we rotated roles, and we observed the equal-division coalitions predicted by the sequential offer model, we might attribute them to a group effect in which players play 'nice' when in a strong position in anticipation of others playing nice with them when they are in a weak position. Fixing roles eliminates this possibility.

bargainers negotiate together more than once. The rotation scheme necessary to accomplish this is more complicated than for the two-person game, and is explained in Appendix C.

While we wanted the negotiation to be relatively unrestricted, there is an obvious need for a formal device to certify an agreement. We chose the simplest one we could think of: All of the parties included in the agreed-upon coalition completed a written contract form indicating which parties were included in the coalition and how the earnings were to be distributed. The form could be completed either during or immediately after the negotiation period. In order for an agreement to be valid, the record of the member parties had to match, and total profits could not exceed the limits set by the schedule. Anyone that failed to reach an agreement, or was not included in a coalition, earned zero for the negotiation. The monitor verified the contracts at the end of the session, after all games were complete. The contracting procedure is incentive compatible in the sense that any bargainer that makes an agreement has a payoff incentive to write down the agreed upon contract since writing anything else down has a negligible chance of matching-up. All contracts were found to be filled out correctly, and all appropriately matched.

None of the models we consider attempt to describe any learning that might go on, nor for that matter, what information might influence learning. Given this, restricting information to personal observation seems like a natural baseline for a first study. Accordingly, a bargainer received no information about the outcome of a negotiation beyond what he personally observed. Subjects were given a History Form to keep a record of their negotiations, and each bargainer had access to the messages he personally sent and received in previous games. To control for endgame effects, subjects were not told the number of rounds they would play.

3.2 Subject pool, sample sizes, and general procedures

The experiment was run in a computer laboratory at the Harvard Business School. Subjects were recruited through on-campus flyers and campus newspaper advertisements in five Boston universities.[13] Participation required appearing at a special place and time, and was

[13] Harvard, MIT, Boston College, Boston University and Tufts.

restricted to one session. The opportunity to earn cash was the only incentive offered. The experiment involved 99 subjects. Eighteen subjects participated in Unconstrained, Public and *S*-controls, 24 in *C*-controls and 21 in *T*-controls (the variation across treatments is due to variations in subject show-up rates).

Each of the five treatments was run in a single session, with the same monitor in charge in all cases.[14] Once collected in a waiting room, subjects were asked if they knew any of the others; those indicating that they did were assigned the same role so that they would never bargain together. All subjects were then led into the laboratory and assigned a computer. After reading the instructions, there was a brief tutorial on the use of the e-mail system. Negotiations were anonymous; partner identities were not revealed either during or after the session. The finish time of the negotiation was written on a black board, and a clock, visible to all participants, kept time. The monitor verbally announced when one minute was left in the negotiation. Each session lasted approximately 90 minutes, with a short debriefing at the end.

To avoid wealth effects, subjects were paid for just one negotiation, selected by lottery after all negotiations were complete. Each negotiation had an equal chance of being selected. All payments were made privately. Thalers were redeemed in cash at a rate of $0.50 each. Average earnings per subject was $21.40, about $14.25 per hour, with a standard deviation of $10.49 (figures include a $10 show-up fee). The highest paid subject earned $45.00, while 39 subjects earned only the $10.00 show-up fee.

4. Data analysis

We examine the data along five main lines: coalition formation, payoffs by bargainer-type, payoffs within coalitions, the deadline effect, and bargainer heterogeneity.

Some conclusions are clear from the descriptive statistics. For inference tests, we begin with aggregate data, ignoring any factors save for treatment. The round robin design – rotating bargainers – mitigates the influence of individual heterogeneity (precisely the same bargaining

[14] Treatments were run in the order Unconstrained, *S*-controls, *C*-controls, *T*-controls, and Public.

unit is never sampled twice). We nevertheless observe some individual heterogeneity effects (reported in section 4.5). We redo the tests restricting attention to last or first round, a procedure that controls somewhat better for heterogeneity, but sacrifices some statistical power. Finally, we redo the analysis controlling for experience effects with regressions that block for round.[15]

4.1 Coalition formation

We begin by looking at the influence communication has on the frequencies with which coalitions form. The complete set of outcome data is reported in Appendix B.

Table 4. Coalition formation

		coalition frequency				
treatment	n†	*SCT*	*SC*	*ST*	*CT*	*impasse*
Unconstrained	30	.10	.50	.23	.03	.13
Public	30	.30	.53	.03	.03	.10
S-controls	30	.17	.33	.27	–	.23
C-controls	40	.35	.45	–	.03	.18
T-controls	35	.80	–	.20	–	–
Average	33	.36	.36	.14	.02	.13

†n = 5 rounds x games per round. There were 18 subjects in Unconstrained, Public and *S*-controls, 24 in *C*-controls, and 21 in *T*-controls.

Table 4 displays the frequency of each coalition by treatment. Observe that no single type of coalition predominates. (*SC*) is the modal coalition in all but *T*-controls where (*SCT*) is modal. Coalitions lacking a connected communication path never occur, and the incidence of (*CT*) coalitions is in all treatments negligible. Some games end in impasse in 4 of the 5 treatments.

[15] Even so, the analysis does not control perfectly for the historical contagion inherent to the round robin design; that is, for any round beyond the first, some bargainers will have had common partners in their history, and hence the bargaining units are not technically independent. A design that yields unquestionably independent bargaining units would require nearly 500 subjects just to get 33 observations per treatment, and even this is insufficient if we want bargainers to experience multiple games. An alternative approach, common to the two-person bargaining literature, is a series of smaller scale experiments, conducted by independent investigators. Confidence that contagion is not a problem grows with replication, and for the same money that would go into one large-scale experiment, we get a robustness check against any particular set of lab procedures.

Does constraining communication affect coalition frequencies? A contingency table test on the data aggregated across rounds rejects the hypothesis that the frequencies of coalitions formed are the same across treatments ($p < .0001$).[16] Pair-wise comparisons with Unconstrained reject the null hypothesis for all but *S*-controls ($p < .024$ for all but *S*-controls, $p = .476$). Restricting attention to either first or last round data, we again reject the hypothesis that the frequencies are the same across all treatments ($p < .019$ for both); pair-wise comparisons with Unconstrained, however, are not significant, except for *T*-controls ($p < .01$ for both). So with the exception of *S*-controls, there is evidence that constraining communication influences coalition frequencies, with the strongest evidence associated with constraining to *T* controls.

Observe from Table 4 that, contrary to the intuition that the grand coalition is most likely where communication is least constrained, the incidence of grand coalition is lowest in Unconstrained (10 percent), and highest in *T*-controls (80 percent). Nor does a strong coordinating force necessarily help grand coalition formation: *S*-controls had the second lowest incidence of grand coalition (17 percent) even though *S* has, in this treatment, every strategic advantage. Contingency table tests on the proportion of grand coalitions across treatments (data aggregated across rounds) support these observations: We reject the hypothesis that the grand coalition is equally likely in all treatments ($p < .0001$). Pair-wise comparisons of Unconstrained with either *C* or *T* controls rejects equality (in both cases, $p < .01$), and with Public weakly rejects ($p = .058$); there is no significant difference between Unconstrained and *S*-controls ($p = .335$). Restricting attention to first or last round data, we again reject the hypothesis that grand coalition frequencies are the same across all treatments ($p < .043$ for both first and last rounds). For first round data, comparison of Unconstrained with *T*-controls is significant ($p < .029$), and for last round data, pair-wise comparisons of Unconstrained with both *C* and *T*-controls are significant ($p < .001$ for *T*-controls and $p = .058$ for *C*-controls). Other comparisons with Unconstrained are not significant ($p > .20$ in all cases).

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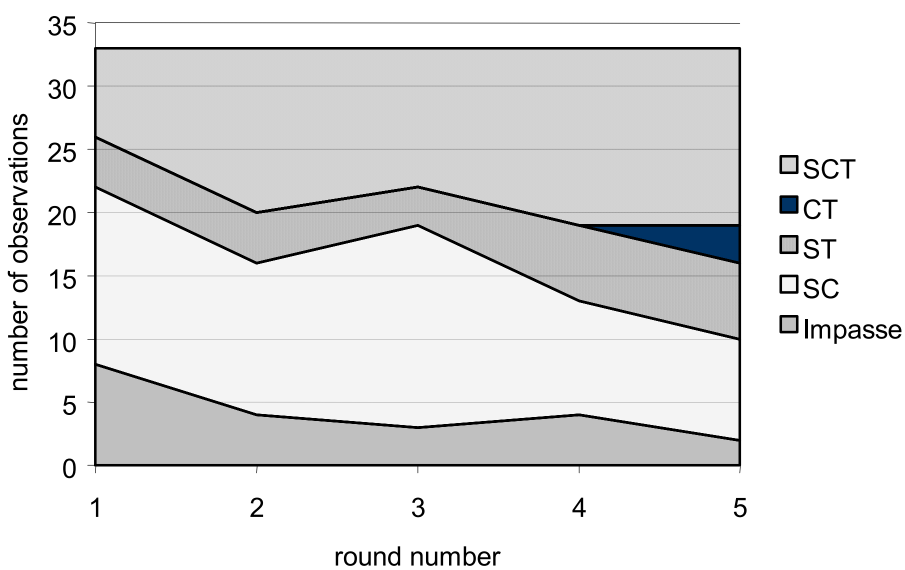
[16] All the contingency table *p*-values we report are calculated from a simulation of the actual distribution associated with the table (5 simulations of 5,000 iterations each). The procedure avoids potential difficulties associated with the chi-square approximation of the distribution, for instance when there is a cell with low expected value.

We now consider whether grand coalition formation varies round-by-round. We ran a logistic regression in which the dependent variable is whether or not the grand coalition formed and the independent variables are round number and dummies for all of the communication treatments, omitting Unconstrained. The regression is significant (X^2 = 49.235, p < .0001), refuting the prediction that grand coalitions will be equally likely in all treatments. So as with the contingency table tests, grand coalitions are more likely in *C*-controls and *T*-controls than in Unconstrained, while the differences are not significant for Public and *S*-controls. The regression also finds a mild but significant round effect (b=.276, s.e.=.139; Wald=3.941, *p*=.047), indicating that the grand coalition is somewhat more likely in later rounds. In sum, we have strong evidence that, by the last round of play, grand coalitions are more prevalent in *C*-controls and *T*-controls than they are in Unconstrained.

Figure 1. Bargaining outcomes (all treatments)



Contingency table tests turn up no strongly significant differences in the frequency of impasses across treatments. In a logistic regression where impasse is the dependent variable and the independent variables are round and dummies for four communication treatments (omitting Unconstrained), only the round coefficient is significant (b=−.362; s.e.=.182; Wald=3.980; *p*=.046). Impasse is less likely in later rounds.

Figure 1 provides a look at the aggregate trend in coalition formation (trends for individual treatments are all quite similar). Regressions indicate that beyond impasses and grand coalitions, none of the other trends are clearly significant.

Summarizing in terms of the models? None of the models predict the impasses. Table 4 clearly rejects the hypothesis, laid down by two of the models, that the grand coalition is the only coalition that will form. The sequential offer model frequency predictions are quantitatively inaccurate, most conspicuously missing the incidence of grand coalition in Unconstrained, Public or *S*-controls; in fact, of the coalitions that the sequential offer model does not predict, 85% (17 of 20) are grand coalitions. The model does, however, capture some qualitative features, namely the coalitions that form (and do not form) in *T*-controls, the higher incidence of grand coalitions in *C* and *T*-controls, and the modal coalition (*SC*) in four of the five treatments.

4.2 Payoffs by bargainer-type

We examine payoffs by bargainer type to compare efficiency across treatments, and to gauge the value of controlling communication.

Table 5. Average per game payoffs

treatment	n	average payoff (std. error) *S*	*C*	*T*	total
Unconstrained	30	39.9 (3.42)	26.5 (3.84)	6.2 (1.68)	72.7 (5.77)
Public	30	43.3 (3.59)	30.8 (2.58)	7.5 (2.19)	81.7 (5.47)
S-controls	30	37.5 (3.95)	21.5 (4.01)	6.3 (1.61)	65.3 (6.96)
C-controls	40	35.3 (2.87)	38.2** (2.89)	3.0* (0.68)	76.5 (5.85)
T-controls	35	33.0** (0.52)	24.2 (2.13)	36.8** (0.54)	94.0** (2.06)

* Indicates difference with corresponding Unconstrained column value at the 0.10 level (2-tail).
**Indicates difference with corresponding Unconstrained column value at the 0.05 level (2-tail).

Table 5 displays, by treatment, average per game payoffs for each bargainer type as well as the average total per game payoff. The table indicates the results of mean test comparisons with Unconstrained. The intuition that unconstrained communication is most likely to promote efficient outcomes is not borne out; in fact, *T*-controls has the highest average per game total payoff (p = .005). The trend holds in each round, although the differences in average total payoffs are not significant in any single round (p > .1)

We regressed total payoff on round and four dummies for the communication treatments (omitting Unconstrained). The overall regression was significant ($F_{(5,138)}$=3.538; p=.005) but accounted for only 10% of the variance in total payoff. The coefficient for round was not significant (*b*=.108; t-test=-1.435; p=.153).[17] *T*-controls had significantly higher total payoffs than did Unconstrained.

Turning to individual payoffs, we see from Table 5 that *C* and *T* benefit from controlling communication, but *S* does not. Restricting attention to the first round, only *T* benefits significantly from controlling communication (*p* < .001), but by the last round, both *C* and *T* benefit (*p* = .033 and *p* < .001).

We also ran separate regressions for *S*'s profit, *C*'s profit, and *T*'s profit. The factors in each case were round and dummies for the treatments, omitting the treatment in which the key bargainer controlled the communication.[18] The overall regression for *T*-profit was significant (F(5,159) = 93.129; p < .0005). The coefficient for round was positive and significant (*b* = .113; t-test = 2.826; p = .055). Each of the coefficients for the four treatments was negative and significant (all *b*<-.750; all t-tests<-15.000; all p<.0005). Similarly, the overall regression for *C*-profit was significant (F(5,159) = 3.845; p = .003). The coefficient for round was not significant (*b* = -.131; p = .075). Each of the coefficients for all treatments were negative and significant

[17] In separate regressions, by treatment, of round effects on total profit, round significantly affects total profit only when *T*-controls the communication (F(1,33) = 4.714, p = .037; R^2 = .125).

[18] For example, in the test of effects on *S*'s profit, the omitted treatment was S-controls. This allows a simultaneous comparison of the effect on *S*'s profit when *S* controls communication, relative to all other communication treatments.

(respectively, *b*=-.373 for Unconstrained; *b*=-.291 for Public, *b*=-.346 for *T*-controls; and *b*=-.408 for *S*-controls, all $p < .001$). The overall regression for *S*-profit was not significant ($F(5,159) = 1.834$, $p > .1$).

We also looked at average payoffs excluding games that ended with impasses (analogous to Table 5). The results are very similar: We find that Public, *C*-controls, and *T*-controls all have higher average total payoffs than Unconstrained ($p < .05$); and *C* and *T* gain from controlling communication ($p < .05$), but *S* does not (average payoff of 48.9 in *S*-controls versus 46.1 in Unconstrained).

To summarize: We have strong evidence that unconstrained communication does not promote the most efficient outcomes. In particular, total profits were highest in *T*-controls. When controlling communication, the weaker bargainers *C* and *T* gain strategic advantage relative to Unconstrained, but there is no strong benefit to the *S* bargainer. Both of these conclusions are in basic accord with the sequential offer model.

Table 6. Average payoffs within coalitions

treatment	coalition freq.†	payoffs (std. error)†† S	C	T
Unconstrained	58 (15)	46.7 (1.16)	43.3 (1.16)	
	.27 (7)	51.9 (1.65)		18.1 (1.65)
	.04 (1)		30 (-)	10 (-)
	.12 (3)	45 (2.89)	38.3 (4.41)	16.7 (6.67)
Public	59 (16)	54.1 (1.89)	35.9 (1.89)	
	.04 (1)	35 (–)		35 (–)
	.04 (1)		20 (–)	20 (–)
	.33 (9)	44.5 (3.53)	36.6 (2.00)	18.9 (3.79)

treatment	coalition freq.†	payoffs (std. error)†† S	C	T
S-controls	43 (10)	45.5 (0.50)	44.5 (0.50)	
	.35 (8)	52.5 (3.00)		17.5 (3.00)
	.22 (5)	50 (0)	40 (0)	10 (0)
C-controls	55 (18)	43.5 (0.64)	46.5 (0.64)	
	.03 (1)		30 (-)	10 (-)
	42 (14)	44.9 (1.21)	47.2 (1.06)	7.9 (0.79)
T-controls	.20 (7)	33.6 (0.92)		36.4 (0.92)
	80 (28)	32.9 (0.61)	30.3 (0.61)	36.9 (0.64)

†Measured as a proportion of coalitions formed (actual number in parentheses.

††A blank indicates that the bargainer is not a member of the coalition.

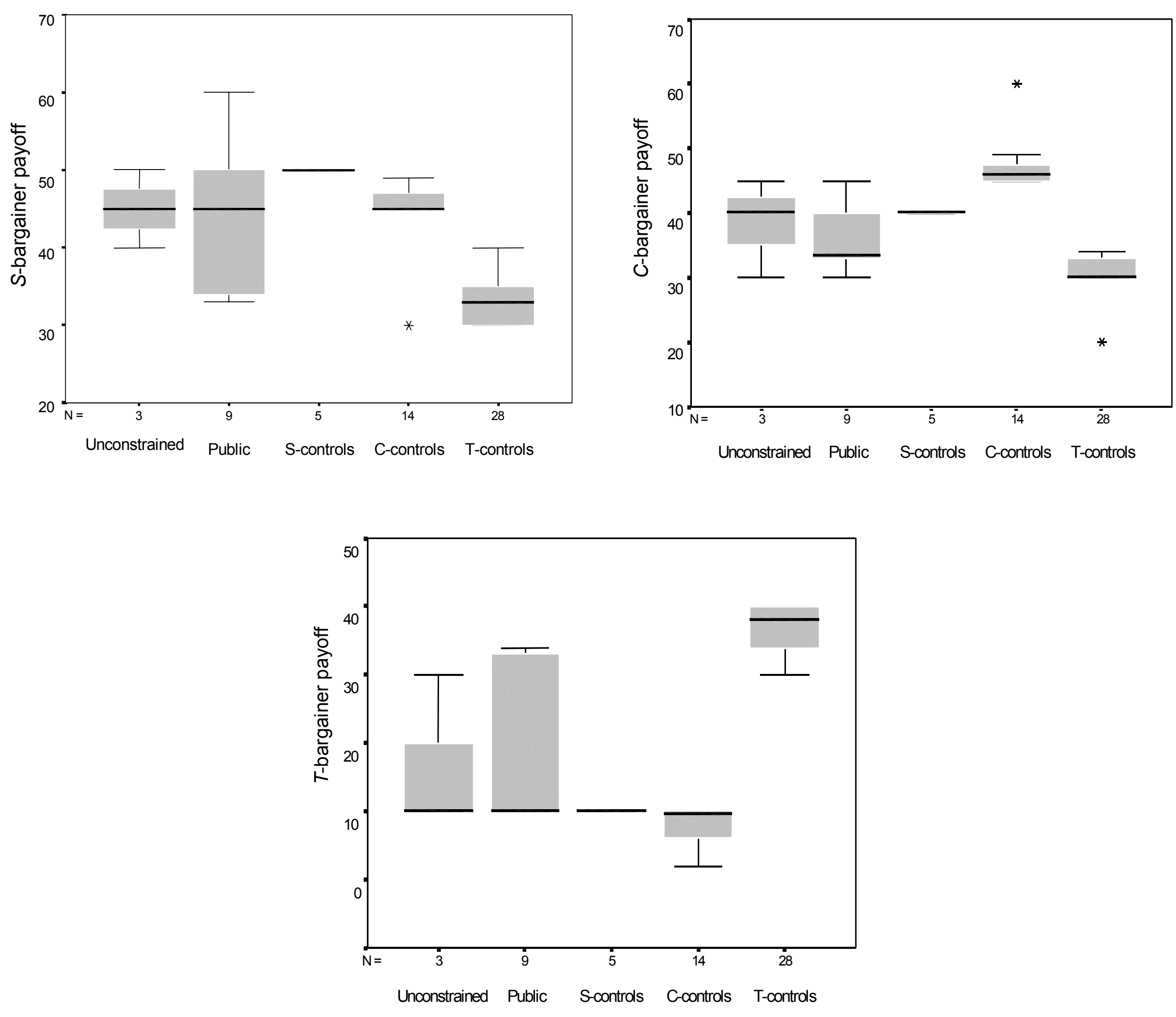
4.3 Payoff allocations within coalitions

Looking at the payoffs within coalitions tells us something important about the nature of the negotiations. In many ways it is the key evidence.

Table 6 displays average payoffs broken out by type of coalition. The most striking feature is the mix of nearly equal-division and clearly unequal-division allocations. The payoffs for the coalitions the sequential offer model anticipates look quite a bit like the predictions. Where payoffs are predicted to be equal-division, they are almost so, and where they are predicted to be competitive, they are at least qualitatively like what the model says they should be. The one exception is the Public treatment, where the *SC* coalitions tend to look competitive, not equal-division as the model predicts. Of course averages can be deceiving. Counting outcomes (Appendix B): 73% (11/15) of (*SC*) coalitions split exactly 45-45 in Unconstrained, 90% (9/10) in *S*-controls, and 67% (12/18) in *C*-controls versus 25% (4/16) in Public (with *S* receiving more than 45 in the other 12 outcomes).

More generally, we count the number of settlements that are within 5 units of the sequential offer model prediction.[19] The percentages are 69 (18/26) for Unconstrained, 65 (15/23) for *S*-controls, 85 (28/33) for *C*-controls, 94 (33/35) for *T*-controls – a weighted average of 80.2% across these four treatments – but only 30% (8/27) for Public.

Figure 2. Boxplot of bargainer payoffs by treatment: Grand coalitions only



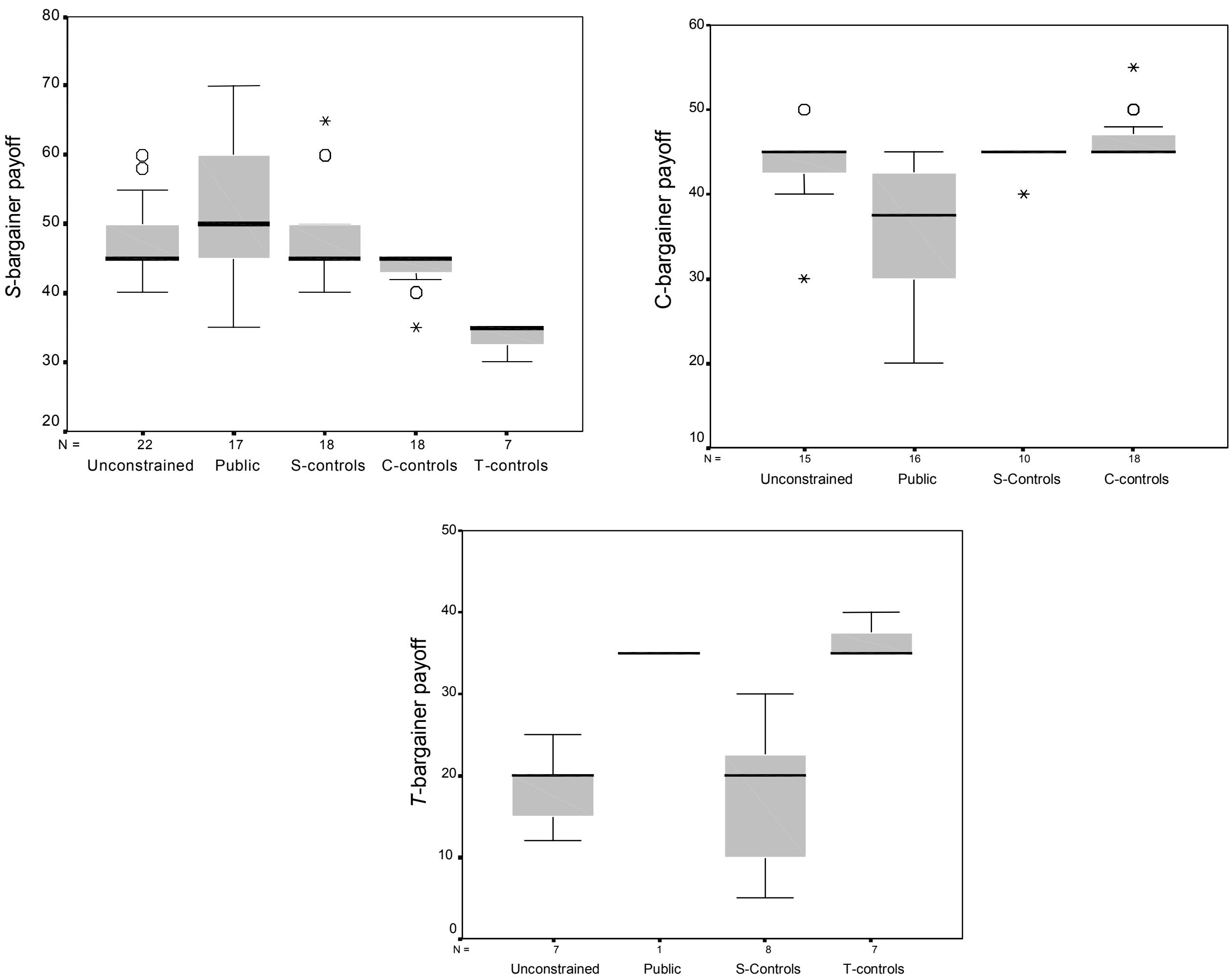
50% of cases have values within the box
Solid lines within box: median

[19] So we exclude impasses from consideration, but include coalitions that the sequential offer model does not predict as wrong predictions. A coalition is "within 5 units" if it is possible to realize the prediction by rearranging no more than 5 thalers of the actual outcome.

Top of box: 75th percentile, bottom of box: 25th percentile
Top and bottom lines: largest and smallest observed values that are not outliers
* Extremes: Values > 3 box-lengths from 25th or 75th percentile

The boxplots in Figures 2 and 3 offer yet a third way of looking at the allocations. The medians of the distributions are quite similar to the averages in Table 6. The distributions are for the most part quite tight; more often than not the entire range is 10 units or less. The one exception is Public where the variance of *S* and *C* payoffs in the grand coalition, and *S* payoffs in two-person coalitions is higher than in other treatments. Note also the clear difference in payoffs for all coalitions in *T*-controls versus analogous coalitions in all other treatments.

Figure 3. Boxplot of bargainer payoffs, by treatment: (*SC*) and (*ST*) coalitions only



50% of cases have values within the box
Solid lines within box: median

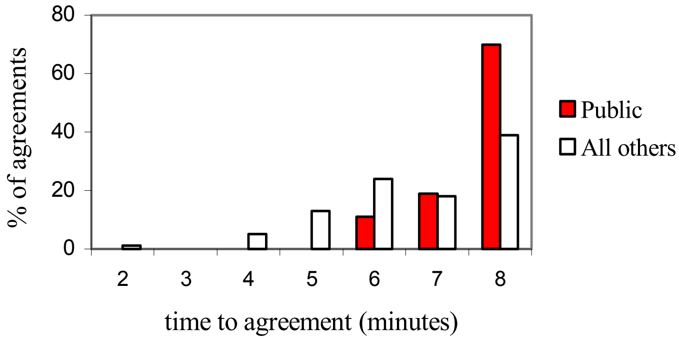
Top of box: 75th percentile, bottom of box: 25th percentile
Top and bottom lines: largest and smallest observed values that are not outliers
❍ Outliers: Values > 1.5 box-lengths from 25th or 75th percentile
Extremes: Values > 3 box-lengths from 25th or 75th percentile

All three models anticipate grand coalitions for *C*-controls and *T*-controls, although the models disagree sharply on what the allocations should be (Myerson value *C*: 35, 55, 10 and *T*: 31.67, 16.67, 51.66; modified core *C*: ≤60, ≥30, ≤10 and *T*: ≤60, ≤30, ≥10; and sequential offer *C*: 45, 45, 10 and *T*: 35, 30, 35). Inspection of Figure 2 shows that the actual allocations are quite close to the sequential offer model, but very different from the other two models.

Only the Myerson value and the modified core predict grand coalitions in Unconstrained, Public and *S*-controls. Looking at Figure 2, only in Public does the distribution of grand coalition allocations intersect with the modified core solution, although only at the extreme of the distribution. In fact, Public is the only treatment where there are any grand coalitions within 5 units of the (60,30,10) core prediction (2 of them); on the other hand, it is also the only treatment, outside of *T*-controls, in which there are any grand coalitions within 5 units of the egalitarian allocation (2 of them). The Myerson value is not a bad point prediction for grand coalitions in Unconstrained and Public, but it overestimates *S*'s grand coalition payoff in *S*-controls.

In sum, within each treatment, we find a pattern of fairly tightly distributed, equal-division and unequal-division (competitive) payoff allocations. The exception is the Public treatment, where most coalitions are, on average, unequal-division, although in this treatment the distribution of payoff allocations is often wide. Excepting Public, the sequential offer model's prediction of which coalitions will be equal-division and which unequal-division is accurate. Most of the coalitions that the sequential offer model does not anticipate are grand coalitions. Among these, the Myerson value is a somewhat better point predictor than the modified core, although both exhibit some apparent biases (we return to accounting for these grand coalitions in section 5).

Figure 4. Time to agreement



	average (minutes)
Unconstrained	6.8
Public	7.6
S-controls	6.4
C-controls	6.8
T-controls	6.7

4.3 *The deadline effect*

While in our experiment there is no formal time discounting of the type important to the sequential offer model, there is time pressure in the form of a deadline. Figure 4 presents time-to-settlement data. A contingency table test found no significant difference in the time to settlement for four treatments, so we have presented the bar graph with these aggregated. There is, however, a significant difference when Public is included (p=.023). The distinctiveness of Public is also apparent from the comparison of time-to-settlement averages, also presented in Figure 4. The bar graph shows that the major way Public distinguishes itself has to do with what is known as the *deadline effect*, the tendency for settlements to happen close to deadline. Fully 70% of Public settlements are reached in the last minute of negotiation, whereas the average is 39% for the other treatments (about 45% when aggregated across all treatments). Roth, Murnighan and Schoumaker (1988) report an analogous deadline effect for 2-person negotiations (we compare these more closely below).[20]

Corresponding to the downward trend in impasses across time that we identified earlier, there is also a downward trend in settlement times. This tendency is similar in all treatments. Average settlement times over the last 2 rounds are lower than those in the first 3 rounds (7.2 versus 6.7 minutes, p =.018). Likewise, settlements in the last minute of negotiating decline from 63.6% in the first round to 39.4% in the last round.

[20] The investigators note that "This "deadline effect" appears to be quite robust, in that the distribution of agreements over time appears to be much less sensitive to the experimental manipulation that is the distribution of the terms of agreement [p. 807]."

The fact that so many negotiations go to the last minute suggests that the deadline is strategically important, and hence we would like to understand the nature of the deadline effect better.[21] There are two prominent potential explanations. One hypothesis is that the time allowed for negotiation was binding, that the bargainers found the 8-minute time limit restrictive with respect to the negotiation problem to be solved. The important implication of the time-is-binding hypothesis is that we might see fewer impasses, and perhaps more grand coalitions, if bargainers were given more time. A second hypothesis is that the deadline is an important commitment device, used to wring concessions from bargaining partners. This hypothesis explains impasses in a different way, as the risk inherent in pressing for a concession at the deadline.

Two pieces of evidence lend themselves to distinguishing between the two deadline effect hypotheses. First, we look at outcomes in Public, where there is evidence of a greater deadline effect than in other treatments. The time-is-binding hypothesis suggests that in the Public treatment, which includes more 3-way interaction and thus requires more time, we would expect a relatively high number of impasses. But, as shown in Table 4, Public treatment impasses are below average. The commitment hypothesis, in contrast, suggests that the greater degree of deadline bargaining implies more concession-wringing behavior. The data are consistent with this: there is greater disparity in the payoffs in all 2-party coalition agreements here than in other treatments.

[21] That time pressure played a role in the negotiations is reflected in the bargaining discussion transcripts. Two quotes from two different negotiations illustrate this graphically: *CC*: "Before time is up, write SC 40 CC 40 Thor 20 or else none of us get anything!!!!!" *Thor*: "Time is running out. Please do something . . . 40-20-20!! Before none of us gets anything!"

Table 7. Classification of Impasse Types

treatment *(# of impasses)* *round*	Still haggling *1*	*2*	*3*	*4*	*5*	Procedural coordination problems *1*	*2*	*3*	*4*	*5*	Deadlock *1*	*2*	*3*	*4*	*5*
Unconstrained (4)	2	1	-	-	-	-	-	-	-	1			-		
Public (3)	1	1	-	-	-			-			-	-	-	1	-
S-controls (7)	3	-	1	-	-	-	1	1	1	-			-		
C-controls (7)	1	-	-	-	-	1	1	1	-	-	-	-	-	2	1

While the time-is-binding hypothesis cannot explain the *difference* in settlement time found between Public and the other treatments, this does not rule out the possibility that it plays a role in *some* of the impasses. The second piece of evidence is Table 7. Combing through the discussion transcripts from the negotiations we were able to catalogue impasses into three categories. 'Still haggling' refers to negotiations where offers and counteroffers are still being made when time runs out. 'Procedural coordination problems' refer to instances when bargainers appear to have settled on a particular coalition, but time ran out before the group confirmed the agreement to one another. 'Deadlock' refers to negotiations that end with all proposals on the table having been rejected by the relevant parties, with no new proposals submitted.

Both deadline effect hypotheses are consistent with 'still haggling' and 'procedural coordination problem' kinds of impasses. Likewise, both hypotheses potentially explain the disappearance of 'still haggling' impasses after round 3; in one case as the result of learning with experience to negotiate more quickly, and in the other case as learning with experience to use the commitment strategy with greater discretion. (The downward trend in settlement times we identified earlier can be explained by both hypotheses in a similar way.) 'Deadlock' impasses, however, would seem to require the commitment hypothesis to explain them. In these negotiations, bargainers appear to have said all they wished to say prior to the deadline. This strategic use of deadlines comes with experience; all deadlock impasses occurred in rounds 4 and 5.

Some additional indirect evidence in support of the commitment hypothesis comes from comparing the magnitude of our deadline effect with that reported by Roth et al. (1988) for 2-person negotiations. Roth et al. begin their paper with a discussion of what they say is a typical time-to-settlement distribution for a 12-minute bargaining game in which each negotiator played but once. In this distribution, 49.4% of settlements are completed in the last minute (41.5% in the last 30 seconds). Taking this as given, and noting our bargainers had but eight minutes to negotiate, the time-is-binding hypothesis would lead us to expect higher rates of deadline negotiating in our experiment.[22] But in fact, as reported above, 45% of our settlements are reached in the last minute when averaged across all rounds (somewhat higher in the first round, and somewhat lower in the last round).

In sum, many negotiations go to the last minute, implying the deadline played an important strategic role in the negotiations. Some of the evidence here is consistent with both the time-is-binding and commitment explanations for the deadline effect. There are two types of evidence that would seem to require a commitment explanation. These are the dichotomy between Public and the other treatments, and the 'deadlock' impasses.

4.5 Bargainer heterogeneity

Table 8. Examples of bargainer heterogeneity

# of observations with given feature within treatment / # of leverage bargainers involved					
data feature	Public	Unconstrained	*S*-controls	*C*-controls	*T*-controls
impasse	3 / 2	4 / 3	6 / 3	7 / 4	0 / -
grand coalition	11 / 4	3 / 2	5 / 2	14 / 8	28 / 7
S payoff > 50	11 / 4	4 / 2	3 / 1	0 / -	0 / -

All three models assume homogeneity across subjects. This does not hold for our data. Table 8 provides some sense of the heterogeneity. It matches particular types of outcomes with

[22] The 8-minute limit was dictated by the desire to keep sessions to 90 minutes.

the number of bargainers in the leverage role involved in those outcomes. We see that in many instances a minority accounts for the phenomenon.

5. Discussion: Why the sequential offer model succeeds and fails

The sequential offer model misses some important features of the data. At the same time, it is clearly the benchmark model that provides the most guidance to the data. The successes are non-trivial, and therefore difficult to attribute to chance. Bargainers in the experiment are not subject to the discounting or confined to the sequential offer structure assumed by the model. Whether the goal is refining the sequential offer model, or building an entirely new model, it seems a good idea to probe the data for clues to the sequential offer model's successes and failures. First a summary of the pattern of behavior identified in the last section:

Coalition formation

- (*SC*) was the modal coalition in 4 treatments. (*SCT*) was modal in *T*-controls.
- Grand coalitions formed in all treatments, but most often in *T*-controls, and next most often in *C*-controls.

Payoffs

- Average total payoffs were higher in *T*-controls than in Unconstrained.
- Relative to Unconstrained, *C* and *T* bargainers clearly gain (on average) from controlling communication, but there is no strong advantage to *S* bargainers.
- With the exception of Public, the path connected coalition that has the highest per capita payoff exhibits near equal-division payoffs.

Other patterns

- Bargaining in all treatments exhibits a deadline effect, more pronounced in the early rounds but still substantial in the late rounds. This effect is stronger in Public.
- Impasses decrease, and grand coalitions increase somewhat, with experience. Average payoffs within coalitions are stable across rounds.

The sequential offer model accurately predicts where (*SC*) will be the modal coalition, and the two treatments where the grand coalition is most likely (although it does not predict that the two will differ as they do). The model provides quite an accurate guide to the influence of constraining communication on total and bargainer-type payoffs, as well as to the mix of equal-division and unequal-division payoffs. It correctly predicts no difference between Unconstrained and *S*-controls treatments. But for the Public treatment, the model fails on most counts. In all treatments, the model underpredicts the grand coalition, and in three treatments incorrectly predicts none (and so offers no guidance to the payoffs in these coalitions). The model does not predict the impasses. (It does not predict the experience effect, but this is not surprising for an equilibrium model.[23])

We find that much of what the sequential offer model gets right can be traced to the prediction that the coalition with the highest per capita value will exhibit equal-division payoffs. How the theoretical mechanics behind the equal-division coalition differ from what actually takes place appears to explain the model's failure in the Public treatment. Much of the rest that the model gets wrong (impasses being the most prominent exception) can be attributed to the systematic underprediction of the frequency of grand coalitions.

5.1 The importance of the equal-division coalitions in the model's successes

In the sequel, we refer to the (two-person) equal-division coalition predicted by the sequential offer model as simply *the* equal-division coalition. Once we accept the equal-division coalition as fact, many of the important patterns in the data follow rather naturally from a rudimentary examination of the competitive pressures in the environment (independent of reference to the sequential offer model). For instance, we immediately see why only one of the other two-person coalitions is viable, and that the viable coalition must have a competitive looking allocation that favors the member who could otherwise join the equal-division coalition.

We can also sketch an explanation for why *C* and *T*-controls have the highest incidence of grand coalition: In Unconstrained, Public and *S*-controls, any grand coalition proposal that

[23] In the lab, behavior in many, if not most, games played repeatedly exhibits a settling tendency, consistent with learning phenomena in many environment (see, for example, the discussion in Roth and Erev, 1995). Hence we can think of the predictions of an equilibrium model as predictions about where behavior will eventually settle.

gives a prospective member of the equal-division coalition less than the equal-division coalition payoff will be resisted by that bargainer. On the other hand, if the grand coalition proposal satisfies prospective equal-division coalition members, the bargainer excluded from the equal-division coalition will resist since there is a two-person coalition that he likes better, and is also competitive with the equal-division coalition. So in these three treatments, any grand coalition proposal will be actively resisted by at least one bargainer. In contrast, for both *C* and *T*-controls, there are grand coalition proposals that can compete with the equal-division as well as the other two-person coalitions (for example, the one that the sequential offer model predicts). Moreover, there is one bargainer who *must* propose the grand coalition in order to compete with the equal-division coalition. Hence in *C* and *T*-controls (and unlike the other three treatments), the grand coalition has a champion who can make a grand coalition proposal that there is no obvious reason for the other bargainers to resist.

The higher incidence of grand coalition in *C* and *T*-controls immediately explains why unconstrained communication does not necessarily lead to higher efficiency. We can also see why *S* does not benefit from controlling communication: Given the fixed equal-division coalition, the competitive treatments are unchanged from what they would be in the Unconstrained treatment.

The sequential offer model predicts the equal-division coalition, so it is not surprising that the regularities the model gets right are, for the most part, those we just discussed. Recall from section 2 that the key features behind the prediction are slight discounting for time at a common rate, which creates a tendency towards equal-division bargaining agreements, and the extensive form restriction to sequential proposals, which along with the discounting, blunts competitive undercutting and overbidding. There is no explicit discounting in our bargaining game; nor are bargainers restricted to making sequential offers. So the economic drivers behind the data are unlikely to be literally the same as those behind the predictions of the sequential offer model.

One hypothesis is that the equal-divisions are the result of non-strategic equity norms. Norms of this type are well known to have an influence in laboratory two-person bargaining games (see Roth (1995) for a review of this literature). Note, however, that this hypothesis fails to explain the obviously competitive allocations we see. Just as important, it does not explain the *pattern* of equal-division and competitive coalitions; that is, why the equal-division coalitions are almost exclusively those with the highest average payoff.[24]

An alternative hypothesis is that treatments in the actual negotiations mimic the effects of sequential proposals and discounting. For instance, the essential feature of the sequential proposals assumption is that a proposal is responded to by the proposed-to before a competing proposal is put on the table, thus impeding competitive overbidding and undercutting. We went through the bargaining discussion transcripts and found that, with the obvious exception of the Public treatment, every two-person coalition proposal was communicated privately, thus depriving the excluded bargainer of the information that would allow her to jump in with a competitive counterproposal. This natural propensity for private proposals, then, may have the important consequence of the sequential proposal assumption.[25]

Time discounting, within the context of the sequential offer model, also contributes to impeding competitive proposals. With respect to the actual bargaining, it seems reasonable to suppose that the time it takes to respond to a proposal is randomly distributed with a small mean and variance. As a consequence, the probability the bargaining will terminate without a response is initially negligible and only gets within perceptible magnitudes close to the deadline. The probability of termination might then have essentially the same important strategic effects of discounting. Indeed we have already noted the strong deadline effect in the data. Some more evidence is found in the transcripts: Time pressure is explicitly mentioned as a reason or

[24] There is substantial evidence that the strategic environment influences the norms we see in the lab; see, for example, Binmore, Swierzbinski, Hsu, and Proulx (1993), Van Huyck, Battalio, Mathur, and Van Huyck (1995) and Van Huyck, Battalio and Rankin (1997).

[25] It might also explain why previous studies have come to different conclusions concerning private messages. As noted in the introduction, Murnighan and Roth (1977) found that allowing private messages tended to move coalition divisions closer to equal division, whereas Rapoport and Kahan (1976) found that it had no effect. The rules of the bargaining game studied by Rapoport and Kahan required that an agreement be made public prior to ratification, independent of whether the agreement had been arrived at by private messages. Any bargainer left out of the tentative agreement was then given a chance to make a counterproposal. Hence Rapoport and Kahan's game guaranteed an opportunity for competitive overbidding and undercutting even in treatments with private messages. No such mechanism was available in the bargaining game studied by Murnighan and Roth.

argument for the settlement arrived at in about 48% of the games that end in a two-way agreement (percentage roughly the same across treatments).

The other important implication of slight time discounting at a common rate is that it tends to push negotiations towards equal-division settlements. That a deadline can have the same effect is confirmed by a recent experiment by Sterbenz and Phillips (1998). The experiment is directed at testing Ma and Manove's (1993) deadline bargaining model in which players can choose to postpone responding to an offer without losing one's turn, and there is a random component to the transmission times of messages.[26] The investigation finds some evidence for the model. Perhaps most important for our purposes, the experiment includes a control cell in which bargainers A and B have three minutes to come to agree on the division of a monetary pie. The bargainers make sequential offers, and the clock begins to run when A makes the first proposal. Sterbenz and Phillips find that A and B earnings are "nearly identical" even though there is room here for strategic manipulation; for example, bargainer B could conceivably wait until very close deadline to make a very demanding counteroffer.

So it may be that private proposals and deadline bargaining fill the same strategic role in the actual bargaining as discounting and sequential proposals fill in the model. Perhaps the best argument for this is that Public, the one treatment where there can be no private proposals, and the deadline effect plays out differently, is also the treatment where the sequential offer model has the least success. And many (not all) of the outcomes are as we would expect from the argument above: They are more competitive looking. The more competitive nature of Public negotiations is also reflected in the discussion transcripts. In the transcripts, we find that the rationale for the equal-division coalition suggested by the sequential offer model equilibrium, is quite common in Unconstrained (mentioned in 47% of the games),[27] but is never mentioned in Public.[28]

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[26] Ma and Manove's explanation of the deadline effect thus combines both strategic delay and randomness. We essentially focus on the second effect, which gives rise to an effective probability of termination.

[27] As one *S*-player explained to a *C*: "A contract between *SC* and *CC* can yield us the greatest profits each. If we split it, we get 45. Any other contract would not yield that much unless one of the parties took a smaller profit than the others."

[28] Chatterjee and Dutta (1998) study public and private offers in a game with two heterogeneous buyers and two identical sellers, with offers from each side of the market being made simultaneously, as are responses from the side

Where then are the equity norms that appear in two-person bargaining games? There are two relevant observations. First, with respect to the coalition with the highest average payoff, the sequential offer model implies that strategic considerations will simply reinforce any non-strategic tendency toward equal-division. So for these coalitions, equity norms and the underlying strategic factors are, in effect, redundant. Second, there is a competitive factor in the three-person bargaining game – a bargainer can be left out of a settlement – that is absent in the two-person game. And the sequential offer model implies that it is precisely this factor that is behind the competitive coalitions we see in the data.

To summarize, private offers and deadline bargaining plausibly impede overbidding and undercutting in a manner that has the same impact on the outcomes of the actual bargaining, as the sequential proposal restriction and discounting have on the outcomes in the sequential offer model. The Public treatment where private proposals are not possible, and the deadline effect is observably different, is also the treatment where outcomes look more competitive than predicted by the model.

5.2 The importance of underprediction of grand coalitions in the model's failings

We might take the unanticipated frequency of grand coalitions as evidence that the factors behind one or both of the other two models are having some influence. But this is not so. Outside of Public, none of the grand coalitions look like the predictions of the modified core, and while average grand coalition allocations in Unconstrained and Public are close to the Myerson value predictions, the grand coalitions for *C* and *T*-controls are markedly different (see section 4.3). There was also no tendency for the payoffs *within* the grand coalitions to change with experience. So payoffs are neither at nor moving those predicted by the cooperative models.

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receiving offers. The public offers game has an equilibrium in the core, which is destroyed by heterogeneity on both sides of the market. Under private offers, the (public, perfect mixed) equilibrium involves a positive probability of delay and is not in the core.

Table 9. Modified sequential offer model predictions vs. the data
Italicized numbers are predictions; regular font is data (average payoffs).

treatment	coalition Frequency		payoff allocations† S		C		T	
Unconstrained	*.44*	.58	*45*	46.7	*45*	43.3		
	.33	.27	*45*	51.9			*25*	18.1
	.22	.12	*45*	45.0	*40*	38.3	*15*	16.7
Public	*.44*	.59	*45*	54.1	*45*	35.9		
	.33	.04	*45*	35.0			*25*	35.0
	.22	.33	*45*	44.5	*40*	36.6	*15*	18.9
S-controls	*.44*	.43	*45*	45.5	*45*	44.5		
	.33	.35	*45*	52.5			*25*	17.5
	.22	.22	*45*	50.0	*40*	40.0	*15*	10.0
C-controls	*.44*	.55	*45*	43.5	*45*	46.5		
	.56	.42	*45*	44.9	*45*	47.2	*10*	7.9
T-controls	*.44*	.20	*35*	33.6			*35*	36.4
	.56	.80	*35*	32.9	*30*	30.3	*35*	36.9

†a blank space indicates the bargainer is not a member of the coalition

Can we explain the unaccounted for grand coalitions by modifying the sequential offer model? The reason the sequential offer model predicts relatively few grand coalitions is because it is marginally more costly in terms of time to include another bargainer in the coalition and compensate him for not rejecting than it is to leave him out altogether. But suppose instead that after making a two-person agreement, the agreeing bargainers propose the grand coalition to the third bargainer giving him whatever is left over after the two bargainers get their agreed upon shares. Suppose this happens a third of the time the sequential offer model says there will be a two-person agreement. The remainder of the time the grand coalition doesn't form either because there is not enough time to offer it to the third bargainer, or the third bargainer turns it down. This is not entirely speculation. The pattern of behavior we are proposing here is close to what Rapoport and Kahan (1976) found in their coalition experiment.[29]

[29] Rapoport and Kahan report that "It was found that although the 3-person coalition formed the majority of the

The resulting predictions are shown in Table 9. The predicted frequencies are close to actual in Unconstrained, *S* and *C*-controls (a goodness-of-fit test fails to reject in all three cases, $p > .188$), and although they are far from correct for *T*-controls, they have moved in the right direction relative to the original predictions. The grand coalition equilibrium payoffs in *T*-controls are relatively close to equal-division, which may have made it easier to agree upon. Also observe that we pick up the grand coalitions that the original model misses, and that the predicted expected grand coalitions allocations too are close to the actual values. Note how the expected grand coalition payoff values reflect the values of the viable two-person coalitions.

If we now repeat the exercise in section 4.3 of tallying the settlements that are within 5 units of prediction, we get, in percentages: 77 (20/26) in Unconstrained, 41 (11/27) in Public, 87 (20/23) in *S*-controls, 85 (28/33) in *C*-controls, and 94 (33/35) in *T*-controls. This is an improvement in all but *C* and *T* controls where adherence to prediction was already very high. The amount of adherence in Public is still substantially smaller than in the other treatments.

The only treatment where the hypothesis is glaringly inaccurate is the Public treatment, but again this may reflect a fundamentally different pattern of negotiation that is beyond the reach of a model premised on sequential proposals.

Summarizing the discussion in this section: First, it may be the case that deadline bargaining and private proposals fill roughly the same strategic roles as discounting and sequential proposals do in the theory. Perhaps the best evidence for this is that the one place the model fails completely, the public configuration, is also the one place where there can be no private offers. Second, much of the rest of what the model gets wrong can be traced to the underprediction of the grand coalition. The payoffs in the unpredicted grand coalitions can be rationalized, at least informally, in terms of the payoffs of the predicted coalitions. These conclusions are conjectural, and we advance them with some caution: They are constructed with

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time, the effects of 2-person coalitions were important and direct, and provided a basis for determining the specific ratified PC [p. 271].” In particular, the investigators note that a large percentage of 3-person coalitions result from an initial 2-person agreement that is then modified to include the third player [p. 268]. Rapoport and Kahan generally observe more grand coalition in their experiment than we observe in ours. One potential explanation is that our experiment imposed a strict deadline on negotiating time whereas Rapoport and Kahan’s appears to have been more open ended. A strict deadline might make coordination failure more likely.

the benefit of hindsight, and the evidence is indirect. Still, we think the case is persuasive enough to suggest promising avenues for new, more definitive research.

6. Final comments

Our major findings have to do with the nature of the influence of the communication configuration on coalition formation. Some of these findings challenge traditional thinking. For example, the grand coalition formed much more often in the *T*-controls configuration than in the unconstrained configuration, where all bargainers could communicate freely. Also, while controlling the communication flow can increase a bargainer's expected payoff, as it did for *C* and *T*, it need not do so: *S*'s payoffs were essentially unchanged even though *S* generally received substantially less than the core payoff in the unconstrained configuration.

All three models we consider assume that the coalitions that lack a connected path through the communication configuration will not form. This base supposition is consistent with our data: We never observed an unconnected coalition. All of the models go on to imply that changing the set of coalitions with connected communication paths in certain ways can change the coalition(s) that do form. Our experiment confirms this; we found some statistically discernable effect for every change in connected paths save for the one involved in *S*-controls.

On the other hand, contrary to all three models, the elimination of private communication in the Public treatment, a change that does not alter the set of coalitions with connected paths, nevertheless had a discernable influence on coalition payoffs. Our analysis led us to the conjecture that forcing all communication to be public leads to somewhat more competitive bidding among bargainers, although formalizing this idea would require further work.

The bargaining deadline plays an apparent role in the negotiations in our experiment, and we posited in the last section that its strategic influence in the actual bargaining might be similar to the influence of time discounting in the sequential offer model. One avenue for further research would be to manipulate the contracting procedure for establishing a coalition, something that is arguably an important factor in the influence of the deadline.

In one respect the success of the sequential offer model is surprising: Bargainers in our experiment were not restricted to the sequential offer model's extensive form. In another respect it is not so surprising: Both Maschler (1963, 1978) and Selten (1987) develop models to explain data from coalition bargaining experiments.[30] Maschler's model applies "power transformations" to the bargaining set. The power transformations embody both an equity principle and a measure of the strategic strength of a coalition. Selten's is a satisficing model that rests on the application of an equity principle within the context of an assessment of the strategic strength of each bargainer. While both of these models are cooperative games, they nevertheless share an important commonality with the non-cooperative sequential offer model: They posit an interaction between competition and equity as the key to coalition formation. Our data suggests that this interaction should be explored further.

[30] Neither model deals with the communication issue, nor is it immediately clear how to go about adding communication to them.

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Appendix A. Written Instructions to Subjects

General. Please read the instructions carefully. If at any time you have questions or problems, raise your hand and the monitor will be happy to assist you. From now until the end of the session, unauthorized communication of any nature with other participants is prohibited.

During the session, you will engage in a series of negotiations, carried out over e-mail with other participants. Each negotiation gives you an opportunity to earn cash.

Description of the Negotiation. Each negotiation involves representatives from three cement making companies: the Scandinavian Cement Company (SC), the Cement Corporation (CC), and the Thor Cement Company (Thor). The three companies are contemplating a formal merger. Each firm would bring value to the merger greater than its own individual profit, because of the synergy that would be realized. But how much extra value depends on the mergers that are formed. The following schedule shows the total profit value of all possible mergers, in a fictional currency called thalers (how thalers translate into dollars is explained below):

Merging Parties	Total Profit of Merger (in thalers)
SC, CC, and Thor	100
SC and CC	90
SC and Thor	70
CC and Thor	40

Only one merger is allowed per negotiation. Before entering into a merger, representatives from the merging companies must agree on how to divide the profits. The goal of each representative is to get the most profits possible for his or her own company.

You have the role of a company representative. The company you represent is indicated on the top, right hand corner of this sheet.

Each negotiation lasts at most 8 minutes. During this time, company representatives may bargain with one another. All negotiations are conducted by computer e-mail. Instructions on how to operate the e-mail will be provided after everyone has finished reading the instructions. The rules of communication are as follows:

SC may send a message to either CC or Thor or to both.
CC may send a message to either SC or Thor or to both.
Thor may send a message to either SC or CC or to both

OR

Thor may send a message to either SC or CC or to both.
CC may send a message to Thor *but not to SC*.
SC may send a message to Thor *but not to CC.*

The only way for SC or CC to get a message to one another is to send it through Thor.

Please note: under no circumstances are you allowed to identify yourself by your real name.

Once an agreement is reached, the merging parties must complete a contract stipulating the terms of the agreement. In order for the contract to be valid, a contract form must be completed by each merging party by the time the monitor announces the end of the 8 minute period. A merger is valid only if each merging party has entered the same information about partners and profits onto the form. In addition, any contract which has total profits exceeding the limits set by the above schedule will be considered invalid. All companies not in a contract at the end of the negotiation receive zero (0) profit for that negotiation.

Contract Form. At the conclusion of each negotiation, all of the parties included in the agreed upon merger must fill out a contract form for each negotiation. There are a number of these forms attached. Fill in how much each party to the agreement receives, note what role you are playing, state your e-mail ID (e.g., Mock 4), and sign your name. Each person will have an identical form. We will pay you what the contract states you have earned <u>only</u> if the forms from all the parties in the agreement match.

Negotiation Record. A blank 'History' form is provided in your folder. At the conclusion of each negotiation, please fill out this form. The completed form provides you with a history of your past negotiations, and you may reference it at any time during the session.

Grouping Procedure. You will change bargaining partners for each negotiation. You will never negotiate with the same person more than once. Partner identities are confidential and will not be revealed at the end of the session. Please do not identify yourself to the other party during the negotiation.

Earning money for yourself during the negotiations. You will negotiate more than once. You will actually be paid for just one negotiation. The payoff negotiation will be selected by a lottery after all the negotiations have been completed. Each negotiation has an equal chance of being selected, so it is in your interest to make as much profit as you can in each and every one. Each thaler you earn is worth $0.50. For example, if the second negotiation were selected in the lottery and you earned 40 thalers in that negotiation, you would be paid $20. Immediately upon conclusion of the session, you will be paid your earnings in cash.

Appendix B: Outcome data

The table summarizes the outcomes for all the games in the experiment. Data from round 6 of the Public treatment was dropped from the analysis presented in the paper for comparability reasons (there were 5 rounds in all other treatments). Condition key: 1 = Unconstrained, 2 = Public, 3 = *S*-controls, 4 = *C*-controls, and 5 = *T*-controls.

condition	round	S profit	C profit	T profit	Tot. profit
1.00	1.00	45.00	45.00	.00	90.00
1.00	1.00	.00	.00	.00	.00
1.00	1.00	45.00	45.00	.00	90.00
1.00	1.00	.00	.00	.00	.00
1.00	1.00	50.00	.00	20.00	70.00
1.00	1.00	45.00	45.00	.00	90.00
1.00	2.00	.00	.00	.00	.00
1.00	2.00	50.00	40.00	.00	90.00
1.00	2.00	40.00	50.00	.00	90.00
1.00	2.00	45.00	45.00	.00	90.00
1.00	2.00	50.00	40.00	.00	90.00
1.00	2.00	55.00	.00	15.00	70.00
1.00	3.00	45.00	45.00	.00	90.00
1.00	3.00	45.00	45.00	.00	90.00
1.00	3.00	45.00	45.00	10.00	100.00
1.00	3.00	50.00	.00	20.00	70.00
1.00	3.00	45.00	45.00	.00	90.00
1.00	3.00	45.00	45.00	.00	90.00
1.00	4.00	45.00	45.00	.00	90.00
1.00	4.00	55.00	.00	15.00	70.00
1.00	4.00	60.00	30.00	.00	90.00
1.00	4.00	50.00	40.00	10.00	100.00
1.00	4.00	50.00	.00	20.00	70.00
1.00	4.00	40.00	30.00	30.00	100.00
1.00	5.00	45.00	.00	25.00	70.00
1.00	5.00	45.00	45.00	.00	90.00
1.00	5.00	58.00	.00	12.00	70.00
1.00	5.00	.00	.00	.00	.00
1.00	5.00	50.00	40.00	.00	90.00
1.00	5.00	.00	30.00	10.00	40.00
2.00	1.00	50.00	40.00	.00	90.00
2.00	1.00	45.00	45.00	.00	90.00
2.00	1.00	.00	.00	.00	.00
2.00	1.00	40.00	40.00	20.00	100.00
2.00	1.00	33.33	33.33	33.33	100.00
2.00	1.00	60.00	30.00	.00	90.00
2.00	2.00	.00	.00	.00	.00
2.00	2.00	45.00	45.00	10.00	100.00
2.00	2.00	60.00	30.00	.00	90.00
2.00	2.00	34.00	33.00	33.00	100.00
2.00	2.00	60.00	30.00	10.00	100.00
2.00	2.00	60.00	30.00	.00	90.00
2.00	3.00	50.00	40.00	.00	90.00
2.00	3.00	45.00	45.00	.00	90.00
2.00	3.00	50.00	40.00	.00	90.00
2.00	3.00	60.00	30.00	.00	90.00
2.00	3.00	45.00	45.00	.00	90.00
2.00	3.00	55.00	35.00	.00	90.00
2.00	4.00	35.00	.00	35.00	70.00
2.00	4.00	60.00	30.00	.00	90.00
2.00	4.00	50.00	40.00	.00	90.00
2.00	4.00	60.00	30.00	10.00	100.00
2.00	4.00	.00	.00	.00	.00
2.00	4.00	45.00	45.00	10.00	100.00
2.00	5.00	60.00	30.00	.00	90.00
2.00	5.00	50.00	40.00	10.00	100.00

2.00	5.00	70.00	20.00	.00	90.00
2.00	5.00	.00	20.00	20.00	40.00
2.00	5.00	45.00	45.00	.00	90.00
2.00	5.00	33.00	33.00	34.00	100.00
2.00	6.00	50.00	40.00	10.00	100.00
2.00	6.00	.00	27.50	12.50	40.00
2.00	6.00	.00	.00	.00	.00
2.00	6.00	50.00	30.00	20.00	100.00
2.00	6.00	60.00	30.00	.00	90.00
2.00	6.00	50.00	40.00	.00	90.00
3.00	1.00	.00	.00	.00	.00
3.00	1.00	.00	.00	.00	.00
3.00	1.00	.00	.00	.00	.00
3.00	1.00	45.00	45.00	.00	90.00
3.00	1.00	45.00	45.00	.00	90.00
3.00	1.00	45.00	45.00	.00	90.00
3.00	2.00	.00	.00	.00	.00
3.00	2.00	50.00	40.00	10.00	100.00
3.00	2.00	65.00	.00	5.00	70.00
3.00	2.00	45.00	45.00	.00	90.00
3.00	2.00	45.00	45.00	.00	90.00
3.00	2.00	50.00	40.00	.00	90.00
3.00	3.00	45.00	45.00	.00	90.00
3.00	3.00	50.00	40.00	10.00	100.00
3.00	3.00	50.00	.00	20.00	70.00
3.00	3.00	50.00	40.00	10.00	100.00
3.00	3.00	.00	.00	.00	.00
3.00	3.00	.00	.00	.00	.00
3.00	4.00	40.00	.00	30.00	70.00
3.00	4.00	.00	.00	.00	.00
3.00	4.00	45.00	45.00	.00	90.00
3.00	4.00	60.00	.00	10.00	70.00
3.00	4.00	50.00	40.00	10.00	100.00
3.00	4.00	45.00	45.00	.00	90.00
3.00	5.00	45.00	45.00	.00	90.00
3.00	5.00	50.00	.00	20.00	70.00
3.00	5.00	60.00	.00	10.00	70.00
3.00	5.00	50.00	40.00	10.00	100.00
3.00	5.00	45.00	.00	25.00	70.00
3.00	5.00	50.00	.00	20.00	70.00
4.00	1.00	43.00	47.00	.00	90.00
4.00	1.00	45.00	45.00	10.00	100.00
4.00	1.00	.00	.00	.00	.00
4.00	1.00	.00	.00	.00	.00
4.00	1.00	35.00	55.00	.00	90.00
4.00	1.00	45.00	45.00	.00	90.00
4.00	1.00	45.00	45.00	.00	90.00
4.00	1.00	45.00	45.00	.00	90.00
4.00	2.00	45.00	45.00	10.00	100.00
4.00	2.00	45.00	47.00	8.00	100.00
4.00	2.00	30.00	60.00	10.00	100.00
4.00	2.00	45.50	45.50	9.00	100.00
4.00	2.00	45.00	45.00	.00	90.00
4.00	2.00	43.00	47.00	.00	90.00
4.00	2.00	45.00	45.00	.00	90.00
4.00	2.00	.00	.00	.00	.00
4.00	3.00	45.00	45.00	.00	90.00
4.00	3.00	40.00	50.00	.00	90.00
4.00	3.00	46.00	46.00	8.00	100.00
4.00	3.00	45.00	45.00	.00	90.00
4.00	3.00	.00	.00	.00	.00
4.00	3.00	45.00	45.00	.00	90.00
4.00	3.00	49.00	49.00	2.00	100.00
4.00	3.00	45.00	45.00	.00	90.00
4.00	4.00	45.00	45.00	10.00	100.00
4.00	4.00	.00	.00	.00	.00
4.00	4.00	45.00	45.00	.00	90.00

4.00	4.00	40.00	50.00	.00	90.00
4.00	4.00	45.00	45.00	10.00	100.00
4.00	4.00	45.00	45.00	.00	90.00
4.00	4.00	.00	.00	.00	.00
4.00	4.00	45.00	45.00	10.00	100.00
4.00	5.00	.00	30.00	10.00	40.00
4.00	5.00	49.00	49.00	2.00	100.00
4.00	5.00	.00	.00	.00	.00
4.00	5.00	45.00	45.00	.00	90.00
4.00	5.00	47.00	47.00	6.00	100.00
4.00	5.00	42.00	48.00	.00	90.00
4.00	5.00	47.50	47.50	5.00	100.00
4.00	5.00	45.00	45.00	10.00	100.00
5.00	1.00	33.00	33.00	34.00	100.00
5.00	1.00	30.00	.00	40.00	70.00
5.00	1.00	30.00	30.00	40.00	100.00
5.00	1.00	40.00	30.00	30.00	100.00
5.00	1.00	35.00	.00	35.00	70.00
5.00	1.00	30.00	30.00	40.00	100.00
5.00	1.00	35.00	.00	35.00	70.00
5.00	2.00	30.00	30.00	40.00	100.00
5.00	2.00	35.00	30.00	35.00	100.00
5.00	2.00	33.00	33.00	34.00	100.00
5.00	2.00	35.00	.00	35.00	70.00
5.00	2.00	34.00	33.00	33.00	100.00
5.00	2.00	30.00	.00	40.00	70.00
5.00	2.00	30.00	30.00	40.00	100.00
5.00	3.00	30.00	30.00	40.00	100.00
5.00	3.00	35.00	30.00	35.00	100.00
5.00	3.00	33.00	33.00	34.00	100.00
5.00	3.00	35.00	33.00	32.00	100.00
5.00	3.00	35.00	.00	35.00	70.00
5.00	3.00	30.00	30.00	40.00	100.00
5.00	3.00	30.00	30.00	40.00	100.00
5.00	4.00	30.00	30.00	40.00	100.00
5.00	4.00	33.00	33.00	34.00	100.00
5.00	4.00	35.00	.00	35.00	70.00
5.00	4.00	40.00	20.00	40.00	100.00
5.00	4.00	32.00	32.00	36.00	100.00
5.00	4.00	35.00	30.00	35.00	100.00
5.00	4.00	30.00	30.00	40.00	100.00
5.00	5.00	35.00	30.00	35.00	100.00
5.00	5.00	30.00	30.00	40.00	100.00
5.00	5.00	30.00	30.00	40.00	100.00
5.00	5.00	30.00	30.00	40.00	100.00
5.00	5.00	34.00	34.00	32.00	100.00
5.00	5.00	40.00	20.00	40.00	100.00
5.00	5.00	34.00	33.00	33.00	100.00

Appendix C: Rotation of bargaining partners

With fifteen subjects, it is possible to have each subject play five games in the same role, and never assign any subject to play with any other subject more than once. The algorithm for assigning bargaining partners begins with the table below. Each row number corresponds to a subject assigned the roles of SC, and each column number to someone assigned CC, and the entries in the table to those assigned Thor.

subject	**2**	**5**	**8**	**11**	**14**
1	3	6	9	12	15
4	6	9	12	15	3
7	9	12	15	3	6
10	12	15	3	6	9
13	15	3	6	9	12

The first set of games, along the main diagonal, would be 1 2 3, 4 5 9,7 8 15,10 11 6, 13 14 12. The next set of games would be 4 2 6, 7 5 12, 10 8 3, 13 11 9, 1 14 15; followed by 7 2 9, 10 5 15, 13 8 6, 1 11 12, 4 14 3; 10 2 12,13 5 3, 1 8 9,4 11 15,7 14 6; 13 2 15,1 5 6, 4 8 12, 7 11 3, 10 14 9.

Thus subject 1 would play with subjects 2,3; 14,15; 11, 12; 8,9; 5,6. Therefore 1 would play with all subjects with the CC role (2,5,8,11,14) as well as all subjects with the role of Thor (3,6,9,12,15). Subject 5 (CC) would play the following sequence of opponents: 4,9; 7,12; 10,15; 13,3; 1,6. The other subjects would be assigned in the same way.