How Institutions Affect Outcomes in Laboratory Tradable Fishing Allowance Systems

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The objective of this paper is to illustrate that economic institutions matter, i.e., that different rules of trade present different incentives for bidding, asking, and trading in new markets, and that these different incentives lead to different price discovery patterns, which yield materially different outcomes. In a laboratory tradable fishing allowance system, when trade takes place through a double auction, which parallels an institution common in extant tradable allowance systems, markets are characterized by high volatility, and equilibrium does not obtain. However, when only leases, and not permanent trades, are permitted in the early periods, volatility is significantly reduced and equilibrium obtains. This dependence of equilibration and outcomes on institutions implies policy-oriented economists must consider institutions in designing new market-based management systems.

Key Words: asset markets, experiments, fishery management, ITQs, tradable fishing rights, transferable allowances

Policy makers are making increasing use of tradable allowance systems to address environmental and natural resource management problems, including water use, pollution, and over-fishing (Tietenberg, 2002). A management authority that applies a tradable allowance system typically sets an allowable level of activity, allocates the allowance among users, and gives users the right to trade their allocations to others.[1] In doing so, the management authority effectively establishes a market for an entirely new asset, which can be of great value, and represents a significant portion of the wealth of the resource users, particularly in water and fishing applications where the users are often small or family businesses. However, because the asset is new, there is little basis on which the market participants can draw to determine the prices that are likely to emerge.

Participants in this new market know only their private values, and have little idea of the market-wide marginal value of allowance, which the competitive model predicts will emerge as the equilibrium price. As a result, each participant must rely on the information she can glean from the market—the bids, asks, and trades of others, as well as the market reaction to her own bids and asks—to determine whether or not a prospective trade constitutes a good deal. It is not surprising, then, that different institutions, which provide different amounts and different types of information, and possess different incentives for revealing information through bids and asks, yield systematically different sequences of bids, asks, and contracts, and therefore equilibrate differently.

The objective of this study is to illustrate that economic institutions matter, i.e., to show these different

The author is assistant professor, Department of Environmental and Natural Resource Economics, University of Rhode Island. This paper is a synthesis of results from a series of joint papers with Jon Sutinen, without whom I would know little about fisheries. His knowledge and experience have contributed greatly to my thinking, and I am grateful for his partnership in the project presented here. I am also grateful for research assistance on the reported experiments provided by Samuel Buckley and Matthew Freeman, to Rhode Island Sea Grant for support of the experiments, and to the Rhode Island Agricultural Experiment Station for support of the Policy Simulation Laboratory (contribution no. 4061). Opinions, conjectures, inferences, and errors are my own.

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[1] In fisheries, the term "allowance" is used to refer to the privilege to access a resource at a certain level. This term encompasses both transferable production allocations (ITQs and IFQs) and transferable effort allocations (e.g., days-at-sea or trap certificates). In the United States, these allocations are not true property rights, in the sense that they may be revoked by the government without compensation. Hence, I avoid use of the term "right."

patterns of equilibration yield materially different outcomes. Specifically, in a laboratory evaluation of a significant tradable fishing allowance system, one commonly used institution performs poorly while a simple modification leads to reliable equilibration. While the research being discussed is ongoing, there is sufficient evidence to argue that policy makers and economists must consider the equilibration process, and the institutions affecting it, in developing new market-based management systems. The wrong institution can lead to so much volatility during initial trading that effective price discovery cannot occur, and equilibrium is never reached. Alternatively, bad outcomes can arise during price discovery, and although the market eventually stabilizes, perhaps even at competitive equilibrium prices, trades made during equilibration lead to gross inequities among similar participants based solely on when they traded.

The implication of outcomes' dependence on institutions is that policy-oriented economists must begin asking a question which has previously not been posed: *How should the rules of trade be designed to best achieve policy objectives?* This question is new because there is nothing in competitive microeconomic theory which suggests equilibrium outcomes depend on institutions; there is no mention of institutions in popular graduate microeconomic theory texts such as Varian (1992); Silberberg (1994); or Mas-Colell, Whinston, and Green (1995). As a result, there is a common perception among economists, politicians, and the public that if regulators establish property rights for natural resource use or environmental harms and allow trade, markets will emerge and efficient allocations or least-cost abatements will arise (e.g., Gwartney et al., 2002). Unfortunately, it is not so simple.

Economists have not devoted attention to the equilibration process, or to the institutions on which it depends, because most of the markets historically of interest are already well established, or can be based on established markets, so the initial price discovery process has already occurred. Consequently, there is not, and has been little need for, a theory of equilibration.[2] However, markets for tradable natural resource or environmental damage allowances are created, and the associated price discovery process can have important effects on outcomes for the market participants. Therefore, effectively implementing market-based management measures requires considering the effect of institutions on price discovery, and on the market outcomes that are determined during equilibration.

In this paper, the role of institutions in determining outcomes is illustrated with a series of experiments designed to assess tradable fishing allowance management. The study is motivated by a 2001 industry proposal to implement a tradable trap certificate system in the Rhode Island inshore lobster fishery. This is one of many U.S. fisheries considering adoption of tradable allowance management, following recommendations of national panels convened to study fishery management issues (National Research Council, 1999; Pew Oceans Commission, 2003; U.S. Commission on Ocean Policy, 2004), and the expiration in the fall of 2003 of a six-year moratorium on new tradable allowance systems. The plan was recently approved by the Atlantic States Marine Fisheries Commission, which manages American lobster in the northeastern United States. However, the details of the trading arrangements, which inspired this research, have not yet been determined.

The following section of the paper discusses why the price discovery and equilibration process of the tradable allowance market is important to the functioning of the regulated industry. Next, previous cases are described in which experiments have contributed to designing markets for controlling environmental harm, managing natural resource use, and other high-value policy applications. The experimental evidence for the dependence of outcomes on institutions in tradable fishing allowance markets is then presented. It is shown that when trade takes place through a double auction market, which shares many features with the institution most commonly used to trade fishing allowances in extant programs, prices are volatile, based on speculation rather than fundamental values, and do not converge to equilibrium. However, by prohibiting permanent allowance trades in the first few years of the program, a market for temporary lease trades can establish a price signal which carries over to the permanent allowance market, facilitating equilibration. Although this process is not yet sufficiently well understood to ensure initial lease markets will work in the field, the final section offers a discussion of the broad policy implications of institutions' important role in determining outcomes.

[2] Walras' (1954) tatonnement concept presents a way to think about price discovery and convergence, but without disequilibrium trades during the price discovery process, it cannot be sensitive to variations in information structure among non-tatonnement institutions. See Anderson et al. (2004) for a discussion of the relationship between tatonnement dynamics and equilibration in non-tatonnement institutions.

The Policy Significance of Price Discovery and Equilibrium

The equilibration process of allowance markets carries policy importance because many of the commonly cited advantages of allowing markets to determine effort allocation or production rely on being in equilibrium, whereas many of the outcomes feared by managers and resource users are the result of disequilibrium. When prices are based on fundamental values, as they are in equilibrium, price changes are predictable based on changes in market fundamentals. In fisheries, this means prices change based on beliefs about changes in the fishery, including new technology, stock fluctuations, and product market demand. In equilibrium, prices are indicators of future profitability, and therefore serve as signals for capital investment. In addition, the value of held allowances values incumbents' access to the fishery, and provides security for retirement. From a normative standpoint, when trades are based on private fundamental values, allowances will trade from those who can earn less profit by fishing them to those who can earn more, maximizing the profitability of the fishery.

However, when the allowance market is not in equilibrium, outcomes that are feared by resource users and managers arise. When prices are not based on fundamental values, they can fluctuate unpredictably. Even for those who do not participate in speculative trading, and who trade only when it is in their private interest to do so, there are reasons to fear volatility. The inability to predict future prices complicates long-term business and capitalization decisions. This includes the decision of whether to participate at all, since arbitrary fluctuations can significantly affect the value of a participant's wealth or retirement savings. Volatility can also shift regulated industries away from family businesses, as the risk associated with investment in volatile allowances also provides an opportunity for consolidation because diversified large operators may take on allowance market risk that smaller operators are unwilling to accept. In farming towns and fishing villages, such consolidation can threaten a local culture and way of life. In dynamic resource use applications, equilibrium prices aggregate and convey information about stock health (Arnason, 1990; Batstone and Sharp, 2003), but inferences drawn from disequilibrium prices may be incorrect, leading to improper capitalization levels and incorrect management decisions.

While there have been relatively few studies of individual contract price time series from tradable fishing allowance markets, their findings all suggest there is considerable market volatility in the first four to six years of a new tradable allowance program. Newell, Sanchirico, and Kerr (2003) identify price dispersion as a prominent feature of the first four years of the New Zealand 30-species quota management system. During this period, dispersion levels were close to 30% of the average price level; the level of dispersion over the last five years is closer to 10%.[3] In the Florida spiny lobster fishery, Larkin and Milon (2000) report price ranges spanning from one to four times the average price in each of the first five years of the tradable trap certificate program.[4] During these periods, anecdotal evidence suggests people grew unhappy with the system: they learned they sold their allowance at far below its long-term value, or purchased far above it; they saw others reap windfall profits from buying an allowance far below its long-term value, or selling far above it; or they made investment decisions based on incorrect price signals.

Stories of the effects of volatility in these and other programs often enter policy debates surrounding the possible adoption of tradable allowance management. However, for fisheries, or communities within community-based management systems (McCay, 2004, this journal issue), to select the best management alternative for their fishery, they must understand the potential of all alternatives. This requires comparing the likely outcome under a well-designed tradable allowance system to those under other management systems. If equilibration can be accelerated, or the associated volatility reduced, by changing the institution through which trade occurs, then policy makers and managed stakeholder groups could have a better idea of the potential of tradable allowance systems on which to base their decisions.[5] Even if they do not select tradable allowances,

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[3] Newell, Sanchirico, and Kerr (2003) measure dispersion as the ratio of the absolute value of the difference between a trade's price and the month's mean price, and the month's mean price.

[4] Even in small fisheries, where everyone knows how much effort everyone else is applying to earn what money, price discovery is necessary because knowing everyone's average value of an effort or production unit at current production levels is little help in determining the fishery-wide marginal profitability—which determines the allowance price—at the often much lower production levels frequently imposed with new tradable allowance systems (McCay, 2004, this journal issue).

[5] Of course, non-market-based management systems can also be better- and worse-designed, and the comparison should also consider the best-designed version of those alternative systems. The contribution here is that decision makers and stakeholders need to be sensitive to the idea that there are better- and less-well-designed markets.

they can make their choice with a better idea of the strengths and weaknesses of a well-designed system.

The Use of Experimental Methods in Policy Analysis

Since equilibration plays an important role in determining whether the promises or the fears associated with tradable allowance systems are realized, selecting an institution that rapidly and reliably equilibrates is an important factor in achieving a successful policy outcome. Without a theory of how the incentives of different institutions affect the information revealed through bids, asks, and trades, which ultimately guides price discovery, a different tool is needed to understand how alternative institutions affect outcomes.

In economic experiments, human subjects play the role of market participants in a controlled setting designed to reflect the key incentives in the naturally occurring environment being studied. In a fishery management experiment, for example, subjects are given a profit schedule from which their earnings are determined based on their chosen fishing effort and other variables of interest. The profit schedule and available actions are selected to reflect the fishery and management measures being studied. Participants who better respond to these induced preferences are paid more, in cash, at the end of the experiment for their participation (Smith, 1976, 1994; Davis and Holt, 1993). It is axiomatic in economics that people make decisions which maximize their utility, and since money earned in the laboratory can be used to increase utility outside the lab, participants will make decisions during the experiment that earn them the most money. Therefore, if the incentives of the economic environment being simulated have been properly represented in the experiment, then participants acting to maximize their laboratory earnings will make the same decisions as agents trying to maximize their utilities in the natural environment.[6]

Economic experiments can contribute to the analysis of market-based policies in two ways. First, experiments can provide carefully controlled tests of the theoretical models underlying regulatory systems. Many of the reasons cited for using tradable allowances rely on the ability of the market to accurately price the allowances. When the market price is based on supply and demand derived from the marginal profit an additional allowance unit provides fishers, the post-trading allocation of allowances maximizes the profitability of the fishery. Further, allowance costs can be covered with earnings from the additional allowances, and price changes will be predictable based on expected changes in the stock, harvesting costs, and market demand. However, realizing these efficient allocations requires equilibration. An empirical question that can be addressed in the laboratory is whether allowance markets equilibrate, or instead exhibit unstable or nonequilibrium tendencies due to features of the underlying derived demand functions, the asset-like properties of permanent allowance, or particular rules of trade that facilitate speculation or other disequilibrium behavior.

A second way experimental techniques can contribute to analyzing market-based policies is by comparing different ways of structuring the market (Plott, 1994, 1997). Different definitions of the property right, rules for trading it, and complementary institutions affect the speed and nature of convergence, and thus ultimately determine the outcome. When theory offers little guidance, experiments can be used to testbed trading institutions or evaluate the merits of alternative trading policy proposals to identify those that appear best suited for a particular application (Banks et al., 2003). Flaws in proposed designs can be uncovered and corrected before implementation in the field, where such adjustments may be impossible or require much greater expense.

Experimental testbedding has been successful in a number of high-profile, high-value policy applications, including the auction used by NASA to determine space shuttle payload priorities (Ledyard, Porter, and Wessen, 2000) and the auction the FCC has employed to raise more than $9 billion selling licenses to bandwidth used by cellular telephones (Banks et al., 2003; Salant, 2000; Plott, 1997). Cellular licenses are challenging to auction efficiently because there are complementarities in owning adjacent licenses: owning both south and central Florida is more valuable than the sum of owning just south and just central because fees do not need to be paid to the owner of the other to carry calls across zones. In a sequential auction, bidders on south Florida would need to adjust their price strategically, not knowing whether they would be able to afford central Florida, auctioned later. Experiments helped design an auction institution that improves efficiency and maximizes revenue by allowing participants to bid on all licenses

[6] See Anderson and Sutinen (forthcoming); Smith (1976, 1994); Plott (1994); Davis and Holt (1993), among others, for more detailed discussions of experimental methods.

simultaneously, so the synergies of owning adjacent licenses can be priced in the auction. Experiments also addressed practical questions about the efficiency impacts of minimum bid increments, which considerably speed this complex auction.

Most closely related to tradable fishing allowances are a number of applications in water rights trading (e.g., Murphy et al., 2000; Murphy et al., 2003; Cummings, Holt, and Laury, 2004), and tradable pollution rights (Franciosi et al., 1993) (see Shogren and Hurley, 1999, for a survey). Specific cases include the market mechanism for trading sulfur dioxide and nitrous oxide in southern California (Ishikida et al., 2000; Carlson et al., 1993) and the mechanism used by the Environmental Protection Agency to trade pollution permits for sulfur dioxide under the Clean Air Act (Cason, 1995; Cason and Plott, 1996). In the latter case, the EPA implemented a discriminative auction for trading permits in which buyers and sellers each submit sealed bids, and low-asking sellers were matched with high-bidding buyers; buyers paid their bid price to their matched sellers. Experiments demonstrated that this institution's incentives led sellers to underreport the true costs of emissions control in hopes of being matched with lower-bidding buyers, resulting in inefficient trades. These experimental results subsequently led to a change in the auction design for pollution permits. This is an example of how investing in laboratory testbed research before implementing a rights-trading system can improve the outcomes of tradable allowance markets.

Experiments on Tradable Fishing Allowance Markets

To address the question of whether equilibrium, and the policy outcomes associated with it, obtains in tradable fishing allowance markets, a series of experiments was run using alternative trading rules. One series of experiments was run using rules which parallel those commonly used in field tradable allowance markets: trade of the permanent allowance began at the onset of the program, and took place through a double auction, in which both buyers and sellers can advertise a trading price on a central market board, or accept a trading price advertised by someone else. As in many field markets, double auction trading is bilateral, can take place at any time, and different trades can occur at different prices. For comparison, a second set of experiments was run in which only temporary leases, and not permanent allowance trades, were permitted at the beginning of trading,[7] and exchange took place through a call market in which all trades occurred at the same time and price. In the call market, buyers and sellers could submit schedules of prices at which they were willing to trade. At an appointed time the market would close, a central auctioneer would use the submitted schedules of buy and sell prices to construct supply and demand curves, and would execute all trades to the left of the supply/demand intersection at the intersection price.[8]

Figure 1 shows the price observed in five double auction sessions,[9] and figure 2 shows the prices observed in five call market sessions. In each session, 12 to 14 human subjects, each playing the role of a fisherman managed by tradable allowances, interact through a computerized market to exchange allowance units which can be used to earn profit from fishing. Each of the 12 periods begins with a trading stage during which the market is open and trades can be executed. When the market closes, each subject earns profit from fishing based on the quantity of allowance units she holds. Subjects read the amount of profit from fishing they earn for any number of allowance units from a table on their computer screen. In this experiment, all subjects had identical profit functions estimated from 2001

[7] The initial lease period treatment was inspired by the gradual introduction of individual vessel quota trading in the British Columbia halibut fishery (Casey et al., 1995). The quota program began in 1991, and during the first two years, no quota transfers (temporary or permanent) were allowed separate from fishing licenses. After two years, temporary (annual) transfers were permitted, which remained in effect until about three years ago. Both permanent and temporary transfers are now allowed in the fishery (Turris, 2004).

[8] The difference in institutions is the material difference between the two experiments, but there were small procedural differences our debriefing indicates did not affect subjects' understanding of the problem. The instructions for the call market with initial lease period (CMILP) experiment differed from those for the double auction (DA) in that they were abbreviated, and broken into two sections—the first explaining the market software and lease market for the first round, and the second explaining the asset structure administered before the second round. There were two noteworthy software revisions between the DA and CMILP experiments. First, the subjects' software screen had a graph of the profit function in the DA experiment in addition to the table; the graph was not used in the CMILP experiment. Second, the CMILP software had a feature which alerted subjects when they were about to make a bid or ask that would not increase their joint profits from trading and fishing. Debriefing suggests this feature reduced some subjects' confusion more quickly, but did not inhibit subjects for whom trading at a loss was strategic. Based on others' asset market experiments in which similar loss warnings were implemented, and data reported in Anderson and Sutinen (2004) in which a call market with loss warnings but without an initial lease period shows high volatility and above equilibrium prices, I do not believe these changes caused the differences between the figures. Ideally, the DA experiment could be replicated with these features and with instructions which more closely mirrored those used in the CMILP experiment. However, appropriate scientific skepticism aside, it is instructive to look at the data from these experiments side-by-side and learn from the differences between them.

[9] Due to a software glitch, period 3 of round 1 of session C was zero seconds long.

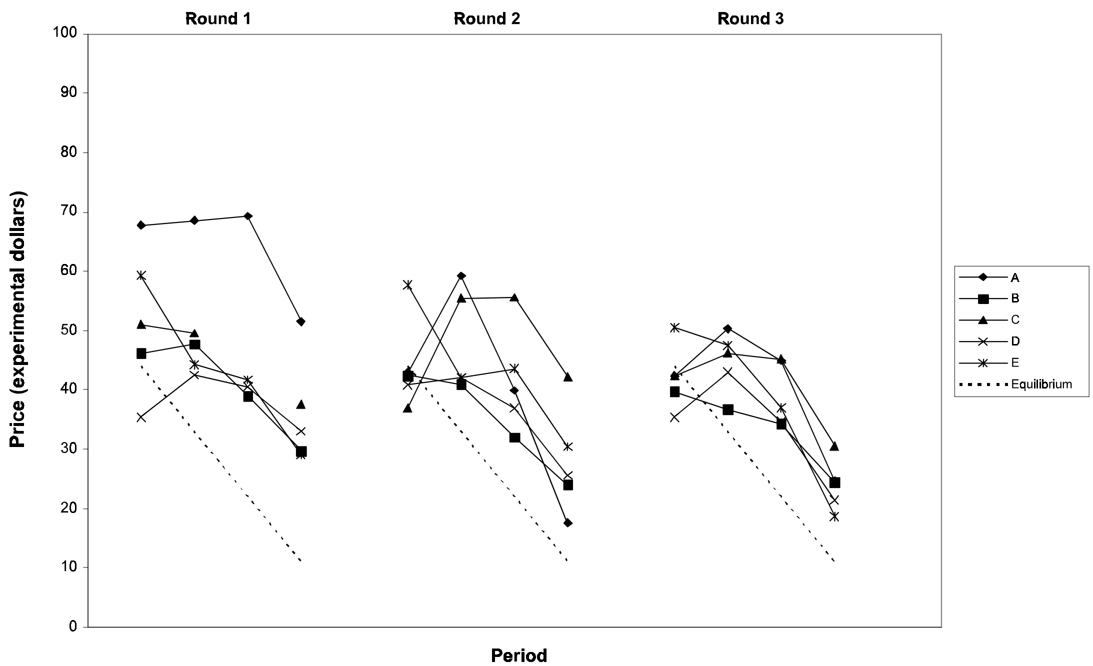

Figure 1. Period average prices in the double auction (DA)

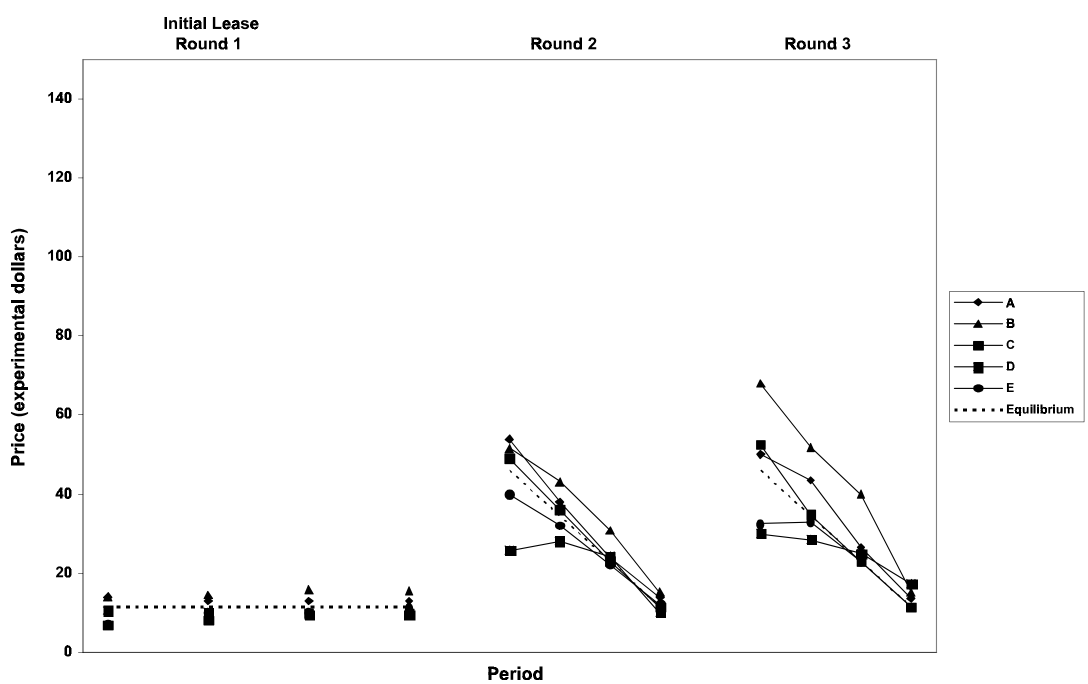

Figure 2. Period average prices in the call market with an initial lease period (CMILP)

logbook data on medium-large lobster operations in Area 2, which encompasses the Rhode Island inshore fishing grounds. At the end of the experiment, subjects are paid, in cash, their total earnings from fishing and net trading profits.

In both figures 1 and 2, the 12 periods are grouped into three rounds of four periods each. In all three rounds in figure 1, and in rounds 2 and 3 in figure 2, there is a downward-sloping dashed line that indicates the upper bound of the competitive equilibrium price prediction, 11.5 experimental dollars times the number of periods remaining in the round.[10] (In round 1 of figure 2, the predicted price line is a constant 11.5 dollars because only single-year transfers are allowed.) Allowances are assets, which in the experiment are given a life of four periods. In the first period of each round, subjects are given an endowment of allowance units and cash. Trades are permanent, in that endowments are not restored until the beginning of the next round. Therefore, an allowance unit purchased in the first period of a round allows the purchaser to earn profit fishing it in all four periods, while an allowance unit purchased in the fourth period provides profit in only one period. If allowance units are traded based on fundamental values, the additional profit that can be earned by fishing them, the equilibrium model predicts prices will decline as periods elapse because there are fewer periods remaining in which to earn profit from fishing with purchased allowance units. Between rounds, endowments are restored to initial levels, and the four-period exercise is repeated to assess the effect of experience.

The major result of this paper is that although the market fundamentals and equilibrium predictions are the same in these two experiments, the outcomes are consistently and systematically different. Consider the average price observations in figure 1's double auction (DA) with those in the similarly structured rounds 2 and 3 of figure 2's call market with an initial lease period (CMILP). The most important difference is that every single price observation after the first period of a round is considerably above the equilibrium prediction in the DA, whereas the equilibrium model describes well the average behavior of prices in the CMILP, where observations are closer to and distributed both above and below the equilibrium prediction. Although the data in both figures begin each round with some spread around the equilibrium price, there is a consistent difference in how prices change in consecutive periods. In the DA, prices often change little, or even increase, in the second and third periods to result in higher than equilibrium prices, as equilibrium predicts prices should fall. In contrast, the price changes between the first and second periods in the CMILP move in the direction of equilibrium, and changes between the second and third periods decrease at about the same rate as equilibrium predicts. Based on this initial examination, trade prices in the DA do not appear to reflect the fundamental value of allowance and do not appear to equilibrate. In contrast, the prices in the CMILP do appear to be responding to changes in fundamental value, consistent with the competitive equilibrium model.[11] This difference can only be attributed to the different market structures used to facilitate exchange.

The effective difference between these sets of trading rules is that in the DA in figure 1, allowing trades to take place at different prices when little information was available led to a great deal of volatility, which in turn reinforced beliefs about the prices others would be willing to pay in the future. This fueled speculation that led subjects to bid up the price based on beliefs about what others would pay in future periods, rather than to trade based on the marginal profit from fishing provided by allowances. In contrast, the CMILP in figure 2 both provided a high-quality initial price signal from the lease market and eliminated contrary price signals arising from contracts occurring at different prices. The net effect is that when the asset market is introduced in round 2 of the CMILP experiment, subjects have information on which to evaluate prospective trades, which allows the market to stabilize quickly.

To establish the statistical significance of the apparent differences in average price patterns, results are pooled across sessions and across rounds using an autoregressive heteroskedastic panel regression. Table 1 presents a model which tests separately for each experiment the prediction of equilibrium theory that prices should equal the single-period

[10] With discrete-unit supply and demand curves, we must select between a price tunnel (an interval of equilibrium prices) and a quantity tunnel (an interval of equilibrium quantities). In experiments with quantity tunnels, trading commissions are often offered to provide incentive to make the inframarginal trade at the equilibrium price. In environments where resale is allowed, commissions cannot be offered, so a price tunnel was used, where the market provides the incentive to trade the inframarginal unit. In these experiments, the competitive equilibrium model predicts the price will be between 10.25 and 11.5 experimental dollars times the number of periods remaining in the round.

[11] Anderson and Sutinen (forthcoming) statistically reject the hypothesis that the average prices and between-period price changes in the DA are consistent with equilibrium, and Anderson and Sutinen (2004) statistically establish that the price levels and changes in the CMILP are consistent with the equilibrium model. See those papers for an analysis of the respective experiment data, and a detailed discussion of the procedures that generated them.

Table 1. Heteroskedastic Panel Model of Average Prices in the CMILP and DA Experiments (*N* = 99)

Variable	Coefficient
Base Model:	
Constant	2.110
	(2.951)
Periods Left in Round	11.332***
	(0.923)
Last Period in Round	!0.629
	(2.091)
DA Differences:	
DA × Constant	36.636***
	(4.158)
DA × Periods Left in Round	!9.737***
	(1.296)
DA × Last Period in Round	!10.806***
	(2.947)
Wald Statistic [degrees of freedom]	475.20 [5]

Notes: Asterisks denote statistical significance at the 1% level. Values in parentheses are standard errors.

profit the inframarginal unit provides its demander times the number of periods remaining in the round for the demander to use it. The upper portion of the table shows estimated coefficients for a *Constant*, the number of *Periods Left in Round*, and *Last Period in Round*, an indicator variable for the fourth period, which may behave differently because there is no future on which to base possible speculation; the bottom section shows these variables interacted with an indicator for the DA experiment in figure 1.

The estimated coefficients in the upper section of table 1, representing the determinants of price in the CMILP experiment, exactly match those predicted by theory: the *Constant* and *Last Period in Round* indicator variables are not significantly different from zero, and the coefficient on *Periods Left in Round* is squarely within the predicted interval of 10.25 to 11.5 experimental dollars. Based on these findings, the competitive equilibrium pricing model cannot be rejected when trade takes place through a call market and there is an initial leasing period.

The lower section of table 1, representing differences in the determinants of price between the CMILP and DA, reveals a significantly different price pattern for the DA experiment. The effect of the number of *DA × Periods Left in Round* is a statistically and economically significant 9.74 experimental dollars lower than in the CMILP, leaving an average price decrease of only 1.59 dollars per period. Instead, prices are explained primarily by the highly significant *DA × Constant*, reflecting that prices do not change as the equilibrium model predicts during the first three periods. The significantly negative coefficient on the *DA × Last Period in Round* indicates that prices crash at the end of each round, dropping more in the final period than in the previous periods in the round. Therefore, the competitive equilibrium pricing model is rejected when the laboratory tradable allowance market uses a double auction, an institution which mirrors many of the features of field allowance trading institutions.

The difference in equilibration between the two institutions leads to a significant difference in the efficiency of the allocation of allowance, and therefore in the total profit earned from the fishery. Figures 3 and 4 show the efficiencies observed in each session, relative to the efficiency level at the endowment.[12] In figure 3, there is little tendency for efficiency to improve through trading. In only two of the observed rounds, session B/round 1 and session E/round 3, are observed efficiencies higher than the initial endowment in every period. From an efficiency standpoint, prohibiting trading would have been better than allowing trade through a double auction.

Figure 4 presents a much different efficiency effect of trading. While there is some price discovery, in four of the five sessions, efficiency improves in all periods of the asset market (rounds 2 and 3); in session B, it improves in six of the eight periods. Treating rounds within the same session as independent, table 2 reports the average efficiency observed at the end of each period in rounds 2 and 3 of the two experiments. The bottom row of the table presents the *p*-value of a Wilcoxon signed-rank test of the null hypothesis that the distribution of efficiencies is the same in the two experiments. This null hypothesis is rejected in each period, as efficiency is significantly higher in the CMILP experiment. Thus, the institution through which trade occurs not only affects the prices that arise, but also the surplus extracted from the fishery through trading. This results in a difference in the distribution of experiment earnings: payoffs to subjects in the DA experiment earned an average of $23.82 with a standard deviation of $3.95, and those in the CMILP earned more on average, $24.59, and with less variation, a standard deviation of $1.21.

[12] The endowment is 94% efficient, a value based on the proposed policy in the Rhode Island lobster fishery. An academic experiment testing a model would normally set a much lower initial efficiency, but the group of managers and lobstermen assisting with the project suggested the more realistic value would ease communicating results to the policy audience.

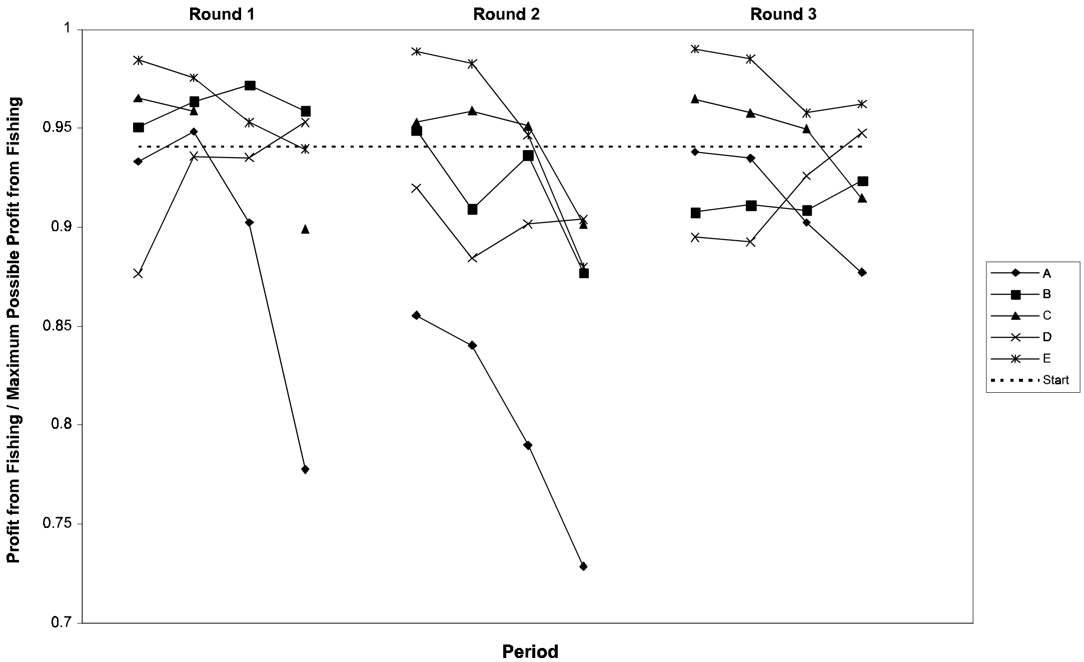

Figure 3. Efficiency of allowance allocations in the double auction (DA)

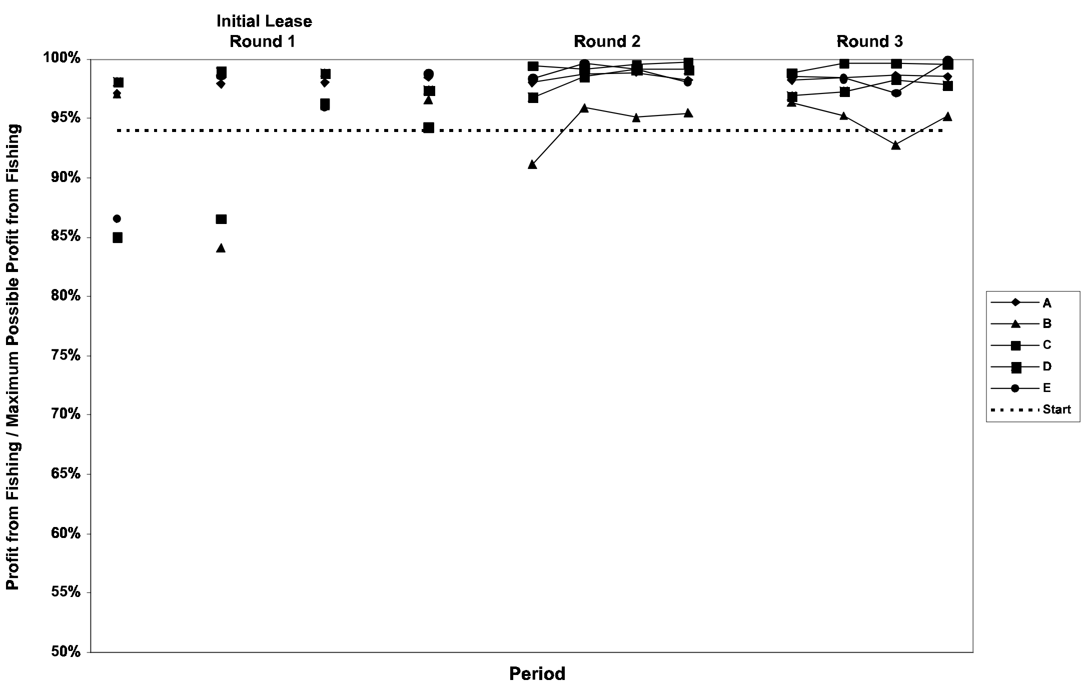

Figure 4. Efficiency of allowance allocations in the call market with an initial lease period (CMILP)

Table 2. Differences in Average Efficiency in Each Period (rounds 2 and 3)

	Period			
Experiment	1	2	3	4
Double Auction (DA)	93.6%	92.6%	91.7%	89.2%
Call Market w/Initial Lease Period (CMILP)	97.3%	98.1%	97.8%	98.2%
Wilcoxon *p*-Value	0.0494	0.0025	0.0012	0.0003

The pattern of higher-than-equilibrium prices which do not fall with changes in the fundamental value, but then crash at the end of the round—seen in the DA experiment—is consistent with bubble-and-crash cycles seen in other experimental asset markets (Smith, Suchanek, and Williams, 1988; Fisher and Kelly, 2000; Noussair, Robin, and Ruffieux, 2001; Lei, Noussair, and Plott, 2001; see Sunder, 1995, for a survey). This is a symptom of some underlying difficulty with price discovery presented by the double auction institution, which is addressed by the call market with an initial lease period. There are at least two differences in the information available to participants in the two experiments' allowance asset markets. First, CMILP subjects had learned the market-wide value of the marginal allowance unit, the price that emerged in the lease market of the first round. Second, because all trades took place at the same price at the end of the trading period in the CMILP, subjects did not receive noisy signals from trade prices which fluctuated wildly during the trading period.

An additional experiment is necessary to determine which of these differences in the institutions' information structures improved price discovery. Figure 5 shows the average prices from three experimental sessions in which allowances are exchanged through a double auction, but in which the asset market is preceded by an initial lease period (DAILP). To prevent subject pool contamination, profit functions were changed from those used in the earlier experiments. In the DAILP, the equilibrium price is between 12.6 and 13.8 experimental dollars per period remaining in the round, but profit functions—and the corresponding elasticities of allowance supply and demand—are similar to those of the DA and CMILP, and the equilibrium volume is the same 49 units. Both the lease round and the asset market rounds appear to be consistent with the equilibrium predictions. In rounds 2 and 3, there is some dispersion of prices across sessions, but sessions beginning near the equilibrium price remain there, those beginning farther from equilibrium grow closer, and prices decrease at about the rate predicted by the equilibrium model.[13] Findings of this experiment suggest it is the initial lease period, rather than the call market, which is expediting price discovery in the market for permanent allowance in the CMILP experiment.

A comparison of the price discovery process in a double auction market for tradable fishing allowance with and without an initial lease period can be made by examining figures 6 and 7. The figures show the time series of individual trade prices from one session in the double auction without and with an initial lease period, respectively. The heavy vertical lines indicate points where the endowment was reset, and the thinner lines indicate changes of period when endowments were not reset. Within each figure, the width of the area between the vertical lines is proportional to the number of trades occurring during that period. The thin horizontal lines indicate the upper bound of the predicted equilibrium price tunnel.

In comparing the graphs, two differences stand out. First, in the asset market following the initial lease period (round 2 in figure 7), there are far fewer trades than occur in the double auction in figure 6. Second, the range and fluctuation in prices are far smaller following the initial lease period. Together, these features suggest that information gathered in the initial lease period leads to a less volatile market.

One measure of volatility is price dispersion, defined as the ratio of the average of the absolute value of the difference between a trade price and the mean trade price in a period, and the mean trade price in that period (Newell, Sanchirico, and Kerr, 2003). Table 3 presents the average price dispersions observed in each round, along with the *p*-value of a Wilcoxon signed-rank test that the distribution of single-period dispersion measures within each round is the same between experiments.[14] The *p*-values indicate the DAILP has significantly lower dispersion than the DA in every round, and in rounds 2 and 3 jointly. In both experiments, the highest dispersions are in the first round, reflecting that price discovery must take place, and necessarily

[13] Anderson and Sutinen (2004) affirm this result statistically.

[14] This discussion (and for table 4 following) compares round 2 of the DAILP, the first asset round of that experiment, with round 2 of the DA, the second asset round of that experiment. This comparison is chosen because it gives the DA its best chance at equaling the performance of the DAILP, and in doing so addresses the argument that experience in an asset market (or with the market software) could achieve a comparable reduction in volatility as an initial lease period. The statistical results are stronger when round 1 of the DA is compared with round 2 of the DAILP.

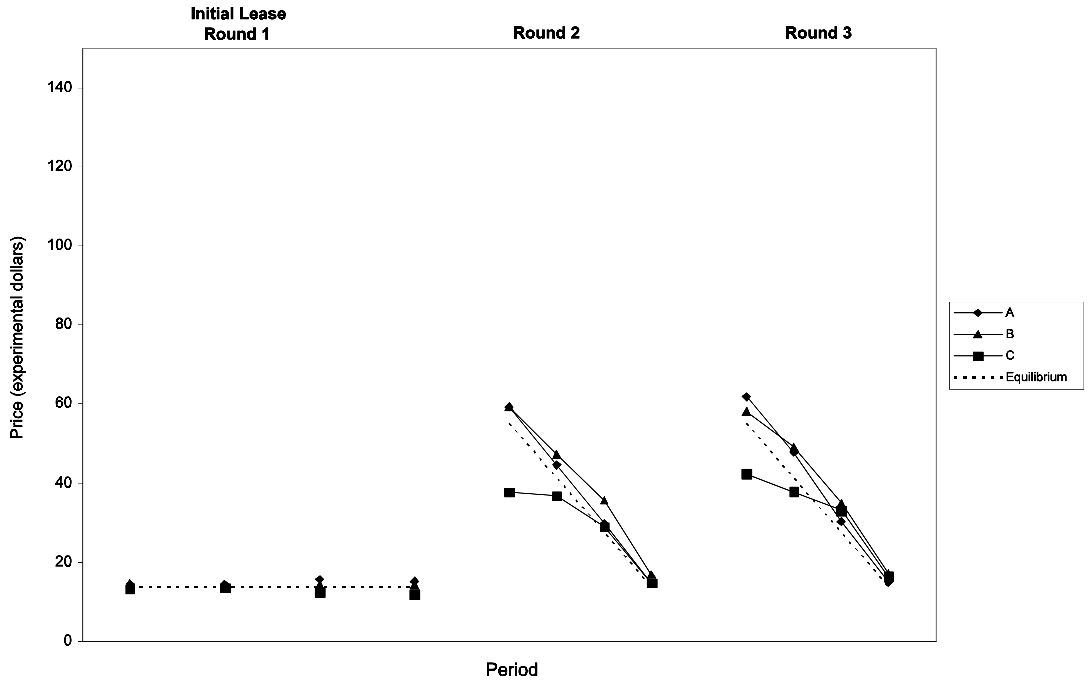

Figure 5. Period average prices in a double auction with initial lease period (DAILP)

involves some fluctuations. It is noteworthy that a substantial portion of this dispersion persists without an initial lease period. Moving from round 1 to round 2, not only does the DAILP (now an asset market) still have lower dispersion than the double auction alone, but also the difference between the two experiments increases. This suggests that, if reducing volatility and facilitating price discovery are prerequisites for meeting policy objectives, the initial periods of the market are better spent with a lease market than with permanent allowance trading. In fact, after three rounds of experience with a double auction asset market, volatility is still higher than in either the initial lease period or the first asset market round following the initial lease period; there is so much dispersion in the double auction market that it is having difficulty converging.

A second sign of volatility is trading volume. Higher than equilibrium volumes suggest inefficient disequilibrium trades are taking place, and later need to be corrected; persistent higher than equilibrium trading volumes suggest trading may occur for reasons other than mutual gains from trade based on the profit that could be earned from fishing, such as speculation. Table 4 shows the number of trades observed in each period, averaged over sessions and rounds 2 and 3 for each experiment. The bottom row presents *p*-values from a Wilcoxon signed-rank test that the distribution of observed trading volumes is the same in each period of the two experiments. Although the two experiments do not differ significantly on the number of trades in the first period (the average for the double auction experiment is heavily influenced by one very high volume round, which does not so heavily influence the nonparametric test), there is a significant difference in all subsequent periods. While the average number of trades in the first period of both experiments is very close to 49, the minimum number necessary to achieve equilibrium, trading continues at that volume in all subsequent periods in the DA treatment, when equilibrium predicts no trades will occur. There is significantly less persistent trading following an initial lease period, though still a nonzero amount. This trading could result from subjects continuing to refine their holdings to maximize profit following disequilibrium trades, speculation (e.g., Smith, Suchanek, and Williams, 1988), or boredom (Lei, Noussair, and Plott, 2001). In the DAILP, efficiencies stabilize or increase after the first period of each round, suggesting that these trades are at least welfare neutral. However, efficiency can be seen falling in figure 4, implying the

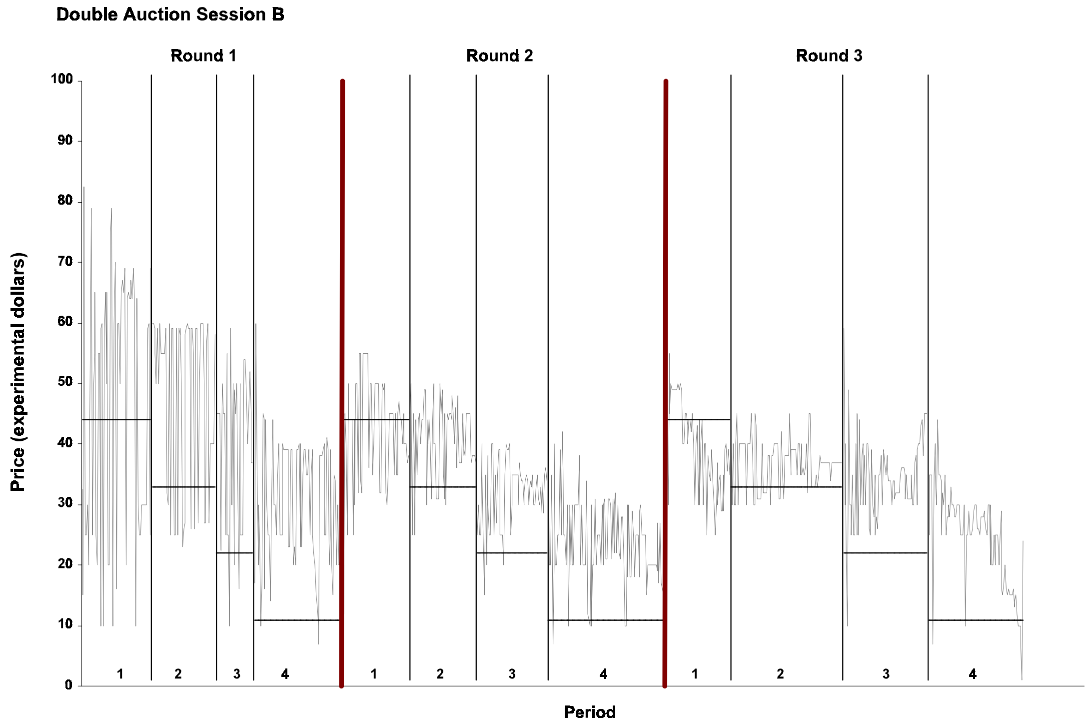

Figure 6. Time series of contract prices in a double auction (DA) session

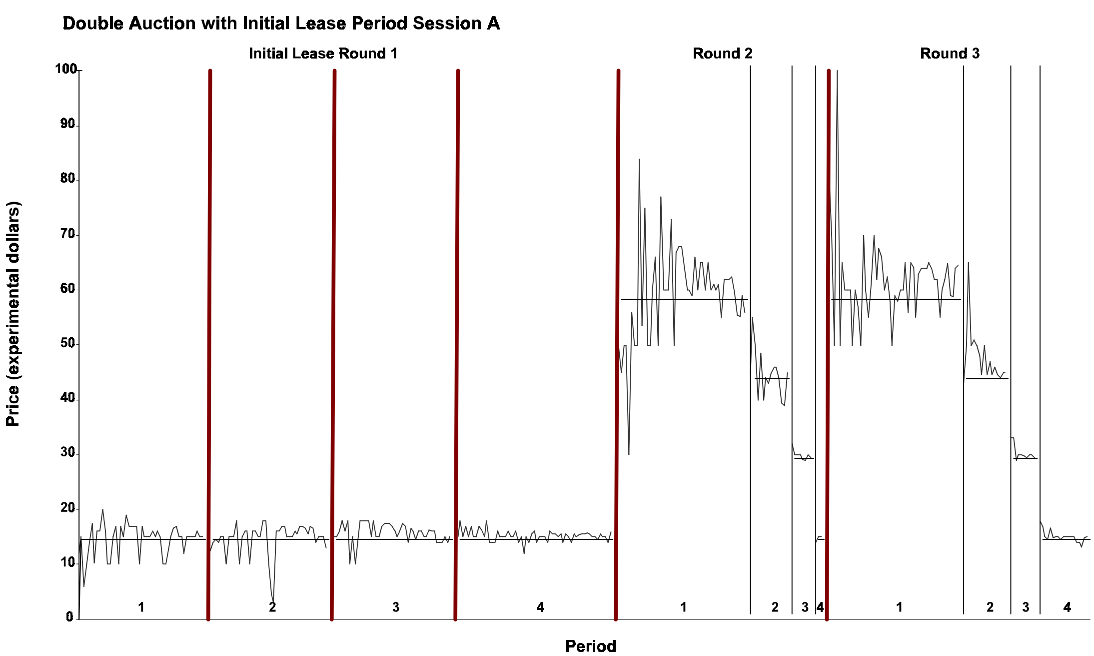

Figure 7. Time series of contract prices in a double auction with initial lease period (DAILP) session

Table 3. Average Per Period Price Dispersion in Each Round

	Round			
Experiment	1	2	3	2&3
Double Auction (DA)	0.245	0.209	0.217	0.213
Double Auction w/Initial Lease Period (DAILP)	0.160 [a]	0.081	0.086	0.083
Wilcoxon *p*-Value	NA	0.0001	0.0001	$< 10^{-8}$

[a] Round 1 of the DAILP is the initial lease period, not an asset market.

Table 4. Average Trading Volume in Asset Market Rounds 2 and 3

	Period			
Experiment	1	2	3	4
Double Auction (DA)	63.4	56.8	50.8	55.3
Double Auction w/Initial Lease Period (DAILP)	44.7	18.5	17.5	15.7
Wilcoxon *p*-Value	0.1927	0.0048	0.0034	0.0011

persistent trading activity in the double auction is not mutually beneficial, and is motivated by reasons other than market fundamentals. When trades are not based on fundamentals, price discovery is very difficult.

Discussion

Tradable rights systems have gained popularity in recent years for managing a variety of natural resource problems. With the expiration in fall 2003 of a six-year moratorium on new tradable fishing allowance programs in the United States, stakeholders and managers unsatisfied with the outcomes of other management systems are considering this newly available option. However, stakeholders and managers wish to avoid some of the aspects of the outcomes of previous experiences with tradable allowance management, which could have resulted from high levels of market volatility. As suggested by these experiments, while some volatility during price discovery is inevitable, persistent, large price swings are associated with the particular rules that are most frequently used to facilitate trade. In the laboratory, a higher-quality price signal derived from a single-period lease market, which equilibrates reliably, significantly reduces volatility and facilitates price discovery, leading to efficient, stable equilibrium outcomes.

The general lesson to be taken from this research is that the rules of trade matter: *Efficient market outcomes are not an automatic result of establishing a property right and permitting its trade.* For policy makers, this implies that attention must be paid to the rules of trade, as well as to traditional factors such as the definition of the allowance, who is eligible to receive it, and the quantity to be allocated. For resource users and policy makers assessing whether or not a tradable allowance system is appropriate for their fishery, the effect of institutions on outcomes also means that what can be inferred from previous experiences depends on features specific to the fishery *and* to the institution that was used. Because the presented experiments suggest features of commonly used trading rules may not effectively facilitate convergence, the potential of tradable allowance management may differ significantly from past experiences.

A common reaction of policy makers and stakeholders to adverse experiences with tradable allowance programs is to implement new programs with substantially similar institutions, but with restrictions on trade designed to address previously identified problems. Examples include restrictions on resale to discourage speculation, or on the maximum amount of allowance any participant can hold to limit consolidation. However, these experiments suggest bad outcomes may be symptoms of a deeper problem with the chosen rules of trade. The best way to prevent volatility, consolidation, and other feared outcomes may be to identify an institution which works well, rather than imposing limitations on trade within one which does not.

One argument economists frequently put forward when faced with the result that institutions matter is that some unspecified amount of experience will improve market performance measures and lead to equilibration. In our application, this argument has two shortcomings. First, past experience with tradable allowance programs has shown that the transition from command-and-control management and the price discovery process are very important in determining winners and losers, and satisfaction with the system. In fact, Newell, Sanchirico, and Kerr (2003), and Larkin and Milon (2000) both document reduced volatility four to six years into the New Zealand and Florida spiny lobster allowance systems, respectively. However, during the initial years of volatility, some participants were hurt or upset by what turned out to be, in retrospect, poor business decisions made in response to price signals which did not accurately represent market fundamentals.

The second counterpoint, which is specific to the asset market nature of the experiments and disequilibrium behavior observed here, is that the rejection of the equilibrium hypothesis in the double auction experiment is not based merely on prices' statistical distance from equilibrium predictions. Rather, there is systematic movement away from the equilibrium, similar in structure to the bubbles observed in other experimental asset markets (e.g., Smith, Suchanek, and Williams, 1988), most of which have much longer asset lives. From these, we know additional periods lead only to longer-lived bubbles, which crash shortly before the asset expires; asset markets do not learn their way out of bubbles.

That institutions play a significant role in determining policy outcomes poses a problem for economists, who now must add another dimension to their analyses. Institutions are particularly challenging because there is no received theory, no model, with which to understand what institutions will be well suited to a particular application. This is why experimental economics is an important tool. In addition to testing hypotheses about economic theories, it can be used to evaluate institutions in a controlled setting (and with knowledge of important market variables such as individual profit functions, which are difficult to know in the field), and to compare alternative institutions to determine those that best achieve policy goals. Despite being a relatively new tool, an increasing literature of successful applications to the design of real institutions suggests experimentation can inform and improve field implementations of market-based policies; experiments may be the best available science for assessing features of market-based institutions, and perhaps others as well.

Although the role played by the rules of trade in determining outcomes imposes the additional burden of verifying that market-based management achieves its intended goals, it also provides a powerful new degree of freedom for achieving policy objectives. Through careful design, testing, and selection of trading rules, institutions can be chosen that not only equilibrate effectively, but also achieve secondary policy objectives less obviously related to market outcomes. Here, too, experiments can play an important role, as they can be designed to test for, or compare among institutions, other regularities of market outcomes.

However, like any science, foundational knowledge must be built slowly and carefully before it can be reliably applied. Because so little is known about how and why different institutions yield the consistently different outcomes they do, care must be taken in each application to ensure the reason for any regularity in the laboratory transfers to the field. Even in the absence of a formal theory, it is necessary to test a story about the interplay of information and incentives to expect external validity. Although it is tempting to conclude from the data presented here that initial lease periods would enhance equilibration in new tradable allowance markets, it is important to understand exactly why they work prior to field implementation.

Future work can focus on what exactly market participants learn in the initial lease period. Do they learn only that the per period price is $11.50? Do they actually learn about the relationship between assets and fundamental values as represented by their profit functions? Or is it something different altogether? Such a focus carries policy importance because it allows prediction of the sorts of market variations to which initial lease market results might be robust. For example, if participants learn only that the price is a particular value, what they have learned is completely devalued by any market shock. On the other extreme, if subjects have learned how to value assets, the stability induced by the initial lease period may persist through any shock. More likely, subjects have learned something more than the price, but less than the rules of asset valuation, such as the quantity of allowances to demand. This information could be robust to some shocks, such as changes in stock health and market demand, but not others, such as changes in technology that shift the equilibrium distribution of allowances.

Although it has not been widely acknowledged by economists, the rules of trade play a significant role in determining market outcomes. This is particularly true when a market is created for an entirely new commodity or asset, and traders have little market information on which to evaluate prospective contracts. Tradable allowance systems are an increasingly popular tool for managing environmental and natural resources, but they establish new assets about which little value information exists. This creates a policy need for designing trading institutions that equilibrate quickly, and with a minimum of volatility, which can produce irreversible extreme outcomes. Lacking a theory on which to base such development, the laboratory serves as a convenient and flexible environment in which to evaluate alternative institutions in a controlled way—comparing them on the basis of efficiency, volatility, equilibration speed, and other application-specific criteria. By identifying the institution that best achieves the bio- and socioeconomic goals of each application, the full potential of tradable allowance management can be realized. Only then can tradable allowances be compared to other management alternatives, and the best management system for each community, fishery, and resource be selected.

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