Heterogeneities, Information, and Conflict Resolution: Experimental Evidence on Sharing Contracts

Steven Hackett
Department of Economics and Workshop in Political Theory and Policy Analysis
Indiana University

Dean Dudley
Department of Social Sciences
U.S. Military Academy

and

James Walker
Department of Economics and Workshop in Political Theory and Policy Analysis
Indiana University

September 20, 1993

Financial support from the National Science Foundation (Grants SES-8820897, SES-8921884, and SBR-9222656) is gratefully acknowledged. Data are available upon request from the authors. Send inquiries to Professor James M. Walker or Professor Steve Hackett, Department of Economics, Ballantine 901, Indiana University, Bloomington, Indiana 47405.

BIOGRAPHY

STEVEN HACKETT is Assistant Professor of Economics and a Research Associated of the Workshop in Political Theory and Policy Analysis at Indiana University. His principal research focus is on contracting and the activities of firms, with recent attention to problems of *ex-post* contractual negotiations. Recent publications include "A Comparative Analysis of Merchant and Broker Intermediation" Journal of Economic Behavior and Organization, "Incomplete Contracting: a Laboratory Experimental Analysis" in Economic Inquiry, and "Bottlenecks and Governance Structures: Open Access and Long-Term Contracting in Natural Gas" (with T, Lyon) in Journal of Law, Economics, and Organization.

DEAN DUDLEY, is Assistant Professor of Economics in the Department of Social Sciences at the United States Military Academy. Current working papers include, "Individual Choice in Common Pool Resource Environments: an Experimental Approach," "Forecasting Behavior in Experimental Common Pool Resource Appropriation and Public Good Provision Environments," and "Individual Provision Choice in Voluntary Contribution Public Good Environments: an Experimental Approach." Current research focuses on strategies for downsizing large organizations.

JAMES WALKER is Professor of Economics and a Research Associate of the Workshop in Political Theory and Policy Analysis at Indiana University. His principal research focus is the use of experimental methods in the investigation of behavior related to the voluntary provision of public goods and the use of common-pool resources. Recent publications include "Covenants With and Without the Sword: Self-Governance is Possible," (with R. Gardner and E. Ostrom) American Political Science Review, "Rent Dissipation and Probabilistic Destruction of Common-Pool Resource Environments: Experimental Evidence," Economic Journal, (with Roy Gardner), and "Group Size and the Voluntary Provision of Public Goods: Experimental Evidence Utilizing Large Groups," (with R.M, Isaac and A. Williams), Journal of Public Economics.

ABSTRACT

A growing body of field and experimental literature provides considerable evidence that individuals may evolve and adopt self-governing institutions that enable conflict resolution. A principle focus of this paper is the role of heterogeneity in individual attributes as an obstacle to conflict resolution. Results are presented from two ongoing research programs: (1) individual and group decision making in the context of a commonly held resource that is subtractable in units of appropriation, and (2) ex post negotiation of surplus shares in incomplete contracts. Both programs have been designed to investigate conflict resolution when subjects are heterogenous in costly investments they have incurred.

Heterogeneities, Information, and Conflict Resolution: Experimental Evidence

Sharing Rules and Distributional Conflict

Consider a situation in which a group is making allocation decisions that determine the distribution of a commonly held surplus. Prior to the allocation decision, individuals make capital investments. The ultimate value of the investments is assumed to depend on the group's ability to resolve conflicts arising over the distribution of joint surplus. Examples include the construction of water injection wells by those who own mineral rights on a common oil field, investments in maintenance of a commonly held irrigation system, or the construction of product-specific manufacturing facilities by parties to a joint venture. What will be the linkage between these individual capital investments and group-devised sharing rules? To what extent is this linkage affected by the degree to which information on investments is public or private? What are the broader implications of heterogeneous investments and imperfect information for joint surplus? In this paper we investigate these issues using laboratory methods from two related economic applications: the study of input allocation rules for common-pool resources (CPRs) in the natural resources literature, and the study of ex post negotiation of surplus shares in incomplete contracts in the literature on contracting and the firm.

A growing body of field and experimental literature provides considerable evidence that individuals may evolve and adopt self-governing institutions that enable conflict resolution. A principle focus of this paper is the role of heterogeneity in individual attributes as an obstacle to conflict resolution. The literature provides several arguments that point to heterogeneity as a deterrent to cooperation (Hardin 1982, Johnson and Libecap 1982, Libecap and Wiggins 1984, Wiggins and Libecap 1987, Ostrom 1990, Kanbur **1991,** Hackett 1992). For example, Kanbur (1991, 21-22) argues,

> ... theory and evidence would seem to suggest that cooperative agreements are more likely to come about in groups that are homogeneous in the relevant economic dimension, and they are more likely to break down as heterogeneity along this dimension increases.

The task of agreeing to and sustaining agreements is more difficult when individuals are heterogeneous in relevant attributes because of the distributional conflict associated with alternative sharing rules.[1] In heterogeneous settings, different sharing rules may produce different distributions of earnings across individuals. While all individuals may be made better off by cooperating, some may benefit more than others. Consequently, individuals may fail to cooperate on the adoption of a sharing rule because they cannot agree upon what would constitute a fair distribution of benefits produced by cooperating.[2]

This paper reports results from two ongoing experimental research programs that are relevant to this issue. Both programs have been designed to investigate conflict resolution when subjects are heterogenous in costly investments they have incurred. In the CPR study, parties make up-front investments in inputs that can be applied to the CPR production process, while in the incomplete contracting study, parties make up-front investments in value enhancement or cost reduction. Moreover, the information individuals have about each others' attributes, and the role this information plays in the resolution of conflict over sharing rules, are key research questions. The studies differ in terms of emphasis: the CPR study focuses on the allocation of inputs to a CPR production process, and on the use of face-to-face negotiations to resolve the social dilemma of individual incentives deviating from those that maximize joint surplus. In contrast, the incomplete contracting study focuses on tests of bargaining theory in a much more structured negotiation setting where negotiation occurs after parties have made transaction-specific investment. The CPR and incomplete contracting studies are described below.

HETEROGENEITIES AND CPRs

Common-pool resources (CPRs) are natural or man-made resources in which: (a) exclusion is nontrivial (but not necessarily impossible) and (b) yield is subtractable (Ostrom, Walker, and Gardner, 1992). Individuals jointly using a CPR are assumed to face a social dilemma — commonly referred to as the tragedy of the commons - in which individual resource users ignore the external harm they impose on other users, leading to outcomes that are not optimal from the perspective of the group. Policy proposals for resolving CPR dilemmas often follow one of two approaches--privatizing the resource or centralizing its management within the state.

Building on the experimental research of Walker, Gardner, and Ostrom (1990) and Hackett, Schlager, and Walker (forthcoming), this section examines a decision setting where individuals make input allocation decisions between a CPR and an outside alternative with a fixed marginal return. Heterogeneity is introduced by varying the input endowments of subjects. The principle question is to what degree do heterogeneities hinder individuals' ability to coordinate their use of the CPR? In this experimental setting, coordination of input use and the evolution of self-governing rules of use are examined by allowing subjects to discuss the decision problem in face-to-face communication sessions.

The Game Theoretic Decision Setting

Assume a fixed number n of appropriators with access to the CPR.[3] Each appropriator i has an endowment of inputs e_i which can be allocated to the CPR or allocated to an outside activity with a constant marginal return, w. The payoff to an individual appropriator from allocating inputs to the CPR depends on aggregate group allocations to the CPR, and on the appropriator's allocation as a percentage of the aggregate. Let x_i denote appropriator i's allocation to the CPR, where $0 \leq x_i \leq e_i$. The group return to allocations to the CPR is given by the production function $F(\Sigma x_i)$, where F is a concave function, with $F(0) = 0$, $F'(0) > w$, and $F'(\Sigma e_i) < 0$. Initially, allocating inputs to the CPR pays better than the opportunity cost $[F'(0) > w]$, but at some level of allocation ($x_h < \Sigma e_i$) the outcome is counterproductive $[F'(x_h) < 0]$. Thus, the yield from the CPR reaches a *maximum net level* when individuals allocate some but not all of their endowments to the CPR. More specifically, CPR rents are maximized (where *rents* per unit of input allocation are defined to be the average revenue product of allocations to the CPR less the average revenue product of allocations to the outside option) where the marginal return from the last input allocated to the CPR equals the marginal return from the outside option.

Let $x = (x_1,\ldots,x_n)$ be a vector of individual appropriators' input allocations to the CPR. The payoff to an appropriator, $u_i(x)$, is given by:

$$u_i(x) = \begin{cases} we_i & \text{if } x_i = 0 \\ w(e_i - x_i) + (x_i/\Sigma x_i)F(\Sigma x_i) & \text{if } x_i > 0. \end{cases} \qquad (1)$$

Equation (1) reflects the fact that if an appropriator allocates all of his endowment in the outside alternative, he gets a sure payoff (we_i), whereas if he allocates some of his endowment to the CPR, he gets a sure payoff $w(e_i-x_i)$, plus a payoff from the CPR. An appropriator's payoff from the CPR depends on the yield from total allocations, $F(\Sigma x_i)$, multiplied by his share of overall group allocations $(x_i/\Sigma x_i)$.[4] Previous studies have simplified the analysis of the CPR game by using designs that yield fully symmetric non-cooperative equilibria. To see this, let the payoffs in (1) be the payoff functions in a symmetric, noncooperative game. Then each player allocates x_i^* in the CPR such that:

$$-w + (1/n)F'(nx_i^*) + F(nx_i^*)((n-1)/x_i^*n^2) = 0 \qquad (2)$$

The focus of this paper, however, is on appropriator heterogeneity. In particular, the experimental design allows for two levels of input endowments. One subset of appropriators have large endowments, e_i^l, $i=1,2,\ldots,M$; the remaining appropriators have small endowments, e_j^s, $j=M+1,M+2,\ldots,N$, and $e_i^l > e_j^s$ (superscripts refer to endowment size). Parameters are chosen so that the Nash equilibrium is symmetric within appropriator type, but asymmetric across type; large appropriators allocate more inputs to the CPR than small appropriators.[5] This is accomplished by having the small players' endowment be a binding constraint in equilibrium. Allocations at the Nash equilibrium satisfy:

$$-w + (x_i^*/(Z+Mx_i^*))F'(Mx_i^*) + F(Mx_i^*)[Z+(M-1)x_i^*]/(Z+Mx_i^*)^2 = 0 \qquad (3a)$$

for $i=1,2,\ldots,M$ large endowment players, and

$$x_j^* = e_j, \qquad (3b)$$

for $j=M+1,M+2,...,N$ small endowment players ($Z \equiv \Sigma x_j^*$). Group allocations to the CPR at this asymmetric Nash equilibrium are greater than optimal, but not all rents from the CPR are dissipated. To see this, compare this deficient equilibrium to the optimal solution. Summing across individual payoffs $u_i(x)$ for all appropriators i, one has the group payoff function u(x),

$$u(x) = w\Sigma e_i - w\Sigma x_i + F(\Sigma x_i), \tag{4}$$

which is to be maximized subject to the constraints $0 \leq \Sigma x_i \leq \Sigma e_i$. Given the above conditions on F, the group maximization problem has a unique solution characterized by the condition:

$$-w + F'(\Sigma x_i) = 0. \tag{5}$$

According to (5), CPR rents and total group earnings are maximized when the marginal return from a CPR equals the opportunity cost of the outside alternative for the last input unit allocated to the CPR. While the asymmetric Nash equilibrium depends critically on the endowment parameter e_i, the group payoff maximizing level of allocation does not. There are many different rules that can distribute individual allocations to the CPR such that total rents from the CPR are maximized. Since endowments are heterogeneous, different rules (e.g., equal allocation to the CPR versus CPR allocations proportionate with endowment) imply different wealth distributions. Such inequities may lead to disagreement over the type of sharing rule, and ultimately a reduction in CPR rents.

The experimental setting is designed for the subjects to play the CPR game a finite number of times with a publicly announced end point. Denote the CPR game by X.[6] If the game has a unique equilibrium, then the finitely repeated game has a unique subgame perfect and subgame consistent equilibrium (Selten 1971). Thus, equation (3) characterizes a finite sequence of equilibrium outcomes.

Face-to-face communication represents an interesting empirical anomaly from the perspective of game theory. If the games implemented in the laboratory setting accurately induce the valuations corresponding to the payoff function of equation 1 and the parameters we control in our experimental setting, then finitely repeated, complete information, noncooperative game theory ascribes no strategic content to nonbinding communication.[7] Face-to-face communication (and resulting verbal commitments), however, may change subject's expectations of other players' responses. In particular, if subjects believe a cooperative play will induce cooperation from others, then cooperating can be sustained as rational play in the framework of incomplete information regarding player types.

The Laboratory Setting and Design

The experiments used subjects drawn from undergraduate economics classes at Indiana University. All experiments were conducted on the NovaNET computer system. At the beginning of each experimental session, subjects were told that: (1) they would make a series of allocation decisions, (2) all individual allocation decisions were anonymous to the group, and (3) they would be paid their individual earnings (privately and in cash) at the end of the experiment. Subjects then proceeded at their own pace through a set of instructions summarized below.[8]

> Subjects faced a series of decision rounds in which they were endowed with a specified number of tokens, which they allocated between two markets. Market 1 was described as an allocation opportunity which yielded a fixed (constant) rate of output per token, and that each unit of output yielded a fixed constant monetary return. Market 2 (the CPR) was described as an allocation opportunity which yielded a rate of output per token dependent upon the total number of tokens allocated by the entire group. The rate of output at each level of group allocation to Market 2 was described in functional form as well as tabular form. Subjects were informed that they would receive a level of output from Market 2 that was equivalent to the percentage of total group tokens they allocated. Further, subjects knew that each unit of output from Market 2 yielded a fixed (constant) rate of monetary return.

Subjects knew with certainty the total number of decision makers in the group, their own token endowment, the total number of tokens in the group, and the number of decision rounds in the current treatment condition. After each round, subjects were shown a display that recorded their profits in each market, total group token allocations to Market 2, and a total of their cumulative profits for the experiment. During the experiment, subjects could request, through the computer, this information for all previous rounds for the current treatment condition. Subjects received no information regarding other subjects' individual allocation decisions.

Parameters and Predictions

The decision setting is operationalized with eight appropriators ($n = 8$) and quadratic production functions $F(\Sigma x_i)$ for Market 2, where:

$$F(\Sigma x_i) = a\Sigma x_i - b(\Sigma x_i)^2 \tag{6}$$

with $F'(0) = a > w$ and $F'(\Sigma e_i) = a - 2b\Sigma e_i < 0$.

For this quadratic specification, one has from (5) that the group optimal token allocation satisfies $\Sigma x_i = (a-w)/2b$. Further, the CPR yields 0% of optimal rents when token allocation is twice as large as optimal.

The Nash equilibrium for a finite game with complete information (based on an individual's payoff function as shown in equation 1) for large and small appropriators is given by:

$$\Sigma x_i = (M/(M+1))(a-w-bZ)/b,\ i=1,2,\ldots,M, \text{ and} \tag{7}$$

$$\Sigma x_j = Z \equiv \Sigma e_j,\ j = M+1, M+2,\ldots,N.$$

The following constraints were placed on the choice of parameter values for a, b, c, d, e, and w in this study. First, to preserve equilibrium uniqueness, Nash equilibrium x_i and x_j must be integer valued, a constraint imposed by software design. Second, in order for heterogeneity in endowments to create a heterogeneous Nash equilibrium, the small players' endowments had to be sufficiently small to be a binding constraint in non-cooperative play.

The experiment parameters are shown in Table 1. Each small player was endowed with 8 tokens per round, each large player with 24. Further, each player was charged an endowment fee of $.02 per token per period to lower the cost of the experiments. This fee is a sunk cost, thus having no effect on Nash equilibrium or optimal allocation levels. There exists a unique Nash equilibrium where total tokens allocated to Market 2 equals 96: (i) small endowment players each allocate all 8 of their tokens in Market 2 and (ii) large endowment players each allocate 16 tokens in Market 2 and 8 tokens in Market 1. At the Nash equilibrium subjects earn approximately 49% of the *maximum rents* from Market 2, the CPR. Computing earnings from both Market 1 and Market 2 at this equilibrium, small players receive a per-period payoff of (8 x $.09) - (8 x ($.02) = $.56. Large players receive a per-period payoff of (8 x $.05) + (16 x $.09) - (24 x $.02) = $1.36. With a total group payoff per period of $7.68.

In order to maximize group earnings, 56 tokens must be allocated to Market 2, yielding a group per period payoff of $11.78. Various allocation rules can be used to achieve the group optimum of 56 tokens allocated to Market 2. Different allocation rules, however, generate meaningful differences in individual payoffs (displayed in Table 1). Under the rule of *equal allocation,* each player allocates 56/8 = 7 tokens at the group optimum. Each small player receives a net payoff of $1.23, while each large player receives a net payoff of $1.70. Using the noncooperative Nash allocation level as the reference point, *equal absolute reductions* in tokens allocated to Market 2 requires each player remove 40/8 = 5 tokens from Market 2. Each small player allocates 3 tokens in Market 2, with a net payoff of $.66. Each large player allocates 11 tokens in Market 2, with a net payoff of $2.26. (Note that small players are still better off with this rule relative to the Nash equilibrium). Again using the Nash equilibrium as the reference point, an *equal proportionate reduction* in tokens allocated to Market 2 requires the group to cut token allocations to Market 2 by 42%. Each small player allocates 5 tokens in Market 2, with a net payoff of $0.94. Each large player allocates 9 tokens in Market 2, with a net payoff of $1.98.

Treatment Sequences

Subjects participated in two (consecutive) ten round sequences of the asymmetric game.[9] In the first ten rounds subjects were not allowed to communicate. In the final ten rounds the subjects were informed that prior to each decision round they would have the opportunity to discuss the allocation problem (10 minutes prior to the first decision round and 3 minutes prior to each subsequent round).

No physical threats or side payments were allowed.[10] Thus, the structure of the experiment can be summarized as follows:

Sequence 1 Sequence 2

X?X,. .,X C-X,C-X,...,C-X.

Prior to each ten round treatment sequence, four subjects were assigned the "large" token endowment (24 tokens each), while the remaining four subjects were assigned the "small" endowment (8 tokens each). Subjects had to make costly investments in order to secure one of the large endowment positions. Two distinct auction mechanisms were use to generate information settings where auctions prices were common (public) or private information.

Treatment 1: Common Price Auction

The first auction mechanism used for assigning endowment positions was a multiple unit ascending price auction. Prior to the ten decision rounds with no-communication and again prior to the ten decision rounds with communication the subjects received a set of instructions summarized below.

> For each of the next 10 rounds four subjects would be assigned 8 tokens, while the other four would each be assigned 24. Tokens would be assigned using an auction in which each subject bid for the right to have 24 tokens. The auction began with each subject raising their right hand. The auctioneer called out bids that increased every 5 seconds, in $.25 intervals. When the auctioneer reached a bid that was the highest total amount a subject was willing to pay to have 24 tokens rather than 8 tokens each round, the subject should lower their hand. This meant the subject was out of the auction. When there were only 4 persons left with their hands raised the auction stopped. Each of the 4 persons remaining in the auction were allocated 24 tokens each round for the next 10 rounds, paying a one time auction price equal to the last bid that was called by the auctioneer when the auction stopped. The 4 persons who dropped out of the bidding process were allocated 8 tokens each round.

This **"common price"** auction mechanism was chosen for several reasons: (1) the price paid for the large endowment position should theoretically correspond with the maximum value placed on this position by the subject with the fourth highest valuation -- the four subjects who won the auction should be those who placed the highest value on having the large endowment; (2) the price paid for the large endowment position was common to all auction winners ~ simplifying the decision setting; and (3) the price paid for the large endowment position was common knowledge to all subjects.

An overview of results from the experiments utilizing the common price auctions is organized around two design cells: (1) No-Communication-Common Price Auction Assignment (NC-CP) and (2) Communication-Common Price Auction Assignment (C-CP). The discussion focuses first on individual token allocations to Market 2, followed by a summary of rent accrual as a percentage of optimum. This overview will be followed by a discussion of agreements to specific allocation rules, adherence to these agreements, and auction prices.

Individual Decisions

Figure 1 displays frequency distributions of individual Market 2 decisions for both design cells. As seen, in the no communication condition, NC-CP, the modal Market 2 allocation is 8 tokens. Recall that low token endowment subjects had an endowment of 8 tokens. The high frequency at 8 can be attributed primarily to those subjects allocating their entire endowments in the CPR in numerous decision rounds (consistent with the Nash prediction). Focusing on specific decision rounds, however, the pattern of allocations at the individual level is not strictly consistent with the Nash prediction of 8 tokens for low endowment subjects **and** 16 tokens for high endowment subjects. To illustrate this result, consider the 10th round of experiment 3 of the NC-CP design. The four large endowment subjects allocated 16, 11, 16, and 21 tokens to Market 2, while the four small endowment subjects allocated 8, 7, 8, and 8 tokens to Market 2. The results from this decision round are representative of decision rounds in other NC experiments. A high percentage of low endowment subjects allocate their entire endowment of 8 tokens to Market 2, while Market 2 allocations by high endowment subjects is quite varied, falling primarily in the range of 14 to 24 tokens.[11]

The opportunity to communicate led to a noticeable change in Market 2 allocations. With the allocation rules agreed upon in communication rounds, subjects concentrated their aggregate Market 2 allocations near the optimal allocation of 56 tokens. In the C-CP condition, individual Market 2 allocations were clustered in the range of 6-10 tokens.

Rents

Rents could be dissipated through an excessive allocation of tokens to Market 2 and/or by the bidding competition for token endowments. First consider rent dissipation from over-allocation to Market 2. Table 2 displays summary information regarding the level of rents generated across the two design conditions. In the no-communication condition, mean rent accrual was 45.8%, relatively close to that predicted by the Nash equilibrium (48.9%). The opportunity to communicate led to a noticeable shift toward optimality. In condition C-CP, overall rents increased to an average of 96.1 % Thus, even in an environment of extreme heterogeneity in subject endowments, communication remains a powerful mechanism for promoting coordination.

Auction Prices

One would expect auction prices to be dependent upon subjects expectations of the value of having 24 tokens rather than 8. One possible source of these expectations is the value of the 16 additional tokens at the Nash equilibrium in the CPR game. The expected payoff for subjects with the small endowment is $.56 per round, while that for large endowment subjects is $1.36, a difference of $.80 per round. Because auction winners were endowed with an additional 16 tokens in each of 10 rounds, this leads to a prediction of $8.00 as the auction price. On the other hand, auction prices could be consistent with other expectations. For example, in conditions allowing for face-to-face communication one might conjecture that subjects might be forward looking in the sense that they anticipate group cooperation with an allocation to Market 2 of 64 tokens (the level of Market 2 allocations that they seem to perceive to maximize earnings). This conjecture yields a wide range of possible payoffs ($4.80 to $24.00) depending upon the distribution of tokens one anticipates for allocations to Market 2.

As displayed in Table 3, auction prices were similar across the eight common price auctions. The four NC-CP auctions generated prices of: (1) $5.25, (2) $7.75, (3) $9.50, and (4) $8.25 for an average of $7.69. The four C-CP auctions generated prices of: (1) $8.00, (2) $7.25, (3) $9.75, and (4) $7.00 for an average price of $8.00. The competitive bidding for obtaining the large endowment position dissipated rents beyond that due to over appropriation to Market 2. This point is illustrated in Table 3, where actual earnings (net of auction prices) are reported as a percentage of maximum possible earnings.

Allocation Rules: Summary

In all experiments in the C-CP design, subjects adopted allocation rules that explicitly attempted to equalize net payoffs (net of auction price), while achieving close to optimal allocation in Market 2. A few representative comments illustrate the nature of the discussion process:

"We have to decide which is the best number...I think the best number is 64 ...."

"Obviously we want to maximize our group return, right?... that's at 64."

"We need to allow the people who bid for the 24 to make up their bid price."[12]

In 36 of the 40 decision rounds, rules designed to equalize net payoffs resulted in subjects choosing allocation rules that allowed large appropriators to allocate more to Market 2 than the small appropriators. The most commonly agreed-to allocation rule was a Market 2 allocation of 10 tokens by each large endowment subject and 6 by each small endowment subject. Under this rule large endowment subjects had 62.5% of the total token allocation to Market 2, compared to their 75% share of total token endowment. Thus, this most commonly used rule is weakly proportionate with endowment shares.

Defections

The occurrence of defections on agreed-upon allocation schemes was relatively minor across the set of 4 experiments. Agreements were reached in all 40 decision rounds. At least one subject defected in 6 of these 40 decision rounds, and the overall defection rate was 7 out of 320 individual allocation decisions (2.2%). In all but 3 instances, however, the magnitude of the defection was no more than 2 tokens above the agreement. Further, defection led to a breakdown of subjects' ability to adopt agreements in none of the 4 experiments.

Treatment 2: Discriminative Price Auction

The results from the four common price auction experiments illustrate the power of face-to-face communication as a mechanism to facilitate cooperation, even with heterogeneous agents. The second treatment condition was designed to investigated the robustness of this result. As noted, in the common price auction treatment condition agreements were designed so that "auction winners" -- the subjects who were assigned the large endowment — were able to recoup there auction investment. We conjectured that this rule selection was facilitated by using a mechanism that yielded a single, publicly known, price.

Experiments utilizing a second auction mechanism were designed to investigate this conjecture. A discriminative price sealed bid auction was used. Prior to the ten decision rounds with no-communication and again prior to the ten decision rounds with communication the subjects received a set of instructions summarized below.

> For each of the next 10 rounds four subjects would be assigned 8 tokens, while the other four would each be assigned 24. Tokens would be assigned using an auction in which each subject bid for the right to have 24 tokens. In the auction, each subject privately submitted a bid stating the amount they were willing to pay to receive 24 rather than 8 tokens each round for the next 10 rounds. None of the bids were announced. The 4 subjects with the 4 highest bids were allocated 24 tokens each round for the next 10 rounds. They paid a one time fee equal to their bid. The 4 persons with the 4 lowest bids were allocated 8 tokens each round and paid no fee. If there were ties among the 4th highest bids the auction winners, the auctioneers randomly choose which of the subjects with the tied bids paid the fee and received 24 tokens and which received 8 tokens.

The **"discriminative"** auction mechanism was chosen for several reasons: (1) it increased the complexity of the decision setting -- subjects with winning bids paid different prices for endowment positions and (2) it added a form of incomplete information in the decision setting. Subjects did not know the auction price paid by winning bidders.

Three experiments were conducted using the discriminative price (DP) auction. Results are reported for two design cells: (1) No-Communication-Discriminative Price Auction Assignment (NC-DP) and (2) Communication-Discriminative Price Auction Assignment (C-DP). Because the results from these three experiments are similar to those obtained using the common price auction, the focus will be primarily in terms of summary observations.

Rents

Table 4 displays information regarding the level of rents generated across the two design conditions. In the no-communication condition, rent accrual was 57.1%, somewhat higher than that predicted by the Nash equilibrium (48.9%). As with the CP design, the opportunity to communicate led to a noticeable shift toward optimality. In condition C-DP, overall rents increased to an average of 93.16%. Thus, even in this environment of heterogeneity in subject endowments and incomplete information regarding costly investments, communication remained a powerful mechanism for promoting coordination.

Auction Prices

The discriminative price auction allows the observation of both "winning" and "losing" bids, as well as heterogeneity in bids. The bid results from the three NC-DP and C-DP conditions are summarized in Table 5. The heterogeneity in bids is considerable, with low bids in the neighborhood of $.02 and high "winning" bids as high as $15.00. As with the CP condition, the winning bids represent significant losses in rents, as shown in Table 5.

Allocation Rules and Defections: Summary

We conjectured that the heterogeneity in auction prices and limited information generated by the discriminative price auction would yield: (a) sharing rules that were more complex than those observed with the common price auction, and/or (b) an increased frequency of breakdown in agreements. In actuality, this treatment change had very little impact on the form of agreements, but did appear to increase defections somewhat.

Parallel to the common price experiments, in all three experiments the subjects tended to focus on a group allocation of 64 tokens allocated to Market 2. In experiments, 1 and 2, the agreements were primarily an allocation of 6 tokens by small endowment subjects and 10 by large endowment subjects. In experiment 3, the early agreement was an allocation of 8 tokens by all subjects, later modified to an allocation of 9 tokens and 8 tokens by large and small endowment subjects respectively.

Agreements were reached in 30 of 30 decision rounds. In 15 of 30 decision rounds -- 33 of 240 (13.8%) individual decisions — at least one subject was observed to have defected. Most defections were small, one or two additional tokens allocated to Market 2. In a few instances, however, large endowment subjects allocated as many as 14 tokens over the agreed upon level. In all instances, groups were able to overcome such defections and maintain Market 2 allocation levels closer to optimum than observed in the no-communication decision rounds.

INCOMPLETE CONTRACTING IN THE LABORATORY

Building on the experimental research of Hackett (1993a) and Hackett (1993b), this section examines the investment and surplus-sharing process in incomplete contracts. The theoretical research by Grossman and Hart (1986) and others has lead to what can be viewed as the standard incomplete contracting model.[13] The model describes a one-shot game with two stages. A stylized example of the game is a product-improving innovation. A buyer and seller have agreed to a joint venture in which they will trade a fixed quantity of some good in the future, after which the relationship will be terminated.[14] The parties are assumed to have already agreed on a basic design for the good, the value and cost of which are normalized to zero. All decisions are therefore related to implementation of a quality-enhancing product innovation. The innovation is in the works at the time the parties agree to contract, but the value and the cost associated with this improvement have a stochastic component that is not realized until after the buyer and the seller have made independent investments in value and cost, respectively.

While contracting parties may fix a price up front, the circumstance of interest is one in which price is (re)negotiated after stochastic shocks to demand and cost are realized.[15] Given the simple nature of the model, ex post price determination is zero sum -- equivalent to determining a surplus sharing rule.

The Laboratory Incomplete Contracting Process

The laboratory incomplete contracting process is outlined in Figure 2. In the first stage the buyer's induced value (V) of the product improvement is uncertain, and can either be "high" (V_h) with probability X, or "low" (V_l) with probability (1-X). Similarly the seller's induced cost (C) of the product improvement is uncertain, and can either by "low" (C_l) with probability Y, or "high" (C_h) with probability (1-Y). The process begins with the buyer and seller independently making investments that increase expected value and decrease expected cost, respectively. To simplify the investment decision, buyers choose X, the probability that value is high, by choosing a number $0 \leq X \leq 1$ at (sunk) cost X^2. Likewise the seller chooses the likelihood that cost is low by choosing a number $0 \leq Y \leq 1$ at (sunk) cost Y^2. In the experiments described below, a 2-cell treatment design is utilized where X and Y are **common information** to both buyer and seller (CI) and where X and Y are **private information** (PI).

After the buyer and seller choose X and Y in the first stage, the second stage begins with the realization of value and cost. Value is determined by comparing X to a random number drawn from a uniform distribution over the unit interval; if X is greater than or equal to the random number then value is high, otherwise value is low. Cost is determined in a similar manner by comparing Y to a random number. V and C then become common knowledge. Once value and cost are realized, buyers and sellers are confronted with a bargaining decision and a veto decision. First, a buyer and seller must decide whether to bargain over the rule used to divide realized surplus (V-C).[16] Second, and regardless of whether any bargaining actually occurs, each buyer and seller must decide whether to veto (terminate) the joint venture, which has the effect of causing value and cost to become zero.

In equilibrium, the incomplete contracting model features a successfully negotiated surplus sharing rule and implementation of the product improvement (no veto).[17] Further, parties foreseeing the outcome of second stage bargaining compute their optimal first stage investment. If V and C are independent random variables, and if the buyer and the seller are risk-neutral and capable of perfect foresight, then the buyer will choose X^* to maximize:

$$s[X(Y(V_h-C_l)+(1-Y)(V_h-C_h)) + (1-X)(Y(V_l-C_l)+(1-Y)(V_l-C_h))] - X^2 \qquad (8)$$

where s is the buyer's (fully anticipated) share of ex post surplus determined through ex-post bargaining. The first term is simply the buyer's share of the expected value of (V-C). The seller will similarly choose Y^* to maximize

$$(1-s)[Y(X(V_h-C_l)+(1-X)(V_l-C_l)) + (1-Y)(X(V_h-C_h)+(1-X)(V_l-C_h))] - Y^2 \qquad (9)$$

where the first term is the seller's share of the expected value of (V-C). Maximizing equations (1) and (2) with respect to X and Y yields:

$$X^* = s(V_h - V_l)/2 \qquad (10)$$

$$Y^* = (1-s)(C_h - C_l)/2 \qquad (11)$$

Ex ante investments in this equilibrium depend on anticipated ex post surplus shares, but these surplus shares are independent of ex ante investments.

The laboratory bargaining setting is based on a variant of the alternating offer protocol developed by Rubinstein (1982) and Stahl (1972). In this procedure the parties alternate making proposals indefinitely until a proposal is accepted or the negotiations break down. Some mechanism is required to give parties an incentive to reach early agreement. The particular mechanism used here is a probability of forced breakdown upon the rejection of a proposal, as described in Binmore et al. (1991). Upon rejection of a proposal, a random move determines whether another round of negotiations will be allowed, or whether bargaining will end. The possibility of forced breakdown causes bargainers to discount future payoffs, and so creates a motive for reaching immediate agreement.

Subjects and the Decision Setting

Subjects were recruited from economics courses at Indiana University, and had no prior experience with the experiment. The experimental setting was computerized. An experimental session consisted of two practice rounds of the two stage incomplete contracting game followed by eight rounds played for cash payoffs. Each session was played under one of the two information conditions.[18] Four experiments were conducted in each treatment condition. Eight subjects were used in each experiment, except in two cases in which poor turnout required the use of six subjects.

The order of events in a given decision round were as described in Figure 2 and are summarized below.[19]

> Subjects were first randomly and anonymously matched, and randomly assigned a buyer or seller status. Next they independently choose a level of investment (X and Y). At the beginning of the second stage, V and C were determined after the random number n was realized and compared to X and Y. To maintain complete privacy in the private information (PI) condition described below, independent draws of n were performed for buyers and sellers.[20] The values of n drawn for buyers in each of the ten rounds were: .04, .65, .38, .38, .02, .60, .72, .12, .87, .21 while the values of n drawn for sellers in each of the ten rounds were: .21, .62, .14, .11, .85, .71, .04, .56, .83, .50.
>
> V and C were then revealed to both parties.[21] Under information condition CI, X and Y were also revealed to both parties. Each subject then chose whether to enter the process of bargaining over (V-C). If both parties agreed to bargain, they proceeded into the bargaining phase, alternating offers. Offers were computerized and contained only a proposal for a percentage sharing rule for the joint surplus. In odd numbered contracting rounds buyers made the first offer, while in even numbered rounds sellers made the first proposal. Rejection of a share offer led to a chance that negotiations would exogenously be ended with no surplus sharing. Following Binmore et al. (1991) the number of allowed rejections before forced breakdown was set in advance.[22] The maximum number of rejections allowed in each of the ten rounds of a experimental session were:
>
> 9,2, 11,2, 10,7, 7, 16, 12, 8.

This is the same set used by Binmore et al. (1991). One cannot statistically reject the hypothesis that upon rejection of the first proposal, a breakdown occurs independently with probability 0.1. Finally, subjects privately and noncooperatively decided whether to veto. After the veto decision each subject had their payoff for the round added to their cash account.

Parameters, Treatment Conditions, and Predictions

Parameters

Induced buyer and seller investment incentives were symmetric: V could take on the values of \$5 or \$3, while C could take on the values of \$2.50 or \$0.50. Thus both buyers and sellers could increase surplus by up to \$2 with their investment. One advantage of this parameterization was that bargainers could not use investment incentives to infer anything about relative investment levels when investments were unobservable. As noted above, buyer investment (X) occurs at cost X^2, while specific seller investment (Y) occurs at cost Y^2. For example, if a buyer chooses X = 70, there is a 70% chance that V = \$5 and a 30% chance that V = \$3, and as a consequence the buyer incurs a sunk cost of \$0.49.

Treatment conditions

When investments are common information (CI) , X and Y, along with V and C, are shown to the buyer and the seller prior to negotiation. In contrast, when investments are private information (PI), the buyer is not informed of the seller's investment, and the seller is not informed of the buyer's investment.

Sharing Rule Predictions

First consider the predictions of a perfect equilibrium model. Let the induced payoffs be the payoffs to a noncooperative game. Then the "forced breakdown" sequential bargaining protocol has a unique subgame-perfect bargaining equilibrium, where the prediction for buyer and seller surplus shares depends on which party is the first proposer. If the buyer is the first proposer, then the buyer's predicted equilibrium surplus share $s^* = 1 - [\delta/(1+\delta]$, while the seller's predicted equilibrium surplus share $(1-s^*) = [\delta/(1+\delta]$, where $\delta = (1-d)$, and d is the common discount rate. These shares are reversed when the seller is the first proposer. The predictions of the perfect equilibrium benchmark bargaining model can be summarized as follows:

-All first proposals will be accepted.

-Given an induced discount rate of 10%, surplus sharing agreements will feature a first proposer premia of 2.6 percentage points: the first mover is predicted to get 52.6% of surplus, and thus the first decider is predicted to get 47.4% of surplus.

-Surplus shares will be independent of the parties' transaction-specific investment.

An alternative "equity" theory can also be used in this game setting. As discussed by Adams (1963), Homan (1974), Selten (1978), and Levinthal (1980), among others, traditional equity theory is based on the notion that humans believe that rewards and punishments should be distributed in accordance with recipients' inputs or contributions. Guth (1988, 1992) extends traditional equity theory by developing a behavioral model of distributive justice in which the allocation rule arrived at from bargaining is predicted to depend on the information content of the bargaining setting. The predictions of the equity-theoretic benchmark bargaining model can be summarized as follows:

-There is no reason why first proposals will not be accepted.

-No first proposer premia are predicted.

-In condition PI, where bargainers cannot observe others' investments, the fair allocation rule is based on an individual equality rule, in which case surplus is predicted to be divided equally. In condition CI, however, where bargainers can observe each others' investments, bargainers can allocate surplus in proportion to investments. With this additional information, a strictly proportionate rule would set the buyer's surplus share $s = X^2/(X^2+Y^2)$, and the seller's share $(1-s) = Y^2/(X^2+Y^2)$. Note that these equity-theoretic predictions are independent of discount rate.

A third set of predictions derive from the notion that bargainers are likely to have different conceptions of what constitutes a fair allocation [Bolton, 1991; Guth, 1992; Rabin, 1992; Levinthal, 1980], where these conceptions are hereafter referred to as a "fairness" type, and that an individual's fairness type is private information that is costly to credibly transmit to other bargaining parties [Kennan and Wilson, 1993]. This hypothesis of heterogeneous fairness types and private information has the advantage of realism, but this realism comes at the cost of sharp point predictions.[23] Several predictions do follow, however:

-First proposals will not always be accepted, since proposal rejection is a signal of fairness type.

-First proposer premia are not inconsistent with this hypothesis.

-Surplus sharing agreements that share a portion of surplus proportionately with cost shares from transaction-specific investment are not inconsistent with this hypothesis

Predictions Related to Investments

The nature of the surplus sharing agreements anticipated by contracting parties is a central determinant of their incentives for investment. The perfect equilibrium benchmark model described above predicts a first proposer premium in surplus sharing agreements. If parties anticipate these premia, the first proposer will have incentive to invest more than the first decider. In contrast, if parties anticipate surplus sharing rules indexed to shares of investment, as suggested by the latter two surplus-sharing hypotheses described above, this indexing scheme can lead to stronger investment incentives for both parties, and thus enhance contractual efficiency.

As a consequence the following investment predictions are given:

-Under the perfect equilibrium benchmark model the first proposer receives a larger share of surplus. Thus the contracting party to be the first proposer will invest more than the party to be the first decider.

-Under the equity-theoretic benchmark model surplus shares are allocated proportionately with shares of transaction-specific investment when these investments are observable. Thus making investments observable may increase overall investment as both parties attempt to gain greater shares of joint surplus.

Results

There are two interrelated issues of interest: surplus-sharing rules and buyer and seller investments. Given that the incomplete contracting model is solved backwards, surplus-sharing rules are discussed first, in particular the comparative-static predictions regarding each bargainer's information on investments. One of the central predictions that follows from the incomplete contracting model is that investment incentives derive from the surplus-sharing rules anticipated by the contracting parties. Following the discussion of sharing rules, the buyer and seller investment decisions are considered. The analysis utilizes all 8 periods in which subjects received cash payments for their decisions.

Treatment effects are tested for in the following way. First two samples are constructed from the two treatment conditions. Statistical techniques are then used to test the hypotheses that (i) the two samples derive from the same underlying stochastic processes, and (ii) the mean value of the two samples are the same. The Wilcoxon test is used for (i), and the t-test for differences in sample means is used for (ii). The analysis uses the convention of reporting the surplus sharing rule using the buyer's surplus share; in all cases the seller's surplus share is simply 100% minus the reported buyer surplus share.

Surplus-Sharing Rules

Frequency of successful agreements

Only about 25% of first proposals were accepted (25.8% under CI and 21.7% under PI). These results are consistent with the hypothesis that parties have heterogeneous fairness types and private information. Parties use proposal rejection to signal their type. In contrast, the rate of successful bargaining outcomes was 85.8% under CI and 87.5% under PL[24] It is important to point out that of the 32 instances in which a pairing did not result in a successful agreement, the seller subsequently vetoed in 31 of the 32 cases, a 94% veto rate. Further, of the 208 pairings that resulted in successful agreements, sellers vetoed in only 2 cases, a 1% veto rate. These results for seller veto behavior are generally consistent with the predictions from the incomplete contracting model.

First Proposer Advantage

Relatively little evidence is found for a first proposer advantage in agreements. In the CI condition, the difference in mean buyer surplus shares in two samples, differentiated by whether buyers or sellers were first proposers, was only 1.9 percentage points (54.6% vs. 52.7%, respectively, significant at the 6% level). In the PI condition this difference is an insignificant -0.4 percentage points. These results offer little support for predictions of first mover advantage using the discount rate induced here.

Evidence of attempts to exercise a first proposer advantage can be examined by exploring whether some proposers offered first proposals that were weighted in their advantage had their proposals rejected, or whether proposers did not attempt to extract large first mover premia. This question is investigated with a two-sample comparison of accepted and rejected first proposals across all *Cl* and PI data. First consider data in which sellers were first proposers. In this case the mean buyer surplus shares in first seller proposals that were **accepted** was 50.1%, while mean buyer surplus shares in **rejected** first seller proposals was 45.2%. This difference is significant at the 2% level (t-test). Now consider data in which buyers were first proposers. Mean buyer surplus shares in first buyer proposals that were **accepted** was 54.3%, while mean buyer surplus shares in **rejected** first buyer proposals was 63.7%. This difference is significant at 1% level (t-test). These results support the notion that first deciders are willing to risk contractual failure in order to limit first proposer premia in sharing rule agreements. The analysis lends force to the argument that there are substantial fairness effects influencing surplus sharing in incomplete contracts.

Buyer and Seller Investments

The effects of common versus private information on investments is examined by comparing surplus sharing proposals and agreements using ordinary least squares (OLS).[25]. The dependent variable is the surplus-share agreement, expressed in terms of the buyer's share. In addition to an intercept and a variable designating the decision period, the independent variables include "BFP Dummy" (which is zero unless the buyer was the first proposer, in which case it is one), and "Buyer Investment Cost Share", which is $X?/(X^2 + Y^2)$. As shown in Table 6, OLS estimates an intercept coefficient of 40, implying a minimum buyer surplus share of 40%. The coefficient on Buyer Investment Cost Share is 23.67, which means, for example, that if $XV(X^2 + Y^2) = 0.6$, then on average the buyer's surplus share will be 40 + 0.6*23.67 = 54.02. Other variables are not different from zero at the 10% level or lower. These results are not consistent with either of the benchmark surplus sharing hypotheses. The perfect equilibrium benchmark predicts a 0 weight on buyer investment cost share, while the equity theory benchmark predicts a 0 intercept and a coefficient of 1.0 for buyer investment cost share. The analysis suggests that both bargaining power and equity considerations are at work, which is consistent with the heterogeneous fairness types/private information hypothesis.

Recall that somewhat limited evidence of a first proposer advantage was found in the CI treatment. If these first proposer premia were anticipated, then the premium gives the first proposer an increased investment incentive and the first decider a decreased investment incentive. This can be investigated by constructing two samples based on buyer or seller first proposer, and then comparing buyer shares of overall investment (X^2/X^2+Y^2). In general first proposers tended to invest more than first deciders, this effect is not significant at the 10% level or below in either the CI or the PI treatment.

Recall, the OLS coefficient estimate on buyers investment as a percentage of overall investment shows that surplus-sharing agreements placed a 24% weight on investment cost shares on average. Thus the party who made the relatively larger transaction-specific investment tended to receive a relatively larger share of joint surplus, despite the fact that these investments were sunk. While this relationship has a natural fairness interpretation, it may also serve overall contractual efficiency. The linkage between investments and surplus shares identified in the regression provides buyers and sellers with an increased incentive to invest, and as a consequence enhances the expected joint surplus of the contract. Important to this result is whether buyers and sellers make significantly greater investments in the CI condition, where investments are common information. Strong support is found for the hypothesis that contracting parties anticipate the linkage between observable investments and surplus-sharing agreements, and increase their investment accordingly. Making investments observable raised the mean value of X from 55.2% to 65.9%, and the mean value of Y from 52% to 59.8%. Both of these differences are significant at below the 1% level (t-test).

These elevated investments in the CI treatment condition increase the expected joint surplus generated by the incomplete contract. To see this, note first that under the laboratory parameterization used here, the expected individual surplus-maximizing investments (under the subgame perfect benchmark assumptions, including surplus sharing rules independent of specific investments) are that investments equal surplus shares, which from equations (3) and (4) sum to 100. Thus expected joint surplus is $2. In contrast, the expected joint surplus-maximizing investments are X = Y = 100, yielding expected joint surplus of $2.50. Evaluating expected joint surplus at the mean X and Y values of 65.9 and 59.8, expected joint surplus is $2.22, which represents an 11 % increase in expected joint surplus over the subgame-perfect benchmark level of $2, and which captures 98% of the maximum available expected joint surplus.

SUMMARY COMMENTS

Using evidence from two illustrative experimental research programs, this paper explored the role of heterogeneity in individual attributes as an obstacle to conflict resolution. Individuals appropriating from a commonly held resource that was subtractable in units of appropriation; (1) significantly dissipated rents (reduced efficiency) when placed in a "stark" institutional setting that did not allow face-to-face communication; (2) successfully crafted sharing rules which coordinated appropriation and increased efficiency when face-to-face communication was possible, despite heterogeneities in input endowments. Individuals negotiating surplus sharing rules in the context of an incomplete contract: (1) successfully negotiated contracts in 86.7% of the total cases, and while individuals attempted to negotiate a first proposer premia, proposals with large premia were systematically rejected; (2) relative to the joint optimum, individuals under invested in joint surplus enhancement as predicted.

Both research programs examined common versus private information on individual attributes as a factor affecting sharing agreements and investments. In the CPR decision setting, face-to-face communication generally led to the truthful revelation of information on individual attributes, thus effectively eliminating the private information treatment condition. In the incomplete contract setting, individuals were limited to proposing, accepting, or rejecting share offers. This very limited message space led to outcomes sensitive to the information condition. Specifically, when individuals had only private information on investments the modal sharing rule was fifty-fifty. When investment information was commonly known, individuals linked surplus shares to investments. As a consequence, surplus enhancing investments were significantly increased.

In both the CPR setting and the CI incomplete contract setting, individuals negotiated sharing rules that were consistent with broad notions of fairness - in particular, rules were adopted that effectively reduced differences in net payoffs. Such rules had important consequences for efficiency enhancement. In the CPR settings, agreements were structured so as to minimize net payoff differentials, subject to appropriating at a level that maximized group income. In this context, such agreements increased the earnings for all subjects relative to earnings without such agreements. Thus, minimizing net payoff differentials was used as the foundation for creating group commitment to near optimal resource use. Such rules effectively created a cost for cheating since cheating could imply a reversion back to nonagreement behavior. In the incomplete contracting setting, linking surplus shares to investments had the dual effect of reducing net payoff differences and providing stronger incentives for surplus enhancing investments.

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ENDNOTES

1. Sharing rules can be in the form of agreements regarding inputs or outputs. We use the term "input allocation" to refer to the decision to allocate inputs to the production process of appropriating from the CPR. We use the term appropriation to refer to the actual level of output resulting from this production process. Note, if users are homogeneous in technologies employed (as is the case in the experiments reported here), then identical input allocations imply identical appropriation. In the field, where technologies may differ, this may not be case.

2. These issues have recently been investigated in a theoretical context by Hackett (1992). His work suggests that heterogeneous resource endowments can lead to disagreement over the supply and implementation of rules that allocate access to CPRs. For example, consider two allocation rules commonly found in the field — equal appropriation and appropriation proportionate with capacity or historic use. The interests of large endowment appropriators are served by proportionate allocations, while the interests of small endowment appropriators are better served by equal-sized appropriation rights allocations. When self-governing CPR groups are heterogeneous, rule supply involves a tradeoff between the cost of investing in the "social capital" necessary to reach consensus on an allocation rule, and the added costs of monitoring and enforcing agreements opposed by some subset of appropriators.

3. We rely significantly on the discussion in Ostrom, Walker, and Gardner (1992) and Hackett, Schlager, and Walker (1993) for the discussion of the decision setting.

4. If total input allocation is held constant, one token allocated to the CPR yields the same return regardless of the identity of the player making the investment. Thus heterogeneity is in endowments, not in appropriation skills.

5. The Nash equilibrium can be made symmetric even with large and small endowment appropriators. In particular, a symmetric Nash equilibrium results as long as the small endowment level is greater than or equal to that required for equilibrium play. In such a case small endowment appropriators simply have a lower input allocation level in the outside market relative to large endowment appropriators.

6. Typically, the repeated game has many equilibria. Two equilibrium refinement principles are subgame perfection and subgame consistency. An equilibrium is subgame perfect if it prescribes equilibrium play on every subgame. An equilibrium is subgame consistent if it prescribes identical play on identical subgames.

7. When the game X has a unique equilibrium x*, neither finite repetition nor communication creates new equilibrium outcomes. Let c denote a communication strategy, in the communication phase C, available to any player. As long as saying one thing and doing another has no payoff consequences, then any strategy of the form (c,x*) is an equilibrium of the one-shot game (C,X), and finitely repeated x* is a subgame perfect equilibrium outcome of repeated communication (C,X,C,X,...,C,X). In this situation, subgame perfection is independent of communication.

8. A copy of the instructions is available from the authors upon request. In the instructions, the term "token investment" was used instead of "token allocation".

9. After completing the instructions, subjects had the opportunity to participate in a series of 5 salient reward decision rounds with identical endowments of 20 tokens each. Otherwise the parameters were

identical to those in Table 1. These "trainer" rounds were implemented to give the subjects initial experiences with the logistics of the experiment.

10. Each person was identified with a badge. This facilitated player identification in our transcripts. If unanimous, players could forego discussion.

11. Walker, Gardner, and Ostrom (1990) also found little support for the Nash equilibrium prediction at the individual decision level.

12. Why 64? The summary table subjects received for payoff returns from Market 2 shows possible levels of Market 2 allocations (and resulting total, average, and marginal returns) for allocation levels beginning at 6 tokens and ending with 128 - with intervals of 6 or 7 tokens. 64 tokens is the level of allocation shown on the table to maximize group returns from Market 2. Thus, as observed in many experiments, subjects tended to ignore marginal returns and focus on a total return instead.

13. Accessible versions of this model are presented in Hart and Holmstrom (1987), Tirole (1988), and Holmstrom and Tirole (1989). While this is one of the most influential incomplete contracting models, there certainly are others, such as those described in Wiggins (1991).

14. The example that follows frames incomplete contracts in the context of a vertical relationship between a buyer and seller, as is also done in the experiments. As in Grossman and Hart (1986), however, incomplete contracts can equivalently be framed in the context of lateral or horizontal relationships, such as professional partnerships.

15. Grossman and Hart (1986) argue that ex post contract negotiations occur when one party can credibly threaten to withhold deployment of assets required to transact exchange if price is not (re)negotiated. This credible threat is made feasible in the laboratory experiments below by giving both parties the capacity to prevent implementation of the product improvement. Preventing ex post contract negotiations may be either undesirable (e.g., terms are intentionally left incomplete because the value of ex post adjustment outweighs the cost) or infeasible (e.g., it is very difficult to fashion renegotiation-proof contracts). Factors that lead to ex post negotiation include stochastic shocks to demand and cost, and unobservable attributes of the other contracting parties such as their tastes for opportunism, their norms of distributive justice, or their preferences toward absolute versus relative payoffs. The focus of this experimental study is on behavior within a particular contract structure; the question of what factors influence subject's choice of contract structure is addressed in Hackett, Wiggins, and Battalio (1993).

16. The step allowing subjects to skip bargaining can be omitted with no violence to the properties of the model, as it is equivalent to a breakdown of bargaining in terms of the seller's dominant strategy to veto. This step was added for laboratory investigation so subjects not wanting to bargain would not hold up the others.

17. For a more detailed derivation of this equilibrium, see Hackett (1993b).

18. The programming which enforces the information and message constraints of the experiment, and which performs record-keeping, is written in FORTRAN and operates on a VAX mainframe computer at Indiana University.

19. To help subjects become familiar with the experimental procedures without experiencing loss exposure, and following Binmore et al. (1991), decisions were made without cash reward in the first two rounds.

20. Only one random number sequence was used in the CI experiments, as the inference problem was eliminated by directly revealing investments.

21. The draws were fixed in advance. Given the samples one cannot statistically reject the hypothesis that n was randomly drawn from the unit interval for either set. Subjects were told that the values of V and C would be made known to both parties. By randomizing whether subjects were buyers or sellers in a given period, it would become clear to the subjects that the announced common knowledge of these parameter values is in fact true.

22. Specifically, subjects were told that "[t]he total number of share offers that can be made by you and the other party is limited, and has been fixed in advance....You should reckon that there is a 90 percent chance [33 percent chance in the high discount rate treatments] that at least one more share offer can be made." Binmore et al. (1991) report initial difficulty in communicating breakdown probabilities to subjects, which lead them to fixing them in advance.

23. See Hackett (1993b) for a more detailed description of this hypothesis.

24. In a recent survey of alternating-offer bargaining experiments, Ochs and Roth (1989) report that on average between 10% and 29% of first proposals were rejected in the various experimental studies that they surveyed. Moreover, Binmore et al. (1991) found that about 15% of first proposals were rejected using the same bargaining protocol as the present study. These findings stand in sharp contrast to the 75% first proposal rejection rate reported here. Ochs and Roth (1989) found that at least a majority of counterproposals were disadvantageous (the counterproposer's share was higher in the original rejected proposal) in all of the studies that they survey. Their findings stand in sharp contrast to the findings reported in the present study. Of 168 pairings in which both parties made at least one proposal, only 6 instances of disadvantageous counterproposals were observed, A 3.6% rate. These findings reinforce the argument that context (framing) is an important determinant of bargaining behavior.

25. Note that since individual surplus shares must fall between 0 and 100 percent, one might conjecture that two-limit censoring occurs, in which case OLS estimates will be inconsistent. In fact, Tobit estimation yields the same coefficient estimates as OLS, as there are no limit observations on the dependent variable in the sample.

Table 1
Experimental Design Baseline:
Parameters for a Given Decision Period

Subject Type:	LOW ENDOWMENT	HIGH ENDOWMENT
Number of Subjects	4	4
Individual Token Endowment	8	24
Production Function: Mkt.2*	$33(\Sigma x_k)-.25(\Sigma x_k)^2$	$33(\Sigma x_k)-.25(\Sigma x_k)^2$
Market 2 Return/unit of output	\$.01	\$.01
Market 1 Return/unit of output	\$.05	\$.05
Earnings per Subject at Group Maximum: Evaluated at Benchmark Conventions		
Equal allocation:	\$1.23	\$1.70
Equal absolute reduction:	\$0.66	\$2.26
Equal proportionate reduction:	\$0.94	\$1.98
Earnings/Subject at Nash Equilibrium	\$0.56	\$1.33
Earnings/Subject at Zero Net Yield	\$0.24	\$0.72

* Σx_k = the total number of tokens allocated by the group in Market 2. The production function shows the number of units of output produced in Market 2 for each level of tokens allocated in Market 2. All payoffs include a per period fee of \$.02 per token.

Table 2
Rents as a Percentage of Optimum: Common Price Auction

	No Communication Rounds		Communication Rounds	
Exp. #	1-5	6-10	11-15	16-20
1	61%	54%	91%	90%
2	31%	29%	98%	98%
3	58%	68%	98%	98%
4	34%	30%	97%	100%

Table 3
Common Price Auctions: Prices and Effects on Potential Earnings

NO-COMMUNICATION		COMMUNICATION	
AUCTION PRICE	EARNINGS AS A % of OPTIMUM	AUCTION PRICE	EARNINGS AS A % OF OPTIMUM
$5.25	53%	$8.00	66%
$7.75	26%	$7.25	74%
$9.50	43%	$9.75	65%
$8.25	26%	$7.00	75%

Table 4
Rents as a Percentage of Optimum: Discriminative Price Auction

	No Communication Rounds		Communication Rounds	
Exp. #	1-5	6-10	11-15	16-20
1	67%	76%	98%	98.%
2	67%	46%	94%	88%
3	46%	45%	85%	96%

Table 5
Discriminative Price Auctions: Prices and Effects on Potential Earnings

NO-COMMUNICATION		COMMUNICATION	
AUCTION PRICES RANGE	EARNINGS AS A % of OPTIMUM	AUCTION PRICES RANGE	EARNINGS AS A % OF OPTIMUM
$0.02 - $9.03	60%	$0.03 - $9.60	73%
$0.96 - $12.00	45%	$1.05 - $15.00	59%
$1.52 - $10.80	37%	$1.77 - $11.00	64%

Table 6

Surplus Sharing Agreements Regression
Ordinary Least Squares

Dependent Variable: Surplus sharing agreement
expressed in terms of buyer surplus share (out of 100%)

Independent variable*	Estimated coefficient	Standard error	T statistic
Intercept	40.00	2.38	16.80
BFP Dummy	1.40	.927	1.51
Buyer Investment Cost Share	23.67	3.09	7.65
Period	-0.03	0.18	-0.17

* "BFP Dummy" is 1 when buyers were the first proposers, and 0 otherwise; Buyer Investment Cost Share is $X^2/(X^2+Y^2)$; Period refers to the decision round in the relevant experimental session. White test: Chi-Square value = 7.41; maintain H_0 of homoskedasticity (Prob > ChiSq = .49). F statistic: 21.03; reject H_0 that all coefficient estimates are 0 Adjusted R^2 = .37

Figure 1

INDIVIDUAL INVESTMENTS - MARKET 2
FREQUENCIES ACROSS DESIGN CONDITIONS

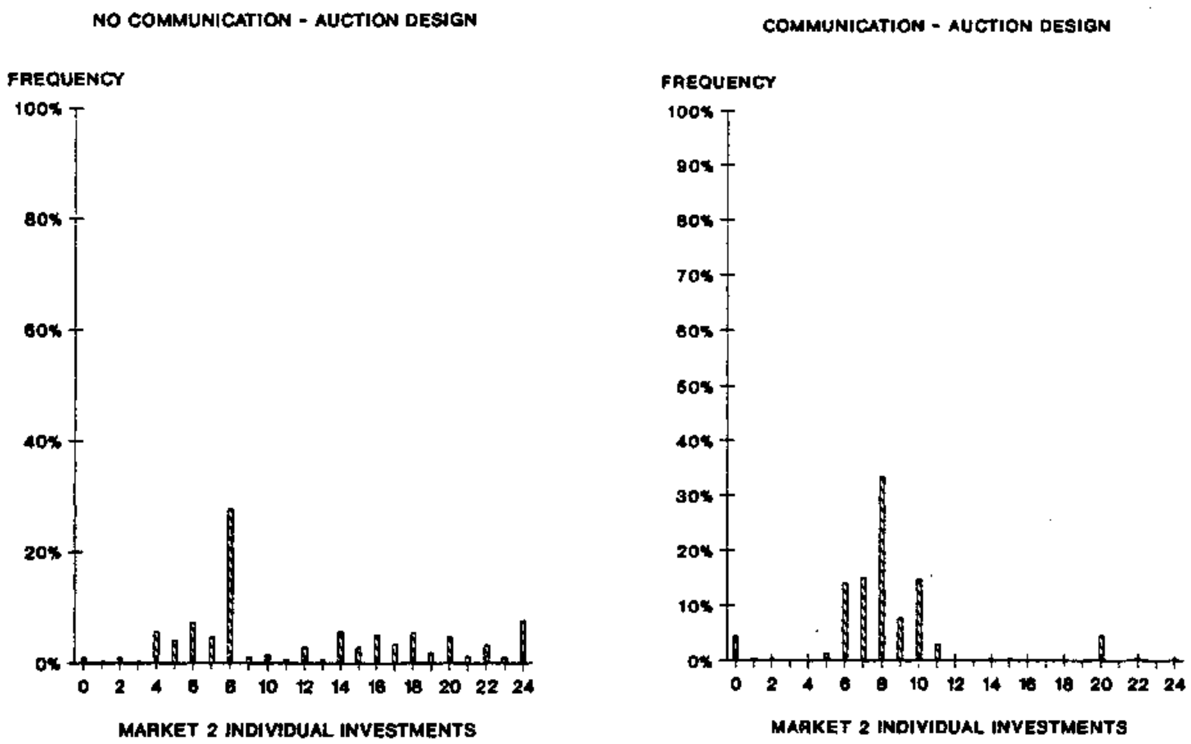
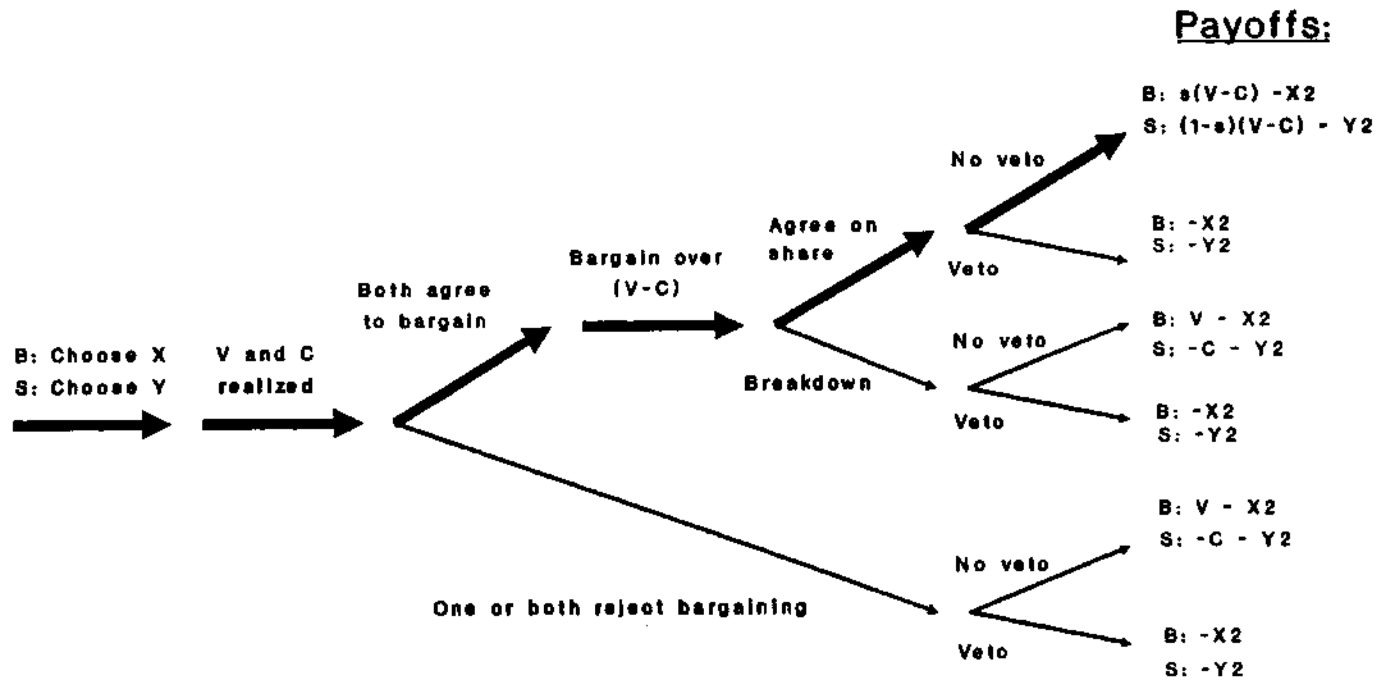


Figure 2
Incomplete Contracting Process



'B' stands for buyer, and 'S' stands for seller
Bold arrows represent the equilibrium path