IMPERFECT INFORMATION, MULTILATERAL BARGAINING, AND UNITIZATION: AN EXPERIMENTAL ANALYSIS[1]

By Steven N. Wiggins, Steven C. Hackett, and Raymond C. Battalio[2]

This paper provides an experimental analysis of bargaining under imperfect information, molded by the circumstances found in oil field unitization. The purpose of the study is two-fold. One purpose is to provide a more in-depth analysis of how information affects bargained shares and contractual failure in unitization. A second purpose is to provide a (partial) link between the unitization field data, and the highly developed experimental bargaining work of Roth and Malouf, and Roth, Malouf, and Murnighan. The results suggest a new interpretation of how imperfect information molds sharing rules and undermines unitization contracting. This interpretation is highly consistent with problems previously identified by Roth and his co-investigators. The analysis then reexamines the field data and shows how the analysis sheds new light on field evidence.

1. INTRODUCTION

This paper provides an experimental analysis of bargaining under imperfect information, molded by the circumstances found in oil field unitization. The purpose of the study is two-fold. One purpose is to provide a more in-depth analysis of how information affects bargained shares and contractual failure in unitization. A second purpose is to provide a (partial) link between the unitization field data, and the highly developed experimental bargaining work of Roth and Malouf (1979), Roth and Murnighan (1982), Roth and Schoumaker (1983), Roth, Malouf and Murnighan (1981). The results suggest a new interpretation of how imperfect information molds sharing rules and undermines unitization contracting. This interpretation is highly consistent with a focal point theory of bargaining previously proposed by Roth (1985). The analysis then reexamines the field data and shows how the analysis sheds new light on field evidence.

Oil field unitization is a classic application of Coasian contracting, with large, documented returns to contracting (Libecap and Wiggins (1984, 1985) and Wiggins and Libecap (1985)). Multiple firms access reserves on common oil pools. Each firm has an incentive to stimulate oil immigration from neighboring leases by rapid production. Rapid production increases output on individual leases as oil is drained from neighboring areas.

In the aggregate, however, rapid production raises marginal extraction costs and lowers ultimate recovery (Wiggins and Libecap (1985)). In particular, rapid production prematurely dissipates pressure by raising the amount of natural gas produced early in a field's life. Natural gas is lighter than oil and under conditions of rapid production, gas leaves solution with the oil and travels more rapidly through the reservoir to well bores. This premature depletion of gas leaves the oil more viscous and harder to move, and dissipates the pressure

needed to propel the oil to well bores. Such dissipation requires the subsequent costly re-injection of natural gas and water to restore pressure and enhance recovery. Even these costly measures, however, ultimately leave significant pockets of oil permanently trapped.

Under unitization, a single firm carries out recovery on a common oil pool to maximize field value. The net revenues are then shared among the various firms according to a predetermined sharing formula. Unitization offers extraordinary gains to contracting. Wiggins and Libecap show that potential gains normally reach into the tens or hundreds of millions of dollars on individual fields; gains typically shared among a few bargaining parties--often only five or ten. Hence unitization provides a primary example where Coasian contracting ought to work well.

Yet, Wiggins and Libecap (1985) show that in practice the success of unitization is highly varied. In some cases, unitization works poorly. In Texas, for example, less than twenty per cent of production is unitized; unitization bargaining is protracted, acrimonious, and commonly ends in failure. Elsewhere, unitization can be highly successful. In Wyoming more than eighty per cent of production is unitized, and negotiations are short, harmonious, and rarely end in failure. The large returns to bargaining and the empirical variation in success make unitization a unique field setting in which to study the factors that affect multilateral negotiations, contracting success, and failure.

Wiggins and Libecap theoretically and empirically examine unitization bargaining, and conclude that a major factor affecting contractual failure is asymmetric information. Specifically the operators of producing leases have better information about the value of their leases than do outsiders.[3] This

information difference leads to a 'lemons' problem during negotiations; parties with favorable private information reject formulas based on public information, just as those with good cars withhold them from the market. These problems undermine negotiations.[4] Wiggins and Libecap then present substantial empirical evidence to support this hypothesis.

The problem with these analyses is that the empirical record in the field data is incomplete. Exact public or private estimates of the value of individual leases are unavailable, which means that one cannot analyze the differential effect of public and private value estimates on observed sharing rules. The absence of such estimates also means that there is little direct evidence regarding how differential information affects parties' bargaining behavior, how such behavior affects proposed sharing rules, nor how sharing rule offers lead to contractual failure. Hence there is much to be learned from additional data regarding the role of information in unitization-style bargaining.

This study uses experimental laboratory methods to provide such data. The paper analyzes multilateral bargaining under laboratory conditions similar to those found in oil field unitization. Experimental methods allow direct measurement of information levels, and a degree of control over the bargaining environment unavailable in field data. These improvements provide major new insights into unit negotiations.

Information molds subjects' focal points in determining a sharing rule. The reliability of information determines how much subjects focus on fairness versus allocating shares according to the value of individual holdings (on the common pool). When information on the value of individual holdings is <u>common knowledge</u>, subjects in successful bargains allocate shares according to value. Fairness plays little or no role. When value estimates become <u>uncertain</u>,

however, parties discount value estimates in assigning shares, and place significant emphasis on fairness. Hence discounting of value estimates is absent when value estimates are known with certainty, but emerges and plays a major role in successful bargains when value estimates are unbiased but random. The implication is that the uncertainty of value estimates affects whether parties discount value estimates--and so place weight on fairness--in assigning shares.[5]

This discounting then appears to play a significant role in bargaining failures under imperfect information. When bargaining fails, the failure occurs because subjects refuse to accept discounts of their value estimates in their assigned shares. Instead, the relationship between final share requests and value is nearly identical to the same relationship in successful bargains under perfect information. The refusal of these offers, as evidenced by the failure to agree, suggests that observed bargaining failures emerge because of a disagreement over focal points. Specifically, the issue is a disagreement over the weight attached to value (versus fairness). The key point is that this disagreement appears to undermine bargaining only when value estimates are uncertain. These problems then complement the role of simple asymmetric information in explaining contractual failure.

The discussion then shows how the results provide a direct bridge between the field data and the analyses of Roth and Malouf (1979) and Roth, Malouf, and Murnighan (1981). These studies examined bargaining over probability on a lottery wheel. When prize values were common knowledge, parties often focused on equal expected payoffs. When prize values were in "chips" of unknown value, parties focused on an equal division of probability, ignoring prize values. Our results show that when prize values are <u>partially</u> uncertain, there is partial discounting, and that such discounting can lead to disagreements and bargaining

breakdowns.

Section 6 reexamines the contractual failures from the primary fields in the original Wiggins and Libecap study. This reexamination suggests that information discounting plays a significant role in contractual failure in the field.

The remainder of the paper is organized as follows. Section 2 provides a brief overview of the unitization problem, and a set of stylized facts regarding when bargaining is successful, the nature of sharing rules, and when contracting is likely to fail. Section 3 then presents the experimental design, which has been chosen to correspond closely to the empirical bargaining environment. Sections 4 and 5 present the results, and Section 6 discusses the field data.

2. BACKGROUND

The experiments below are designed to capture the important stylized facts about the unitization bargaining environment identified by Wiggins and Libecap. According to their analysis, information is the key variable that influences the degree of contracting success. Accordingly, it is useful to briefly summarize that empirical evidence. In addition, it is important to describe other features of the unitization bargaining environment, which theory suggests might complicate bargaining, but which the evidence suggests is unimportant in unitization. In the interest of space, however, the interested reader is referred to Wiggins and Libecap (1985) for a discussion of the theory.[6]

Wiggins and Libecap present a variety of evidence suggesting that asymmetric information is key to the frequent failure of unitization. One key piece of evidence is the considerable variation in the success of unitization across states. In Wyoming, unitization works well, while in Texas and Oklahoma

it works poorly. In Wyoming the federal government has, since the 1930s, encouraged unitization prior to production, and such unitization works well. More than eighty per cent of Wyoming production is unitized, and negotiations take an average of only a few months to complete.[7] Such unitization in Wyoming is effective despite numerous potentially limiting factors. Specific problems include heterogeneities in firm size, potential small-firm hold-outs, and repeat contact of firms over time. Each of these might well complicate negotiations and lead to failure. The empirical evidence, however, suggests that they do not.

In contrast, unitization in Texas and Oklahoma works poorly, and negotiations commonly end in failure. Less than twenty per cent of production in Texas and forty per cent in Oklahoma is from unitized fields.[8] Negotiations that reach agreements, moreover, take an average of seven years to complete, during which many of the benefits to unitization are lost.

The apparent difference between these states and Wyoming is information. Texas Railroad Commission and Oklahoma Corporation Commission rules prohibit unitization until after field development.[9] Field development, however, generates substantial information regarding the value of individual leases, much of which is private (Wiggins and Libecap (1985), Meade, Moseidjord, and Sorenson (1984), and Hendricks and Porter (1988)). This private information, according to Wiggins and Libecap, becomes a central obstacle leading to unitization failure. Most successful contracting, moreover, occurs late in field life after production has resolved informational asymmetries.

The plausibility of the information explanation is reinforced because the complicating factors described above are similar across the states. In all states there are heterogeneities in firm size, potential small-firm hold-outs, repeat firm contacts, and so forth. Since these complicating factors are similar

across states, however, the evidence suggests that they are not the key determinants of success or failure. Hence data from contractual failure across states points toward information as central to contractual failure.

Another type of evidence pointing toward information comes from individual fields in Texas.[10] When unitization fails, a common response is for subsets of similar leases (with possibly correlated private information), to withdraw from a fieldwide unit to form a 'partial unit' covering only a portion of the field. Highly productive leases are a primary example of such withdrawal.

Partitioning fields in this way sacrifices considerable gains to coordinated recovery. Yet the repeated claim in the minutes of negotiating session is that participants with these high value leases will not be equitably treated under proposed fieldwide sharing rules (Wiggins and Libecap (1985), p. 378). Statistical tests show that there is more likely to be significant private information for leases that hold out, supporting the asymmetric information explanation.

A third type of evidence pointing toward information is that late in field life, unitization is much more successful in Texas. As production from a field dwindles, parties will often be able to negotiate a successful unit, whereas earlier they could not. The apparent reason for success is that late in field life, lease values have been revealed through actual production. The implication is that asymmetric information no longer stands in the way of successful bargaining. Wiggins and Libecap argue that these data together suggest strongly that information, and in particular private information, plays a key role in the failure of unitization.

The problem with the field data, however, is that they are incomplete. The field data do not provide direct value estimates, nor direct measures of either

public value estimates nor private information. The absence of such measures means that there is no direct evidence regarding how information molds bargaining, nor how it influences accepted and rejected shares. The implication is that there is little direct evidence regarding exactly how information leads to contractual failure.

The experimental analysis below surmounts these problems by providing direct measures of information. The analysis focuses on the three information conditions that lead to considerable variation in the success of contracting. The first treatment is a Wyoming condition. In Wyoming, unitization occurs before development, and so the primary relevant information is the acreage of individual leases.[11] The second treatment is a Texas private information treatment. In Texas, when unitization is attempted after field development, there is substantial information about relative lease values, some of which is private. When unitization is attempted in this setting, contracting generally fails. The third treatment is the Texas high information treatment. This treatment corresponds to the situation late in field life, where production has defined relative lease values.

In addition to these information treatments other elements of the laboratory environment were molded to capture the important stylized facts regarding the unitization process. Unitization takes place among producing firms that have leased tracts in what proves to be a productive field. Some tracts are large, others are small, and firms repeatedly encounter each other in unitization bargaining across fields. Yet entire groups are sufficiently large and diverse that the same group of bargainers is rarely reassembled.[12]

Firms begin negotiations by appointing an 'Engineering Committee' to compile known facts about leases and the field. These facts include information

like past production, number of wells, and remaining reserves. They do not include, however, any direct value estimates.

The engineering committee reports its findings to the 'Operators' Committee,' which then conducts actual negotiations over a sharing formula. Negotiations are free-wheeling, and there is no particular sequence to offers or counter-offers. Message spaces are unlimited, and parties are free in principle to reveal any information they feel appropriate. The negotiations focus on achieving a sharing rule, generally using the lease characteristics as measured by the Engineering Committee, such as wells, past production, or remaining reserves, but parties are generally free to focus on any of these as they see fit.

Before proceeding, it is important to note the relationship between the analysis here, and the extant experimental work on bargaining. The control conditions here mimic a unitization-style bargaining environment, and so the experimental approach differs significantly from that found in most extant experimental work on bargaining. Most existing experimental work on bargaining has been molded around theoretical bargaining models (see e.g. Binmore, Shaked and Sutton, (1985) and Roth (1987) and the references cited therein). Accordingly, the experimental designs have been chosen to replicate the idealized conditions of such models. In particular, it has been important to sharply limit message spaces (e.g. no face-to-face bargaining), limit repeated subject contact (e.g. no subject identification in repeat-contacts), and focus on two-person bargains, where the theories are sharper. Much has been learned through these analyses.

The analysis here attempts to (partially) bridge the gap between these studies, their theoretical models, and unitization. To achieve this end it has

been necessary to reduce the control over messages, the precise sequence of offers, and so forth. The results show a strong link between this work and problems in unitization. In particular, the analysis shows how the focal points identified by Roth (1985), emerge in our more weakly controlled environment, and appear to be significant factors in observed contractual failures in unitization.

Attention is now turned to the experimental design.

3. LABORATORY EXPERIMENTAL DESIGN

3.1. *The Laboratory Setting*

The experiments focused on negotiations to "unitize" a "common oil pool," using six person bargaining groups. Subjects were assigned to bargaining groups to mimic field conditions. Accordingly, we recruited twelve subjects to participate in six person bargaining groups. At the start, subjects were randomly assigned to one of six "color groups" for the remainder of the experiment. Both subjects in the color group were given the same holdings and information throughout the experimental sessions. The bargaining groups were then created by randomly assigning a subject from each color group to each bargaining group. This assignment creates two identical bargaining groups whose members' holdings represent a productive area that contains a valuable common pool resource. Motivated by field conditions, this method also created a design where subjects repeatedly encountered one another, but where entire groups rarely reassembled.

At the start of each round both subjects in each color group were required to purchase their 'lease' holdings, represented as bags of (poker) chips. The cost of the bag depended on its size, and subjects were generally charged $.03

per chip.[13] As in the field data, these bags varied in size and individual subjects held anywhere from 5 and 33 per cent of the total area.[14]

The 'productivity' of 'leases' varied by including both white and blue chips in the bags. White chips represent unproductive areas, and had a redemption value of $0. Blue chips represent productive areas and could be redeemed at the end of the bargaining round (see below). The sum of the blue chips and their value then represented the total productive potential of the common pool. As in the field data, individual subject holdings of valuable blue chips varied, both in terms of the percentage of chips within their own bag and in percentage of total blue chips in the common pool. The mean percentage of valuable chips to total chips in individual bags was 36 per cent, but ranged all the way from 3 to 84 per cent (SD = 7.2 per cent). Individual subjects also held a mean of 17 per cent of total valuable chips, but this percentage also varied widely from 2 to 40 per cent (SD = 13.6 per cent). This variation was designed to examine how fairness considerations and size influenced bargaining outcomes.

The incentive for a bargaining agreement was to increase the value of blue chips. Each blue chip had a redemption value of $0.10 if no unitization contract was formed. This value increased to $0.12 when an agreement was reached in the first two experimental sessions ($0.11 in the last two experimental sessions).[15] These earnings were recorded at the end of each round, and paid at the end of the evening.

The order of events in each round is illustrated in Table I. After the purchase of chips subjects in individual color groups were randomly assigned to the bargaining groups.[16] They were then endowed with information, according to one of the three information conditions outlined above. In all treatments subjects knew their own and others' bag sizes. The first treatment corresponds

to information conditions in Wyoming, and so bag size was the only information available. The second treatment corresponds to asymmetric information conditions found in Texas (and Oklahoma). Each subject was privately told his number of valuable chips, and other subjects were provided with an unbiased public estimate of this number. The third treatment corresponds to conditions late in field life in Texas and Oklahoma, where production has revealed private information, recreating symmetric information regarding actual lease values; all subjects were told the actual number of valuable chips held by each party.

Public estimates under asymmetric information were provided using a 'sample bag.' Each color group's 'sample bag' contained forty nine numbered chips, uniformly distributed about the true number ranging from twenty four numbers below the actual number to twenty four above. The experimenter randomly drew one of these 49 chips, providing a readily understood, unbiased public estimate of the number of valuable chips.

Following typical procedures of Engineering Committees, each relevant variable was presented to subjects both in raw numbers and in percentages of totals for easy reference during negotiations. Once information was provided, subjects were given a brief time to consider the information, and the timed bargaining session began.

The first bargaining session lasted five minutes, and the others three. Subjects bargained over the percentage shares of the group's revenues to assign each bargainer, with unanimous agreement required. An experimenter was stationed at each bargaining group to prevent threats, to ensure that shares did not exceed one, and to provide simple computation services. The face-to-face bargaining process was otherwise unrestrained. Bargaining ended at agreement, or when time ran out.

After bargaining, subjects privately completed a questionnaire where they rated each other's bargaining behavior on a scale from minus four (highly disagreeable) to four (highly agreeable).[17] Afterwards, subjects returned to their assigned color tables to begin a new round.

3.2. *Design Procedures*

Subjects were inexperienced Texas A&M undergraduate volunteers from economics classes, and there were four evening sessions. After subjects arrived, written instructions were distributed and read aloud by the experimenter (see the Appendix), questions were answered, and the experimental bargaining rounds began.

The order of treatments within each of the four evening sessions is described in Table II. Within each evening session there were eleven periods, except that evening session one contained only nine. To ensure independent bargaining, the two bargaining groups were physically isolated, and communication was only permitted during the timed bargaining periods.

It can be seen from Table II that the first two evening sessions were quite similar in order of treatments, and treatments in the last two evening sessions were identical. Since our primary interest is in the special problems caused by asymmetric information, most periods were run under that treatment. The results of the experiments are discussed below.[18]

4. LABORATORY RESULTS: INFORMATION, FOCAL POINTS, AND SHARING RULES

A central focus of the analysis is how information affects sharing rules in successful bargains. These focal point effects are shown clearly in a simple

OLS regression analysis, reported in Table III.[19] The left-hand side variable is the bargained share, while the right-hand side variables reflect the information available in the various treatments. The baseline treatment is the low information, Wyoming, treatment where subjects know only total chips. Hence information in this treatment is represented by subjects' shares of total chips (TCSHARE), and there is also a constant term (INTERCEP). The remaining variables have a value of zero in this treatment, and are introduced below.

4.1. *The Wyoming Treatment--*

Equal Division Under Low Information

With low information subjects focused on shares of total chips in assigning final shares. The coefficient on total chips (TCSHARE) is .93 (t=9.9). Noting that chip shares sum to one hundred per cent, roughly ninety three per cent of bargained shares were allocated on the basis of total chips. Per capita allocations were also very small; a test of the joint hypothesis that the intercept equals zero and the coefficient on total chips equals one cannot be rejected at normal significance levels (F=0.28). Hence total chips were the key determinant of bargained shares. This result is obtained for treatments where total chips were equally divided and where total chips were very unequally divided. In the unequal division treatments individual total chip holdings ranged from a low of nine per cent to a high of twenty-five per cent.

The relatively small standard error (.094) implies that there was significant uniformity in the use of share of total chips in assigning bargaining shares. The implication is that the relationship between chips and assigned shares was not only positive, but that bargaining groups used this information in reasonably similar ways.

All of the agreements for six person bargaining groups assigned bargaining shares consistent with a sharing rule that is based on the subject's total chip holdings. There was, however, one agreement in a five person bargaining group that used an equal division rule even though total chip holding were quite heterogeneous. Chip shares ranged from a low of seven per cent to a high of thirty-three per cent. Hence these subjects focused on equal division rather than assigning shares based on chip holdings. In this context it is also noteworthy that there were two other cases where total chips were equally divided. In these cases the sharing rule was consistent with both equal division and allocations based on chips. Hence the results show that subjects focused primarily on chip shares though some of the evidence suggests a second focal point of equal division.

The results for the low information treatments replicate the results reported by Roth and his associates. Similar to their results, we observe a grouping of bargaining shares agreements at one of two focal points. These results provide a baseline for the treatments where there was more information available.

4.2. *The Private Information Texas Treatment: Discounts of Value Estimates and Private Information*

The sharing rule under the Texas private information treatment differed markedly. Parties concentrated on different focal points in bargaining as the new information available supplanted total chips as the primary focal point. The results are clearly illustrated by the regression analysis in Table III.

The primary focal point in the private information treatment is the public value estimate provided by the sampling bag--the variable PUBESTSHR. This

variable had a value of zero in the low information Wyoming treatment (and in the high information treatment). The estimated coefficient of PUBESTSHR is large (.60) and highly significant (t=17.3). Noting again that shares add to one hundred per cent, sixty per cent of bargained shares were allocated using this primary focal point. Hence public value estimates emerge as the major factor in assigning final shares. The implication is that subjects place considerable weight on value estimates in assigning final shares.

A significant finding for unitization, as discussed below, is that subjects do not accord shares one-to-one with value, but instead discount the value estimates considerably below such a standard. This discounting is reflected by the fact that the coefficient of PUBESTSHR is significantly less than one. The hypothesis that this coefficient equals one is strongly rejected (F=129.9). The implication is that a one per cent increase in a subject's estimated share generates significantly less than a one per cent increase in assigned share.

The coefficient on the value estimate also has a remarkably small standard error of three and one half per cent (.035). This small standard error reveals a striking uniformity in how value estimates were incorporated in shares in successful bargains. A one per cent increase in a subject's share of the public estimate resulted in between a .53 and a .67 increase in assigned share in nearly all successful bargains. The implication is that in successful bargains, value discounting was a uniformly applied, dominant focal point. The analysis below links this discounting to bargaining breakdowns.

A related finding is that value estimates replaced shares of total chips as the primary focal point. The change in the influence of chips was measured through a Private Information slope dummy, which measured chip share under private information, but was zero otherwise. This dummy, PITCSHR, measures the

reduced influence of total chips on shares in the private information treatment. This slope dummy is large (-.84) and significantly negative (t=-8.3). Accordingly it can be added to the baseline coefficient for share of total chips to assess the effect of chips on final bargained shares under private information. Such addition yields .93 + (-.84) = .09, or 9 per cent. This coefficient is significantly different from zero (F=5.9). Noting again that shares add to one hundred per cent, roughly nine per cent of the final shares were allocated according to total chips in the Texas private information treatment. Hence, the bargainers' total chip shares ceased to play a major role in the outcomes.

The per capita allocation is considerably larger under the private information treatment. An intercept dummy was introduced for the Texas low information treatment, and its coefficient is .041 and is significant at the two per cent level of significance (t=2.40). The point estimate for the intercept, .012 + .041 = .053, is large and significantly positive (F=78.9). With six subjects roughly thirty two per cent of bargained shares are allocated for mere participation, and suggest that a fairness focal point is still present.[20]

These findings are significant for unitization. The evidence shows that subjects discount value estimates and chip shares in their sharing allocations, and allocate significant shares for mere participation. Hence fairness appears to be a significant factor in bargaining in the Texas low information treatment. The discussion below links these findings to unitization, and to Roth's earlier results.

Private information also plays an important role in bargaining. The essence of a 'lemons' story is that parties behave strategically with respect to their private information; car owners are more likely to sell when their private

information is unfavorable. Accordingly, the 'lemons' hypothesis is that favorable and unfavorable information have differential effects on bargaining. To differentially measure favorable and unfavorable private information, the regression analysis incorporated separate slope dummy variables. When privately known shares exceeded public estimates, private information was favorable, and a variable measuring this was introduced by subtracting the public share estimates from the privately known actual share (POSDFSHR). When information was unfavorable (and in the other information treatments) this variable was zero. The companion dummy variable (NEGDFSHR) was calculated by subtracting the larger public share estimate from the privately known value when information was unfavorable. This variable was zero when information was favorable and in other treatments.[21]

'Lemons' reasoning addresses the coefficients of these variables. Strategic play would suggest that parties will attempt to reveal positive information for incorporation into bargained shares. The problem is that other parties may discount revelations since they are not verifiable. Similarly, 'lemons' reasoning suggests that parties should not reveal unfavorable private information, and so the coefficient for NEGDFSHR should be small, or even zero. The incentive not to reveal, however, is offset by the fact that such parties have greater incentive to make concessions to ensure that a bargain is reached. Finally, overall discounting of private information suggests that the coefficient of both private information variables should be smaller than the coefficient of the public share estimate.

The results support the 'lemons' hypothesis. The coefficient for favorable private information is .30 (t=2.9), while that for unfavorable information is .32 (t=3.3). Hence bargained shares reflect both types of private information.

Favorable private information raises bargained shares while unfavorable information, which has negative values, reduces bargained shares. The coefficients for both private information variables, however, are significantly smaller than the coefficient of the public share estimates (.60), with F values of greater than 9.0 in both cases. Hence there is heavy discounting of all private information. This discounting is particularly important because there is already heavy discounting of the public share estimate, and so private information is accorded a very low weight in share assignments. The results, however, offer no support for the more specific hypothesis that favorable and unfavorable information have a differential effect on bargaining (F=0.02).

The key results are that i) parties discount public share estimates when they are uncertain, ii) a significant share of the total is allocated for mere participation or fairness, iii) private information is even more heavily discounted, and iii) there appears to be little difference in the influence of favorable and unfavorable private information on bargained shares.

4.3. *Information and Assigned Shares:*

Public Information and the Absence of Discounting

Bargaining under full information differed markedly from bargaining in the limited information treatments. Once again the change in information shifted the focal point in bargaining, this time to subjects' actual shares of valuable chips. More important, the changed information altered the discounting of share estimates, greatly reduced the role of chip shares and eliminated the role of ex ante fairness in bargained shares.

The dominant focal point in bargaining then became subjects' actual shares of valuable blue chips. These shares determine virtually all of the share

allocations in successful bargains. The coefficient estimate for share of valuable blue chips is .904, which is large and highly significant (t=15.3). Noting once again that shares sum to one, this factor accounts for ninety and one-half per cent of the assigned shares in successful bargains.

This coefficient also shows that there is nearly a one-to-one relationship between assigned shares, and shares of valuable chips. A one per cent increase in share of valuable chips translates into a .904 per cent increase in assigned shares. Further, this coefficient is (marginally) not significantly less than one (F=2.61), which means that the model is consistent with no value discounting in sharing rules under perfect information.

A key finding is the contrast among the sharing arrangements across information treatments, especially differences in how value estimates are discounted. The near absence of information discounting under full information differs sharply from the heavy discounting observed under private information and low information. This finding suggests that subjects discount public share estimates <u>simply because they are estimates</u>. Such discounting, as we shall see, plays a role in the failure to reach agreements.

The decline in fairness considerations can also be measured by examining changes in the per capita share assignments and in the effect of total chips on bargained shares. Accordingly, the regression includes a pair of <u>F</u>ull <u>I</u>nformation dummy variables, intercept dummy for the per capita assignments (FIDUMMY), and a slope dummy for the share of total chips (FITCSHARE). The coefficient for the intercept dummy is negative, -.012 (t=-0.6). To obtain the intercept under full information, one adds this coefficient from the constant of the regression to yield .012 + (-.012) = .000. Hence none of the bargained shares were allocated for simple participation. This result contrasts sharply

with the private information treatment where such allocation accounted for almost thirty two per cent (=5.3*6) of assigned shares.

Total chip shares similarly fade as a determinant of shares. The coefficient of the slope dummy on total chips is -.838 (t=6.7), shows that there is a highly significant difference in the effect of total chips on shares in this treatment compared to the low information treatment. To assess the absolute impact of total chip shares on bargained shares, this slope dummy can be added to the baseline coefficient to yield .933 + (-.838) = .095. The resulting slope coefficient is not significantly positive (F=1.32). A joint test of the hypothesis that the intercept zero and the coefficient on chip shares are zero, and the coefficient on actual shares is one is not rejected (F=0.87). Hence when the relative value of contributions is common knowledge, fairness considerations virtually vanish as a determinant of shares in successful bargains.

The results regarding allocations are closely linked to earlier results of Roth and his co-investigators (Roth and Malouf (1979) and Roth, Malouf, and Murnighan (1981)). Those investigators used two-person bargaining experiments, and analyzed the division of probability that each party would receive a "favorable" prize in a lottery bargain.

In Roth and Malouf in the full-information condition each player knew both prize values and in the partial information condition each player knew only his own prize. The full-information condition is similar to our common public knowledge of all share estimates. Under full-information Roth and Malouf show that subjects focused on rules that would divide equally the expected monetary payoffs. Hence under common knowledge, payoff values were a central factor determining bargaining outcomes. Under the partial information condition subjects focused on an equal division of the lottery tickets and the associated

probability of winning their favorable prize.

These results were extended and replicated in Roth, Malouf and Murnighan where they showed that the original results were not due to differences in strategies available to the players. In these experiments prizes were expressed in chips, and sometimes these values were privately known. Players always knew their own chip values and numbers, but their knowledge of their opponent's number of chips and/or the value of their opponent's chips was systematically varied. As in Roth and Murnighan, the full information treatment parallels our high information treatment. Their treatment where subject's knew their opponent's number of chips but not the value of their opponent's prize is similar to a limiting case of our private information treatment. In particular, "chips" are a very (completely) noisy measure of the prize. Our public estimate is a noisy estimate, but has significant information content. Their results and ours both show that there is considerable discounting when payoffs are uncertain. Their payoffs are completely uncertain, and there is complete discounting; our payoffs are somewhat uncertain, and there is considerable discounting.

Partial information, however, raises a new issue. When subjects' estimated shares are discounted in bargained share assignments, subjects with large holdings have an incentive to reject the bargained share, leading to bargaining failure. We now turn to the general issue of bargaining failure, and this issue in particular.

5. EXPERIMENTAL RESULTS: CONTRACTUAL FAILURE

The analysis above shows how information affects observed sharing rules by determining the focal points used in bargaining. These effects also play a significant role when bargaining fails. The reason is that various parties react

differently to information, and concentrate on different focal points. In particular, while the dominant focal point in imperfect information is to discount value estimates, it is not the only one. The analysis in this section links these disagreements over the focal point to disagreements.

During the experiment the monitors recorded shares that parties offered to accept in an agreement.[22] Such offers were made by roughly eighty per cent of the parties in unsuccessful bargains. Hence there is an extensive empirical record regarding such offers. The key issue is whether the last offers made when there were "strikes" were generated by the same underlying model as the data generating agreements, or whether the models differ significantly.

A simple (OLS) regression was used to investigate this issue. Specifically, a regression was run that pooled the offers from disagreements together with the assigned shares when there were successful agreements. The null hypothesis is that share offers in agreements and disagreements are generated by the same underlying model and parameters. The alternative hypothesis is that the models for agreements and disagreements differ.

To allow for such differences, a complete set of dummy variables was introduced. These dummies took values of zero when agreements were reached, and the value of various RHS variables when agreements broke down. Data limitations resulted in only estimating the disagreement data for the private information treatment (see footnote 22). The full set of dummies included an intercept dummy, and slope dummies for i) public value estimates, ii) favorable private information, iii) unfavorable private information, and iv) share of total chips. The regression results are presented in Table IV. The slope and intercept dummies share the name with the primary variable, but are denoted with the letter N, for Nonagreement, as the last letter in the name. Each dummy is reported

immediately below the primary variable.

The results strongly reject the null hypothesis (F=9.51; Pr>F=0.0001). The parameter values, moreover, provide considerable insight into the nature of disagreements. One important way that agreement and disagreement data differs regards value discounting. The slope dummy PUBESTSHN is large at .47, and highly significant (t=4.5). The results show that when there are disagreements, parties refuse to accept value discounting in share assignments. To obtain the relationship between share requests and value estimates in disagreements, one adds together the coefficients for PUBESTSHR and PUBESTSHN. Addition of these parameter estimates yields 1.074, which is not significantly different than 1.0 (F=0.80). Subjects ask for 1.0 per cent increase in share assignment for each one per cent increase in share of value.

The implication of this result is that disagreement over value discounting played a significant role in bargaining breakdowns. In agreements subjects accepted a significant reduction in the weight attached to value estimates. In disagreements, subjects refused to accept such discounting. In fact, their requests were virtually indistinguishable from the agreement shares under perfect information.

The implication is that there appear to be two different focal points. In one, subjects discount value estimates, and assign shares accordingly. In the second, subjects request shares assigned according to value. The dominant focal point under imperfect information is the one with discounting of public estimates and fairness participation shares. The reason is that when agreements were reached, there was heavy discounting of value estimates and a large share allocated for mere participation. The existence and uniformity of such discounting is reflected in the parameter estimate of .60, and its small standard

error (.035). These parameters strongly reject the hypothesis that a bargain without discounting would be drawn from the same population. Still, not all subjects accepted discounting, and this failure to accept discounting played a significant role in bargaining breakdowns.

The important result is that discounting emerged as a dominant focal point as a function of the type of information that subjects had available. When value estimates were common knowledge, the dominant focal point was to assign shares according to value. Hence this type of bargaining breakdown emerges because of differences in focal points, which emerge as a function of subjects' information.

The analysis also shows that favorable private information was another source of friction. Specifically, in disagreements parties with favorable private information were less willing to agree to bargains that did not reflect that information. In agreements, a one per cent increase in favorable information generated a .30 per cent increase in assigned share. In disagreements such a one per cent increase generated a .61 per cent increase in asked-for share. These differences are not significant (t=1.1), but do suggest that agents with favorable private information are behaving more aggressively when bargaining breaks down.

In contrast, unfavorable private information generated larger concessions when there were breakdowns. Specifically, a one per cent decrease in private information generated a .32 per cent decrease in shares in agreements. In disagreements, such a one per cent decrease generated a 1.01 per cent concession, and the difference is significant at the five per cent level (t=2.3). The explanation for this finding is fairly simple. Even with a 1.01 per cent concession the party is benefitting from the bargaining agreement if it is reached, and so has an incentive to make concessions to encourage more

agreements.

The final differences between the agreement and disagreement data under imperfect information regard the intercept and chip share. The intercept dummy for nonagreements, PIDUMMYN, is positive and small and is not significant (t=0.9). This means that in disagreements parties still request a participation share. In contrast, the dummy slope coefficient on chip share is large and significantly negative. Hence in disagreements parties' final offers do not include a premium for total chip share.

6. DISAGREEMENTS AND BARGAINING BREAKDOWNS IN THE FIELD DATA

The experimental laboratory results provide new insight into the unitization field data, and link contractual failure to the earlier findings of Roth, et.al. In the field, a major element of the failure of unitization is that more productive leases are often withheld from units when they are formed (Wiggins and Libecap (1985)). This problem was originally identified by Raymond Myers (1967) who noted "frequent acrimony as to the respective shares to be given owners of interest in favorable parts of the structure and owners of interests in less favorable areas..." (p. 108). Wiggins and Libecap then present systematic data showing that productive leases are more likely to be withheld, at least in the three fields for which they have systematic data. Hence fields are fragmented along productivity lines, sacrificing valuable gains to field-wide recovery efforts. Further, these disagreements often prevent any coordinated recovery efforts until late in field life, when relative lease values become known and bargaining becomes successful. Wiggins and Libecap go on to explain this behavior primarily in terms of asymmetric information.[23] The experimental

results lend further support for this hypothesis in that private information is heavily discounted in sharing rule assignments, leading to bargaining failures in some cases.

The experimental results, however, also show that discounting of value estimates provides another mechanism through which uncertain lease values can lead to contractual failure. The experimental findings show that when value estimates are uncertain, subjects discount these estimates in sharing rule assignments. In the private information treatment this discounting reaches nearly forty per cent; a one-per cent increase in estimated share only generates a six-tenths of one per cent increase in assigned share. In contrast, such discounting nearly vanishes when value estimates are known with certainty. In the full information treatment, a one per cent increase in share of valuable chips generates a .90 per cent increase in assigned share. The implication is that highly productive leases are more likely to be withheld under the asymmetric information treatment.

This interpretation suggests a need to reevaluate the field data. The experimental analysis suggests that bargaining failures may occur in the field simply because insufficient weight is given to value estimates, while excessive weight is given to non-value criteria--the constant term, or bag size. In the field such non-value criteria can include using a variety of factors that measure lease heterogeneities, but have little to do with potential future productivity. The experiments suggest, moreover, that disagreements should focus on this weight attached to productivity.

This hypothesis is directly testable using data from sharing rules when fields fragment. When bargaining breaks down along productivity lines, there should be systematic differences in the sharing rules used by the more and less

productive fragments. Highly productive areas should place more weight on value estimates, productivity, and so forth. Less productive areas should place weight on acreage and other factors unrelated to value.

To test this hypothesis, we investigated further the nature of the sharing rules and bargaining failures on the three primary fields contained in the original analysis by Wiggins and Libecap.[24] These three fields were the Prentice, Cowden, and Goldsmith/Landreth fields (see the analysis of joinder decisions, Wiggins and Libecap (1985) Table 2, p. 378). When fieldwide unitization failed on each of these fields, the field fragmented into smaller, partial units.[25]

To test the value discounting hypothesis, differences in sharing rules were examined. Specifically, the weight assigned to measures of value in the highly productive and less productive field fragments was examined.[26] We contacted the operators of these units, and obtained the sharing rules for all of the units on the field.[27]

The field data from these three fields suggests that value discounting may in fact have played a significant role in the failure of unitization. On the primary less productive area in the Prentice Field (Prentice Northeast), three factors were used to assign weights for tract participation in the sharing rule. These factors and their weights were: i) reservoir volume (67.5%), ii) output during the year before unitization (20%), and iii) cumulative past output (12.5%). On the residual unit (Prentice Central) formed from the highly productive leases in the central portion of the field, the tract participation was based solely on output during the year before unitization.[28]

The key difference in these formulas is the large weight attached to reservoir volume in the Prentice Northeast formula. To the extent that volume differs from

output, however, it measures oil originally in place that is drained away by neighbors who (generally) lie downhill. The less productive areas in Prentice insisted on high weight for the size of the reservoir under their leases, reflecting "fairness." The more productive leases gave all weight to output, ignoring "fairness." Hence the sharing formulas on the two portions of the Prentice field support the value discounting hypothesis.

The second field considered by Wiggins and Libecap was Goldsmith/Landreth. Unit negotiations broke down on that field, as on Prentice, and two separate (partial) units were formed. Differences in the sharing formulas used for these partial units reflect disputes over the weight placed on current value estimates, though in a less pronounced way than in the Prentice field. For the Goldsmith Landreth Deep Unit, the sharing formula was i) current output (77.5%) and ii) productive acres (22.5%).[29] To the extent that acreage differs from output, moreover, it effects a fairness criterion directly paralleling bag size in the experiments. The second fragment on the Goldsmith field, the San Andres Unit, placed all weight on value measures just like Prentice Central. Output over the year prior to unitization received eighty per cent (80%) of the sharing weight. A second dimension of productivity--producing wells, which play a major role in determining Railroad Commission output quotas--received the remaining twenty per cent (20%) of the sharing weight. Hence on both Prentice and Goldsmith/Landreth the sharing rules of the individual fragments show significant differences similar to those predicted by the value discounting hypothesis.

The third field in the Wiggins and Libecap study was the Cowden Field. The Cowden field differs somewhat from the other two. Valuation and fairness were important in the disagreement, but the analysis is more complex than in the other two fields. In particular, the North Cowden Unit was formed first, and the

leases in what eventually became the Wight Unit of the North Cowden field were withheld. The North Cowden Unit formula weighted natural gas production and cumulative output much more heavily. Both units had a two-phase sharing formula. In the North Cowden Unit, the first phase gave one hundred per cent of the weight to the preceding year's oil and gas output, and was in place for the first twenty five million barrels produced. The second phase formula placed a one hundred per cent weight on cumulative oil output, which measures well a lease's historical ability to produce.

The North Cowden Wight Unit had a short first phase covering only two million barrels. The formula placed fifty per cent weight on the preceding year's oil production, and fifty per cent on the same period's oil and gas. Hence oil was emphasized over oil and gas. In the second phase, the formula gave thirty five per cent to the preceding year's oil, forty per cent to the preceding year's oil and gas, but only twenty five per cent to cumulative oil output.

All of the differences reflect disagreement over dimensions of fairness and valuation. When leases are uphill (high) on a formation, they enjoy high production early in a field's life. This production diminishes comparatively rapidly as heavier oil flows downhill to lower leases. Gas production, however, remains steady or even rises, as lighter gas flows uphill. Lower leases have longer-lived production, and produce less gas.

In the Cowden Field the North Cowden Unit apparently was uphill. Accordingly their formula weighted gas more heavily and for a long time in Phase I, then in Phase II the formula switched to total cumulative output. This is "fair" because the (apparently) downhill Wight Unit leases were draining oil from their uphill neighbors. The Wight Unit leases, however, discounted past production and gas production in their sharing formula. Instead they looked to

current output, and to oil output, which in a significantly sloped field likely better measured future ability to produce.

The implication is that uncertainty over value estimates and fairness may have played a significant role in the breakdowns in all three fields. Uncertainty over the contribution of various leases to field value is pervasive in a field setting, and the sharing rules adopted suggest that there may be discounting of value estimates in fieldwide unitization efforts. The weight attached to valuation criteria was much higher in the partial units formed from the leases withheld when attempts at fieldwide unitization broke down. The experimental results show how this result is highly similar to the discounting of "chips" found by Roth, Malouf, and Murnighan. The suggestion is that imperfect information, per se, affects focal points in bargaining, and this change in focal points can cause bargaining to break down. The field data lend support to this argument.

7. SUMMARY AND CONCLUSION

The analysis above shows how information plays an important, multifaceted role in bargaining. The results provide two advances. The first is to show how imperfect information affects the weight placed on value criteria in bargaining. Roth, et.al., showed that uncertain versus known prize values lead to sharply different focal points in bargaining. In particular, payoffs in "chips" of completely unknown value led to complete discounting of prize values in the bargaining, while dollar payoffs were incorporated fully into the bargaining outcomes.

Our results extend this result to partially uncertain payoffs. When

subjects' own contributions to a common pool are known with certainty, bargains assign shares on nearly a one-to-one basis with contributions. When subjects have unbiased estimates of contributions, subjects heavily discount valuation in assigned shares in successful bargains.

These partially uncertain payoffs, however, create a new incentive for bargaining failure. When payoffs are in "chips" of completely uncertain relative values, as in Roth, et.al., discounting chips affects all subjects symmetrically. Here, in contrast parties whose values are discounted have an incentive to insist on giving full weight to the value estimate. This introduces a potential disagreement over focal points. This disagreement was reflected strongly in final offers in unsuccessful bargains.

We also link the results directly to bargaining breakdowns unitization field data. Value discounting appears to play some role in the bargaining breakdowns in the three primary fields covered in the original Wiggins and Libecap study. Whether this effect is important for the failure of unitization more generally is an important issue for further research.

Texas A&M University

and

Indiana University

and

Texas A&M University

APPENDIX

Instructions

This is an experiment in economic decision making. The National Science Foundation and other funding agencies have provided funds for the conduct of this research. The instructions are simple, and if you follow them carefully and make good decisions you may earn a CONSIDERABLE AMOUNT OF MONEY which will be PAID TO YOU IN CASH at the end of the experiment.

In a few minutes you will be divided up into 6 separate groups. Each group will be identified by a different color and will use a different area as a meeting place. There will be red, yellow, blue, purple, orange and green groups. You will be wearing a colored nametag that identifies your color and participant number, like:

R2

This one belongs to red player number 2. The number on your nametag is very important. It will be your "name" during this experiment and will go on all documentation that is used during the experiment.

An overview of what will happen each round of the experiment follows. First you will meet in the area designated for your color with other individuals of the same color. These areas are marked around the room as you can see. While you are in these areas you will be assigned one of six bags of poker chips. The contents of the bags and how they are assigned are discussed below. Next you will be assigned to a negotiating area by a random drawing. You will then go to the negotiating area (the numbered areas around the room), and negotiate with the people in your negotiating group. At the conclusion of negotiations you will fill out a brief form concerning the negotiations. You will then return to the area designated for your color and complete your earnings record for the round.

When indicated we will begin a new round, and this will continue for a number of periods.

The negotiations concern the bags of poker chips which you were assigned at the start of each round of negotiations. We have here a bag of poker chips like those that will be assigned. As you can see, on the outside of the bag is written the total number of chips the bag contains--this bag contains 200 chips. As I dump the chips on the table you can see that some of them are red, and some of them are blue. The blue chips are valuable, but the red chips are worthless. If you were to count the chips from this bag you would find that this bag had 45 blue chips and 155 red ones.

Your color group will be assigned a bag of chips each round by a random draw. Each player will then be required to pay 3¢ for each chip in their bag out of their starting balance and/or earnings in the experiment. Each participant is given a starting balance of $8.00 that can be used to pay for the chips.

While in your color area before each negotiating round, you will be told the exact number of blue and red chips in your bag. Other individuals participating in the experiment will not be told the composition of your color's bag. The number of blue chips is important because this number, and what happens in the negotiating rounds will determine your earnings in the experiment.

In each round of the experiment you will be negotiating with one person from each group of players -- red, yellow, blue, purple, orange, and green. Each person will be assigned to their negotiating group for that round by drawing a numbered chip out of a cup. You will never be in a bargaining group with people who have the same color as yourself. The negotiating areas are arranged around the room, marked by the numbered signs.

After you have moved to the negotiating areas, you will be given some information about the bags owned by the other players. First, you will be told

the total number of chips owned by each of the other negotiators. This information will be written on the blackboard. You will copy the information from the blackboard to a form like that shown on the next page of these instructions. The number of chips owned by the group of six negotiators will usually total 1000.

You will also be given some information about the number of blue chips in the bags of the other negotiators. You can use this information to determine whether your earnings will be increased or decreased by entering into an agreement. Each bag of chips has a corresponding "sampling" bag. Each sampling bag contains 49 numbered chips. The numbers are centered around the number of blue chips in the real bag. For example, if the actual bag had 45 blue chips in it, then the numbered chips would range from 21 to 69. A proctor will draw one of these chips from each sampling bag, show it to the group, and write the number found on the chip on the board. Should any subject wish to examine the bags after the experiment to ensure that the correct number of chips are in the bags and that they are correctly numbered, they will be free to do so. After the numbers are drawn, they will be summed.

This number gives you useful information regarding the likely number of blue chips in other individuals' bags. For example, if you repeated this sampling procedure 500 times, and then took the average of the number found, then that average would be very close to the actual number of blue chips in the other subjects' bags. In addition, you know that the numbers drawn are always within 24 of the actual number of blue chips in the other persons' bags. So you will know the most and the least number of good chips that could be in the bag, based on the sample. These will be written on the board. This information allows you to put an upper and lower limit on the number of chips in

Subject Number _____ Round _____ Bag Number _____

	Number of Chips	Sample	Percent of Total	High	Low
Yellow					
Red					
Blue					
Purple					
Orange					
Green					
Totals					

the other bags, and the total number of good chips. Finally, you also know that 50% of the time the number drawn will be within 12 of the true number, and that 75% of the time the number drawn will be within 18 of the true number.

Your earnings will be determined by the number of blue chips you own, and by what happens during the negotiating process. Your earnings will thus depend on how well you use the information you have about your own bag, and how well you use the sample information from the other bags.

In those cases where your group does not enter an agreement, your earnings will be the number of blue chips in your own bag multiplied by 10¢. In those cases where a group does enter an agreement, your group earnings will be the total number of blue chips owned by the entire group multiplied by 11¢. This product is then multiplied by your negotiated share. You can make these calculations using your calculators. An agreement will consist of a rule that assigns each member of the group a percentage of the total earnings (percentages must add to no more than 100%). Sharing rules must be agreed upon unanimously.

You should feel free to enter or not enter an agreement using whatever criteria you wish. To calculate your own earnings when you agree you will

multiply your percentage share times the actual number of blue chips owned by the group times 11¢.

Whether or not your earnings will be larger or smaller when you enter an agreement will be determined by how many blue chips are in your own bag, the number of blue chips owned by the entire group, and your negotiated share. You can calculate the likely range of your earnings under an agreement by using your calculator and the information from the sample bags. On average the number of blue chips owned by the entire group will be sum of the numbers on the blue chips drawn from the sample bags. This means that you can calculate an estimate of your earnings when you enter an agreement by multiplying your negotiated share times this sum of the sample numbers times 11¢. You can also place an upper or lower limit on your earnings by using the last two columns on your sample sheet. You simply take the sum where 24 was added, and the sum where twenty four was subtracted, and multiply times 11¢ and then times your share.

The following tells you how to calculate your earnings, both when you enter an agreement and when you do not. Let us assume that the entire group had 1000 chips, and that you had 250 of those chips. You would pay $7.50 for your chips out of your starting balance or accumulated earnings, which would reduce your balance from, say, $11.60 to $4.10:

$11.60 - $7.50 = $4.10.

Let us say that you did not enter an agreement, and that there were 81 blue chips in you bag. You would earn $8.10 and you would have

$4.10 + $8.10 = $12.20.

Now let us say that instead you agreed to a 16% share of the total. After the fact you learn that the number of blue chips owned by the group as a whole was 236, then your earnings would be

236 x $.11 x .16 = $4.16.

You would then have

$4.10 + $4.16 = $8.26,

which is $3.94 less than keeping your original bag. On the other hand, assume you agreed to a 42% share, and the group had 236 blue chips. Then you would earn

236 x $.11 x .42 = $10.91.

You would then have

$4.10 + $10.91 = $15.01

or $2.81 more than by keeping your original bag. In other words your earnings can be either larger or smaller when you enter an agreement.

Whether your earnings are larger or smaller under an agreement depends on the number of blue chips you own, the share you agree to, and the number of blue chips owned by the group as a whole.

The differences between the two payoff procedures again are

(1) on any round where a group does not agree on a sharing rule, each individual will earn 10¢ for each blue chip in their individual bag.

(2) When a group agrees on a sharing rule, each blue chip is worth 11¢, and individuals are paid their agreed-upon percentage of total group earnings.

So that you can become accustomed to procedures, the first bargaining period will be five minutes long. In all subsequent rounds, bargaining periods will be 3 minutes long.

Sharing rule offers can be made by any subject at any time during the negotiating session. They can be based upon any criterion deemed appropriate by the subject making the offer. They could, for example, be based on the relative height, weight, or grade point average of the participants, *or any combination of these*. You can also use any information you have about what you own, what the other subjects own, what the other subjects profess to own, or any other

information you have about the negotiating round. This would include the public information such as each subject's total number of chips and their cost, or the range for each subject's blue chips and their value. Alternatively you may assign 100% to one subject if the group agrees. In other words, there are no illegal or inappropriate criteria for offers for sharing rules, and these offers should be made freely. In summary you may assign shares in any proportions the group unanimously agrees on.

Each subject, on the other hand, may freely decide whether or not to enter an agreement, whatever its basis, depending on whether they feel that is preferable to enter that agreement and receive the assigned share, or not reach agreement, and receive 10 cents for each blue chip in their individual bag.

There will be a proctor at each negotiating table who will record information during the negotiations, and who will certify agreements when they are made. Certification by the monitor will consist of verifying that shares total to no more than 100%, but ensuring that a proposed sharing rule is valid is the group's sole responsibility. No offers can be made or accepted after time is called, and all conversation should stop immediately.

After time is called you will be told the total number of blue chips owned by the entire negotiating group, so that earnings can be calculated in groups that made an agreement.

After each negotiating round, you will calculate your earnings if an agreement is reached and then fill out an evaluation form. Then you will return to your color area and complete your earnings record. Afterwards you will receive your new bags and information, and get your table assignment for the next round.

Summary of a Negotiating Round

1) You go to your color area and observe the composition of your individual bag.

2) You go to the negotiating area assigned in your color room and observe the information from the individual "sample" bags.

3) Negotiations are conducted.

4) You are told the total number of blue chips so that individuals in groups that made agreement can calculate their earnings.

5) You fill out a brief negotiation evaluation, and if an agreement is reached you calculate your earnings.

6) You return to your color area to complete your earnings record.

FOOTNOTES

1. We would like to thank Resources for the Future and the State of Texas Higher Education Coordinating Board Advanced Technology Research Program (grant number 14600), the National Science Foundation (SES-8911032) and Advanced Research Program (grant number 14995) for financial support.

2. Order of names is random. We would also like to thank Gary Libecap, with whom Wiggins often discussed the problems of imperfect information and unitization. Helpful comments were provided by Andreas Ortmann, Jim Walker, Jerry Dwyer, and participants at the Indiana University workshop and the AEA meetings. We are also indebted to Ron Schultz, Texas Railroad Commission, Dan Currens, Amoco, and Darryl van Hoosier, Conoco for helping us obtain additional field data.

3. For similar conclusions regarding the existence of asymmetric information, see Meade, et.al. (1984) and Hendricks and Porter (1988).

4. Accordingly, states that have high unitization rates are ones where policy encourages unitization before asymmetric information emerges during field development. States with low unitization rates mandate unitization after field development. For an in-depth analysis of the political economy underlying the differences in state unitization policies, see Libecap and Wiggins (1985).

5. The analysis here does not attempt to isolate whether risk aversion is the underlying cause of this discounting. Experimental data presented in Murnighan, Roth and Schoumaker (1988) suggest that the focal point effects are likely to dominate any effects due to risk preference differences in the experimental

subjects.

6. For an excellent in-depth discussion of the relevant theoretical issues, see Mailath and Postlewaite (1990).

7. It should be noted that the federal government does offer some exemptions to acreage leasing limitations and does monitor unitization on federal lands. The important point, however, is that unitization on federal lands is only effective when it takes place prior to production (see Libecap and Wiggins (1985) and below). Hence these incentives are not the primary factor encouraging unitization on federal lands.

8. The Oklahoma figure is higher than Texas because Corporation Commission rules allow compulsory unitization. When there is agreement on a sharing rule by sixty three percent of the interests in a field, the remainder of the firms can be forced to enter the agreement.

9. The political economy of the reasons underlying the Texas (and Oklahoma) rule that unitization take place ex post is discussed in Libecap and Wiggins (1985).

10. The unitization experience in Oklahoma is generally unsuccessful, just as in Texas, and apparently for the same reasons. Oklahoma, however, has a compulsory unitization law, which complicates the analysis, and so the original study of private contractual failure focused on Texas fields.

11. Seismographs and other information are generally useful at helping to identify potential reservoirs--areas that might be unitized--but appear highly

unreliable at distinguishing among leases. To the best of our knowledge, such seismographs are not used in negotiations, and do not affect assigned sharing rules.

12. There is also some evidence that bargaining differs when negotiations are proceeding simultaneously on several fields with identical bargaining groups. The incidence of such occurrences, however, is uncommon.

13. The purpose of the payment was to force subjects to purchase their leases, and so to confound simple efforts to "split-the-pie evenly" as a bargaining solution. In the first evening session subjects paid the experimenter $0.02 for each chip. Experience from the first evening session indicated that satisfactory payoffs could be maintained with a slightly higher per chip cost, and so to economize on experimental session costs the cost per chip was raised to $0.03 in the remaining evening sessions. To save time, subjects did not have the choice of buying or not buying chips, nor could they select a particular bag of chips to buy, though these restrictions are potentially important.

14. Except in evening session 1, where one of the groups had only 5 subjects rather than 6.

15. An analysis of the private information and the public, full information treatments using only the data from experiments 3 and 4, where chip cost and unitization redemption values are constant, yields the same substantive results on focal points as reported below.

16. The assignment was made by having one subject in each color group one of two numbered chips from a cup. The subject drawing a "1" was assigned to group one; a "2" to group two; the other subject in the color group was assigned to the other group.

17. An analysis of this questionnaire data is beyond the scope of the present paper. This data will be analyzed in a subsequent report.

18. The data for bargaining groups of size five is excluded from the analysis. The bargaining groups of size five occurred on night one when only eleven subjects showed up. The structure of the estimating model would require dummies for the group size equal to five data and there are insufficient observations to make this practical. Except for one agreement in the low information condition noted below, the data for group size equal to five is comparable to the data reported for group size equal to six.

19. In successful bargains there is a budget constraint, which restricts the shares to sum to one. To preserve the independence of the residuals, one subject from each bargaining group was randomly omitted from the regression analysis.

20. Another possible interpretation of the allocation to the intercept and total chips is that these variables contain additional information about subjects' shares of valuable chips. We investigated this hypothesis and strongly reject that interpretation because the allocation to the constant in bargained shares is much too large to be justified on these informational grounds.

21. More specifically, $POSDFSHR_i$ = ((Actual $Blue_i$/(Estimated $Blue_j$)) - Estimated $Blue_i$/(Estimated $Blue_j$)) if Actual $Blue_i$ > Estimated $Blue_i$ and NEGDFSHR is defined using the same formula when Actual $Blue_i$ < Estimated $Blue_i$. There is also a substantive question regarding the appropriate denominator, since subject's may or may not have substituted their actual blue in calculating the sums in the denominator. We have carried out estimations using both approaches, and find that it does not affect the qualitative results. The regressions reported in Table 4 substitute the actual shares into the denominator.

22. Such offers were not binding. They did, however, uniformly form the basis of successful agreements, and parties only rarely asked for a larger share once an initial offer was made. This data is only useable for the private information treatment because of limited observations in the other treatments. In the low information treatment only one subject's offer is recorded during a disagreement period and in the public information treatment data from only three disagreement bargaining periods and nine subject offers are available. During the private information treatment data is available for eighteen disagreement bargaining periods and eighty nine subject offers.

23. To briefly summarize, when a unit is formed parties who withhold their leases will not subsequently be offered a more favorable share. This means that parties who decline to join must believe that their share operating alone is sufficiently greater than the offered share to more than offset the economies of joint production. The likelihood of such large differences increases with the uncertainty of the public estimate of lease value. Wiggins and Libecap show that public estimates of the value of more productive leases was more uncertain than such estimates for less productive leases. Hence they explain the hold-out of

more productive leases by arguing that it is more likely that such leases have highly favorable or unfavorable private information. That earlier paper also argued that pure imperfections in information might be important in the failure of unitization, but did not address the discounting arguments analyzed here.

24. Investigation of this hypothesis using more extensive field data is planned, but would carry us far from the current, more limited analysis. These fields were chosen simply because they had already been identified in the earlier study as reasonably representative examples of the nature of contractual failure in unitization.

25. As noted above, such partial unitization reaps some of the gains to coordinated recovery efforts, but sacrifices significant portions of the potential gains to fieldwide unitization and recovery. Such partial units are a widespread response to the failure of fieldwide units, and account for roughly thirty percent of the production in Texas.

26. As footnote three suggests, an important role for purely imperfect information was considered in the original Wiggins and Libecap study. Pure discounting of value estimates, however, was not considered because there was no reason to suspect that such discounting would be created by imperfect value estimates.

27. This data was not collected in the original study because that study provided no specific hypotheses regarding how such sharing rules should differ. These data were gathered from firms, but are also available through the Texas Railroad Commission.

28. As is common, the central unit used a two-phase sharing rule and the one reported in the text is the first phase. The second phase, which came into operation after 8.6 million barrels were produced, was 60 percent reservoir volume and 40 percent cumulative output.

29. The Goldsmith Field involved multiple formations and the weight attached to both output and acreage was broken down more finely in the sharing formula. This breakdown is immaterial for the analysis here, but was as follows: i) 15% current oil output from the 5600' zone, ii) 3% current gas output from the 5600' zone, iii) 49% current oil output from the Clearfork zone, iv) 10.5% current gas output from the Clearfork zone, v) 12% acres in the 5600' zone, vi) 10.5% acres in the Clearfork zone. The San Andres Unit of the Goldsmith Field did not employ such detailed breakdowns.

TABLE I

ORDER OF EVENTS IN A BARGAINING PERIOD

1. Each subject is required to buy a randomly determined bag of chips. The bag holds a number of valuable blue and valueless white chips.

2. Subjects are randomly placed in one of two bargaining groups. There are 6 subjects per group (5 in one group in evening session 1).

3. Subjects acquire relevant treatment information on (i) the total number of combined blue and white chips held by all other bargaining group members, or (ii) total chip information above, and a public estimate of the number of valuable blue chips held by other bargaining group members, and private information on the number of valuable blue chips in her own bag, or (iii) total chip information above as well as the actual number of valuable blue chips held by all other bargaining group members.

4. Three (five in the initial period) minute face-to-face bargaining session begins, in which subjects must unanimously agree to a budget-balancing sharing rule for total bargaining group payoffs. The total shares agreed upon must sum to less than or equal to 100 per cent.

5. Following the timed bargaining session subjects are either paid $0.10 per valuable blue chip if there was no unitization contract, or $0.12 ($0.11 in the last two evening sessions) multiplied by her bargained share of total group holdings of valuable blue chips.

6. Subjects complete a questionnaire in which they rate the other bargainers in that period's bargaining group based on how they responded during the bargaining session. Responses range from "4" (very agreeable) to "-4" (very disagreeable).

TABLE II

TREATMENT DESIGN

	Treatment condition by period		
Evening Session	Symmetric information on each subject's total chip holdings	Asymmetric information on each subject's holdings of valuable blue chips	Symmetric, full information on each subject's holdings of valuable blue chips
1	periods 6-7	periods 1-5, 9	period 8
2	periods 6-7	periods 1-5, 9-11	period 8
3	---	periods 1-5, 9-11	periods 6-8
4	---	periods 1-5, 9-11	periods 6-8

need to consider order effects

TABLE III

THE DETERMINANTS OF BARGAINED SHARES

Root MSE	0.02097	R-square	0.8533
Dep Mean	0.16634	Adj R-sq	0.8471
C.V.	12.60918		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.012054	0.01608877	0.749	0.4545
TCSHARE	1	0.932969	0.09403259	9.922	0.0001
PIDUMMY	1	0.041238	0.01717094	2.402	0.0172
PITCSHR	1	-0.839266	0.10166346	-8.255	0.0001
PUBESTSHR	1	0.603317	0.03480019	17.337	0.0001
POSDFSHR	1	0.297854	0.10056844	2.962	0.0034
NEGDFSHR	1	0.320622	0.09760819	3.285	0.0012
FIDUMMY	1	-0.012078	0.01893082	-0.638	0.5242
FITCSHR	1	-0.838197	0.12507923	-6.701	0.0001
ACTSHR	1	0.904208	0.05928936	15.251	0.0001

TABLE IV

THE DETERMINANTS OF BARGAINED SHARES

(INCLUDES DISAGREEMENT DATA)

Root MSE	0.03757	R-square	0.6824
Dep Mean	0.17558	Adj R-sq	0.6675
C.V.	21.39733		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.012054	0.02881820	0.418	0.6760
TCSHARE	1	0.932969	0.16843118	5.539	0.0001
PIDUMMY	1	0.041238	0.03075660	1.341	0.1810
PIDUMMYN	1	0.016279	0.01734936	0.938	0.3488
PITCSHR	1	-0.839266	0.18209959	-4.609	0.0001
PITCSHRN	1	-0.369844	0.10469482	-3.533	0.0005
PUBESTSHR	1	0.603317	0.06233410	9.679	0.0001
PUBESTSHN	1	0.470435	0.10354548	4.543	0.0001
POSDFSHR	1	0.297854	0.18013820	1.653	0.0993
POSDFSHN	1	0.312623	0.28352504	1.103	0.2711
NEGDFSHR	1	0.320622	0.17483579	1.834	0.0677
NEGDFSHN	1	0.690714	0.30667448	2.252	0.0250
FIDUMMY	1	-0.012078	0.03390888	-0.356	0.7220
FITCSHR	1	-0.838197	0.22404191	-3.741	0.0002
ACTSHR	1	0.904208	0.10619910	8.514	0.0001

REFERENCES

BINMORE, Ken: *Essays on the Foundation of Game Theory*, Cambridge, Mass.: Basil Blackwell Inc., 1990.

BINMORE, Ken, Avner SHAKED, and John SUTTON: "Testing Non-cooperative Bargaining Theory: A Preliminary Study," *American Economic Review*, 75 (1985), 1178-1180.

HENDRICKS, Kenneth, and Robert H. PORTER: "An Empirical Study of an Auction with Asymmetric Information," *American Economic Review*, 78 (1988), 865-883.

Libecap, Gary, and Steven *Wiggins*: "Contractual Responses to the Common Pool: Prorationing of Crude Oil Production," *American Economic Review*, 74 (1984), 87-99.

_____, and _____: "The Influence of Private Contractual Failure on Regulation: The Case of Oil Field Regulation," *Journal of Political Economy*, 75 (1985), 690-714.

MAILATH, George J. and Andrew POSTLEWAITE: "Asymmetric Information Bargaining Problems with Many Agents," *Review of Economic Studies*, 57 (1990), 351-368.

MEADE, Walter, Asbjorn MOSEIDJORD, and Phillip SORENSON: "Competitive Bidding Under Asymmetric Information: Behavior and Performance in Gulf of Mexico Drainage Lease Sales, 1959-1969," *Review of Economics and Statistics*, 66 (1984), 505-608.

MURNIGHAN, J. Keith, Alvin E. ROTH and Francoise SCHOUMAKER: "Risk Aversion in Bargaining: An Experimental Study," *Journal of Risk and Uncertainty*, 1 (1988), 101-124.

MYERS, Raymond: *The Law of Pooling and Unitization: Voluntary and Compulsory, 2nd ed.* Albany: Banks, 1967.

ROTH, Alvin E.: "Toward a Focal-Point Theory of Bargaining," in *Game-Theoretic Models of Bargaining*, ed. by A. E. Roth. Cambridge, Mass.: Cambridge University Press, 1985, 259-265.

_____: "Bargaining Phenomena and Bargaining Theory" in *Laboratory Experimentation in Economics: Six Points of View*, ed. by A. E. Roth. Cambridge, Mass.: Cambridge University Press 1987, 14-41.

ROTH, Alvin E., and Michael MALOUF: "Game-Theoretic Models and the Role of Information in Bargaining," *Psychological Review*, 86 (1979), 574-594.

ROTH, Alvin E. and Keith J. MURNIGHAN: "The Role of Information in Bargaining: An Experimental Study," *Econometrica*, 50 (1982), 1123-1142.

ROTH, Alvin E. and Francoise SCHOUMAKER: "Expectations and Reputations in Bargaining: An Experimental Study," *American Economic Review*, 73 (1983), 362-372.

ROTH, Alvin E., Michael MALOUF, and Keith J. MURNIGHAN: "Sociological Versus Strategic Factors in Bargaining," *Journal of Economic Behavior and Organization*, 2 (1981), 153-177.

WIGGINS, Steven, and Gary LIBECAP: "Oil Field Unitization: Contractual Failure in the Presence of Imperfect Information," *American Economic Review*, 75 (1985), 366-385.