AUCTIONS FOR INITIAL SALE OF ANNUAL CATCH ENTITLEMENT

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ABSTRACT

When several new species are introduced into the New Zealand Quota Management System in the near future, some of the quota, or single-year annual catch entitlement (ACE), will be tendered through competitive auctions rather than allocated based on historical catch. This study uses a laboratory experiment calibrated to a representative New Zealand fishery to assess three sealed-bid auctions. In all three auctions, the N units of ACE for sale are allocated to the N highest bidders, but there are three different rules for determining trade prices: an N^{th} price auction, in which all trades are executed at a price of last accepted bid; an $N+1^{st}$ price auction, in which all trades are executed at a price of the highest rejected bid; and a discriminative auction, in which all trades are executed at the bid price. There is no statistical difference in efficiency among the auctions, but there is a clear, statistically significant ordering of revenue capture: the discriminative auction captures an average of 78% of the surplus; the N^{th} price auction 69% of the surplus; and the $N+1^{st}$ price auction captures 57% of the surplus. When a secondary market provides the opportunity for trades following the auction, the added complexity of the bidding strategy in the discriminative auction led to more inefficient trades, and offered more opportunity for speculation than the other two auctions.

Keywords: fishery management; transferable allowance; ITQ; experiment; auction

INTRODUCTION

The Ministry of Fisheries (MFish) intends to introduce a large number of new species to the New Zealand Quota Management System (QMS) over the next few years. As set out in the Fishery Act, provisional catch history (PCH) is created on a kilo for kilo basis to fishers with documented catch history in the fishing years beginning in October 1990 and 1991. After appeals regarding PCH are heard, twenty percent of the overall quota is allocated to the Treaty of Waitangi Fisheries Commission (TOKM) and the remainder is allocated to PCH holders. If the initial total allowable commercial catch (TACC) after the 20% distribution to TOKM exceeds the sum of PCH, this (headroom) quota is likely to be tendered. It is possible that tendering of quota will be delayed and annual catch entitlement (ACE) will be tendered in the interim years.

The auction format used for tendering quota or ACE for new introductions is likely to have some effect both on the magnitude of revenues generated (and the resulting transfer of rents from the industry to the Crown). The format may also affect the distribution of quota or ACE within the industry (e.g., one format may be more favorable for large companies while another might be more favorable for small ones). The concentration of quota or ACE may also be affected. All of these are important questions to the fishing industry and presumably to MFish and the public.

Extant theoretical, empirical and experimental evidence that would shed light on these questions is limited and inconsistent. Evidence from controlled experiments, however, could be used to compare three common auction formats on the extent to which they achieve efficient outcomes, capture surplus for the Crown (which may be undesirable) and allow for profitable speculation between the auction and secondary markets.

MULTI-UNIT AUCTIONS

In auctions where only a single unit of a good is being sold, game theory provides a clear answer comparing first and second price auctions: the Revenue Equivalence Theorem proves that in both auctions, the unit should be should be awarded to the person who values it most, and the expected revenue is the same in both auctions.[1] The intuition for this is that the bidder in the first price auction knows that her bid will be used to determine the price, leaving her without any surplus. As a result, she shades her bid lower, giving up some probability she wins the auction in exchange for increased surplus conditioned on winning. The revenue equivalence theorem establishes that the optimal amount for a risk-neutral bidder to shade her bid leads to the same trading price as in a second price auction, where bidders reveal their reservation values in equilibrium and the bidder with the highest value pays a price equal to the second highest value.

The revenue equivalence theorem has two significant shortcomings in the present application. First, in controlled laboratory tests where reservations values were known to the experimenters, the revenue equivalence theorem is not empirically predictive. Rather, people bid consistently above equilibrium in first price auctions, leading to systematically higher revenues from that institution (see Kagel 1995 for a survey). Second, even if it were empirically supported in the single-unit case, the theoretical result has not been extended to multi-unit auctions. Therefore, previous attempts to understand behavior in multi-unit auctions have relied on experimental comparison of alternative multi-unit auction mechanisms. Most of the previous work comparing behavior in sealed bid auctions has focused on examples each buyer demands only a single unit of the product being sold, although multiple units are begin sold. Smith (1982) reports mixed results from experiments comparing revenue in uniform price and discriminative auctions. Cox, Smith and Walker (1985) reject dominant strategy bidding in uniform price auctions, but obtain mixed results on which auction yields more revenue.

However, the ACE auctions differ further from these experiments in that each buyer demands more than one unit. In single unit demand auctions, the bidder must trade off the surplus conditioned on winning (the difference between the unit's value and the auction price) with the probability of winning. In multi-unit uniform price auctions, there is an additional incentive which affects bids on each bidder's second-highest and lower valued units: that bid affects not only the price paid for it and the probability of winning it, but also the price paid for units on which she submits higher bids. In this case, equilibrium can be very complicated to compute, but will have the general property that bids on the second highest and lower valued units should be lower than if the same value were a bidders highest value, a phenomenon known as demand reduction (Ausubel and Cramton 1996; Englebrecht-Wiggans and Kahn 1995).

Miller and Plott (1985) compared discriminative and N^{th} price auctions when each subject demanded two units of the good. They found that which auction generated the least revenue depended on the elasticity of the demand curve, with inelastic demand curves resulting in higher revenue from discriminative auctions. In the Zambian foreign exchange auction, where bidder values are affiliated, Tenorio (1993) found that the N^{th} price auction yields higher revenues than the discriminative auction. In a test of demand reduction theory, List and Lucking-Reily (2000) auction two sportscards to two bidders using an $N+1^{st}$ price auction and a Vickery auction in which the price on the first unit is the price of the highest of the other player's rejected bids, and the price for the second unit is the other player's second-highest rejected bid (it is a dominant strategy for bidders to truthfully reveal their valuations in this auction). They find that bidder do reduce their demands in the uniform price auction, attempting to use the bid on the second unit to secure a lower price for the first unit.

Most explorations of bidding behavior in multi-unit demand (and supply) auctions use institutions motivated by specific applications, and thus may not be as generalizable as the results for single-unit auctions. Rassenti, Smith and Wilson (2001) find that in repeated multi-unit sealed bid auctions for electricity, seller prices have lower variance but higher levels in a discriminative auction. Kagel and Levin (2000) compare an N+1st sealed bid and ascending price clock auctions for multi-unit demand with synergies, where the value of additional units is superadditive. They find that equilibrium is not achieved in either auction, but that efficiencies are comparable and that bidders are able to leverage the information provided by dropping out in the clock auction to capture a greater portion of the surplus. Cason and Gangadharan (2003) test uniform and discriminative auctions for purchasing reduced fertilizer use on farmland, using an unusual institution in which the auctioneer purchases only one project offered by each seller. They find people better reveal costs in the uniform price auction, but that the discriminative auction achieves higher levels of environmental benefit at lower cost (their reported notions of efficiency are based on environmental benefit rather than allocations).

That there is no consistent trend in efficiency or surplus capture between discriminative and uniform price auctions suggests the importance of analyzing the question within an environment calibrated to critical features of the application under consideration. The next section describes the experiment used to assess the three auction institutions.

Experimental Design

To test the empirical hypotheses that the three auction models were identical on revenue capture, distribution and efficiency, we designed a paper-and-pencil experiment in which six human subjects played the role of buyers of ACE through an auction. In the experiment, two of the six players (the large operators) were given induced reservation values for five units of ACE, and four (the small operators) were given induced values for three units of ACE. With these extra demand units and higher number of above-equilibrium induced values, these larger operators controlled a greater portion of the market share, 25% each on average, mirroring the quota distribution in fisheries such as Ling 7 and John Dory 7, and several others.

Table 1: Sample subject bid worksheet

Auction Price (*A*): __________

			Auction		
	B	*C*	*D*	*E*	*F*
Unit	**Value**	**Bid**	**Buy?** (*A*≤*C*)	**Cost** (*A* if Buy)	**Profit** (*B*-*E*)
1	**30**		Y N		
2	**23**		Y N		
3	**13**		Y N		
				Total	

In each experimental auction, subjects were given a subject worksheet, like Table 1, with their induced values for each unit. Their earnings would be determined by the difference between their value for each unit they purchased and the price which they paid for it in the auction. After being told the number of units for sale, N, the subjects entered a bid for each unit, and returned the sheet to the experimenter. The experimenter then ranked the bids, and awarded the units to the N highest bids at a price determined by the rules of the auction. The subject worksheets were then returned to the subjects, who calculated their profit earned from the units they purchased. Each experimental session included ten auctions, five with and five without a secondary double-auction market in which subjects could negotiate trades of units they were able to buy in the auction. We constructed five sets of induced values for ACE designed to represent the diminishing marginal value of ACE we would expect to see for species that are currently taken primarily as incidental catch and whose value is likely to relate to their shadow value as a constraint on use of existing quota[2]. Each set contains 22 values (five for each of two large players and three for each of four small players), and has associated with it a number of units for sale (from N=9 to N=13). Another set of five values was by adding a set-specific constant to all values in each set, so for each auction without a secondary market, there was an auction with a secondary market with the same distribution of values. To control for order effects, the order of the value sets was rotated between sessions, and the last two sessions of each treatment were conducted with the five auctions with a secondary market preceding the auctions without a secondary market.

At the end of the experiment, subjects totaled their earnings from buying and trading in all auctions. Earnings were converted from experimental currency to US dollars, and subjects were paid in cash as they left the laboratory. Exchange rates between laboratory and US dollars were calibrated so average earnings would be $25 for sessions lasting approximately 1 hour 45 minutes. Substantial payoffs that depend on choices made during the experiment are a critical feature that distinguishes experimental economics from other laboratory social sciences. 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 that 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.[3] Based on observation and debriefing, incentives were sufficient to encourage subjects to make considered bids.

Results

Each treatment was replicated in five sessions with undergraduate student subject bidders recruited from courses in economics, environmental economics and nutrition at the University of Rhode Island. Each of the five sessions in each treatment generated five observations with a secondary market and five without a secondary market, for a total of 50 observations per treatment. To draw statistical information from each auction but control for the non-independence of auctions within each session, we analyze these data with panel regression models which account for the correlation structure between consecutive auctions. The basic regression model explains the measurement of interest (revenue, distribution of units or efficiency) as a function of treatment indicator variables:

$$Y_{it} = \Sigma_j\ \alpha_j\{\text{Vals=j}\} + \beta_1\{\text{N+1}^{\text{st}}\}_i + \beta_2\{\text{N}^{\text{th}}\}_i + \gamma_0\{\text{SecMkt}\}_{it}$$
$$+\ \gamma_1\{\text{SecMkt*N+1}^{\text{st}}\}_{it} + \gamma_2\{\text{SecMkt*N}^{\text{th}}\}_{it} + \varepsilon_{it}$$

In this model, the measure *Y* in auction *t* of session *i* is a function of indicator variables which take on the value 1 when the treatment is described by the treatment variables in curly brackets. The α_js, β_ks and γ_ks are estimated in the regression with the α_js representing induced value set-specific constant terms (for the five value sets) for the discriminative auction (the omitted auction) and γ_0 the change in the mean of the measure in the secondary market treatment of the discriminative auction. The other β_ks show the differences in the mean between the discriminative auction and the indicated auction, and the γ_ks the additional difference observed in the secondary market treatment of the indicated auction. For the measures of market share and revenue capture, ε_{it} is assumed to be autoregressive with a normally distributed stochastic component, and the model is estimated with an AR(1) panel GLS model. Because efficiency observations are close to or at the maximum possible value of 1, a random effects tobit (which lacks an autoregressive error component) is used.

Results are reported in three sections, one exploring the effect of auction design on revenue capture, one considering market share, and one reporting efficiency. The effect of the secondary market on speculation is then discussed.

Effect of Auction Design on Revenue

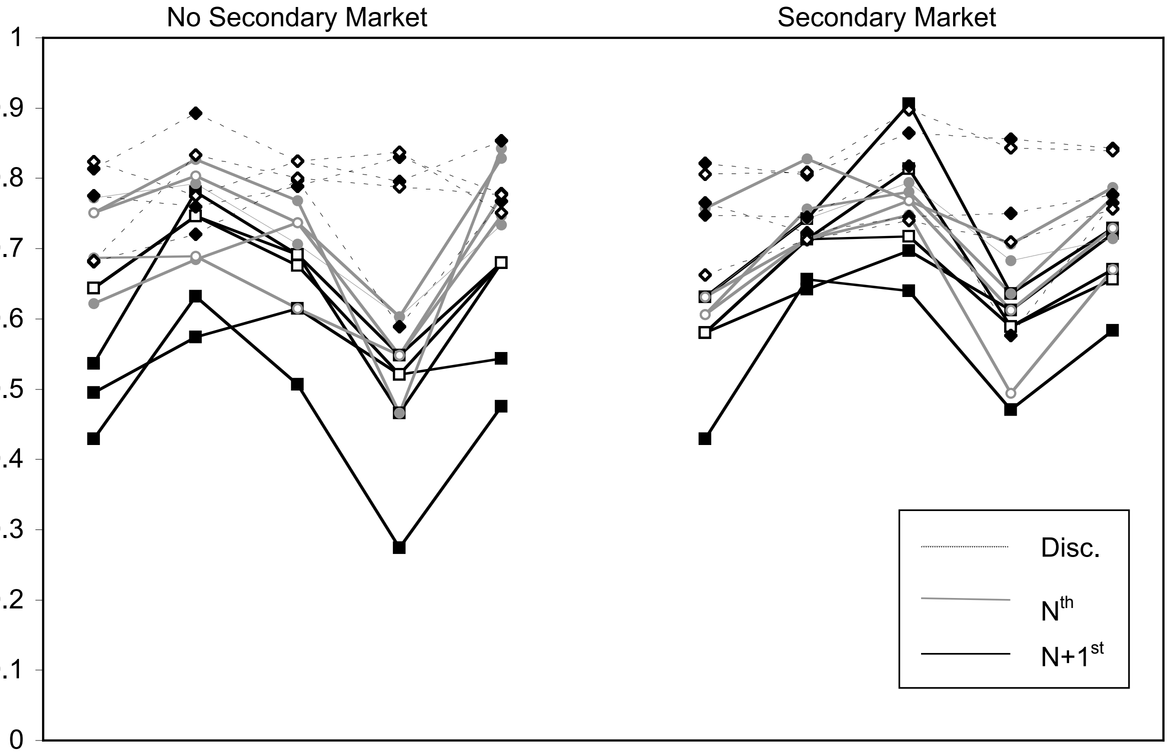

Figure 1: Proportion of surplus captured by the auction

Figure 1 shows the proportion of the surplus captured by the seller (the Crown) in each of the auctions in each session. Auctions within the same session are grouped together, and sessions within the same treatment share the same color. Auctions with hollow markers are from sessions where the auctions with the secondary market was conducted prior to the auctions without a secondary market.

In the graph, there is a clear tendency for the highest level of revenue capture to be in discriminative auctions (dashed black line with diamond markers), followed by Nth price auctions (gray line with round markers), followed by the N+1st price auctions (black line with square markets). Based on this graph, there is a systematic difference among the auctions in the level of revenue capture. This difference can be confirmed statistically by looking at the first column of Table 2, which shows the level of revenue capture as a function of indicator variables for treatment and the presence of a secondary market. In the first column, the constant represents the level of surplus capture in the discriminative auction (the excluded treatment variable). The N+1st variable is highly significantly negative ($p<10^{-12}$), indicating the revenue capture is much lower in the N+1st price auction, about 57% compared with 78% in the discriminative auction. The Nth price auction indicator is also significantly negative (p=0.005), indicating the Nth price auction also has significantly lower revenue capture than the discriminative auction, about 69% on average. The difference between the revenue capture in the N^{th} and $N+1^{st}$ price auction is also statistically significant ($p<10^{-5}$).

Table 2: Model estimates

Model	Revenue Capture AR(1) panel GLS	Market Share AR(1) panel GLS	Efficiency R.E. tobit
Average Constant	0.780	0.481	0.971
(Discriminative)	(N/A)	(N/A)	(N/A)
$N+1^{st}$	-0.189	-0.027	0.008
	(-7.12)	(-0.88)	(0.79)
N^{th}	-0.075	0.052	0.007
	(-2.84)	(1.71)	(0.68)
Secondary Mkt	-0.005	0.005	0.006
	(-0.20)	(0.17)	(0.82)
SMkt × $N+1^{st}$	0.069	0.020	0.008
	(1.99)	(0.50)	(0.73)
SMkt × N^{th}	0.006	0.006	0.004
	(0.16)	(0.16)	(0.44)
Wald(9)	182.86	16.92	24.42

Asymptotic z-statistics are in parentheses

Effect of Auction Design on Market Share

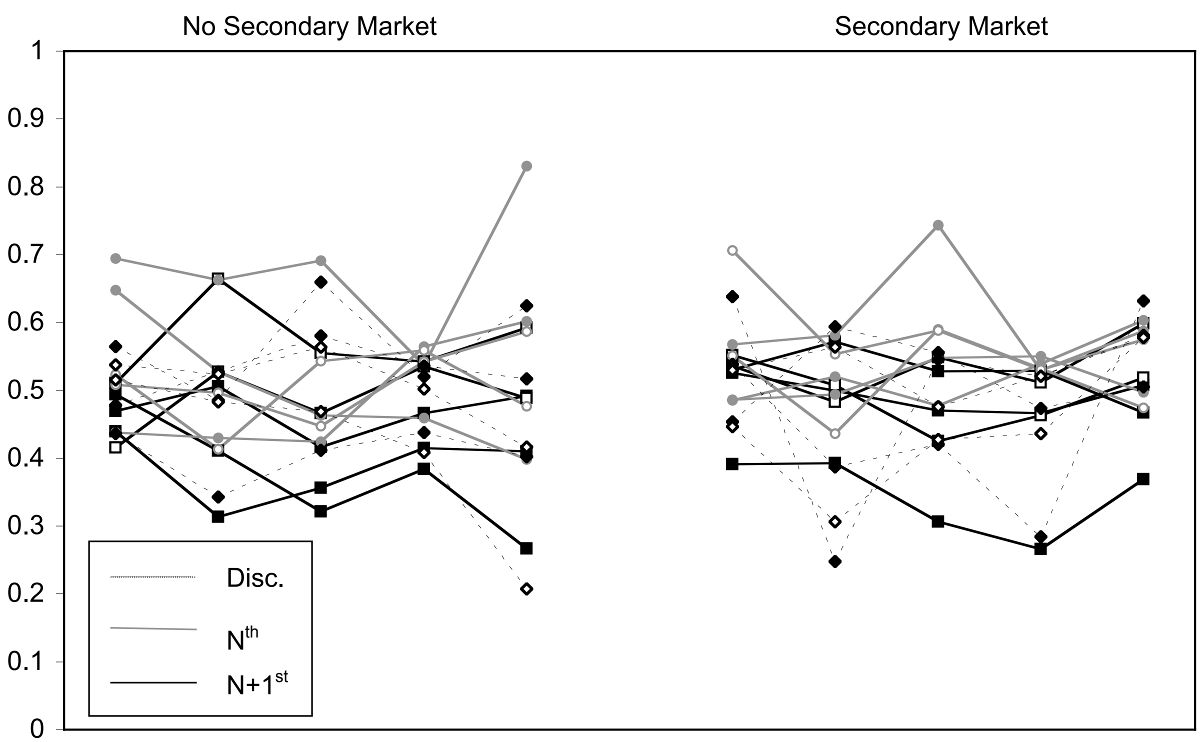

Figure 2: Portion of ACE purchased in the auction by two large operators

Figure 2 shows the fraction of the units purchased by the two large operators in each auction.[4] Because this fraction can take on a limited number of values, many observations are stacked upon one-another and it is difficult to develop a clear impression of the data from the graph. However, there does appear to be a tendency for the market share of the large operators to be higher in the N^{th} price auction.

The second column of Table 2 shows how the market share of the large operators varies among treatments. The average market share of the large operators is 48% in the discriminative auction, and the $N+1^{st}$ price auction is not significantly different. The market share is slightly higher (p=0.087), about 54%, in the N^{th} price auction. This difference is an average of less than one unit per auction, and its cause is unclear.

Effect of Auction Design on Efficiency

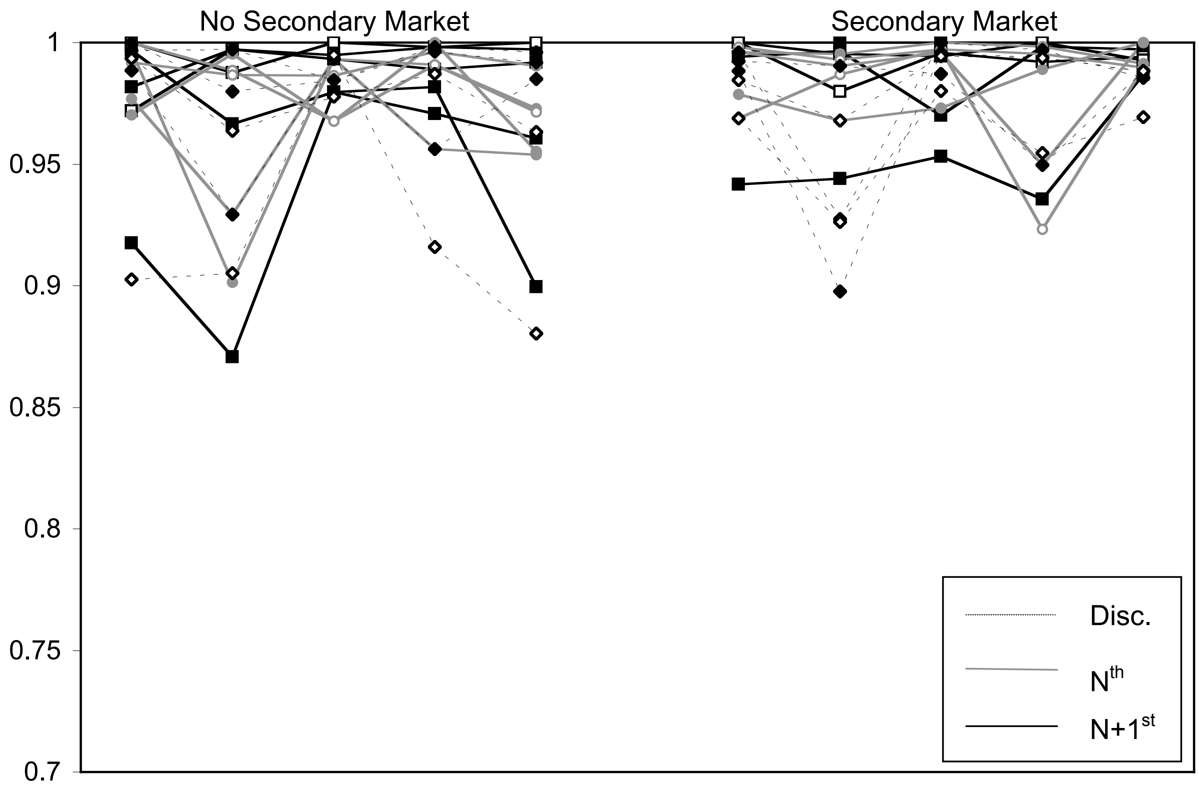

Figure 3: Efficiency of allocations after the auction

Figure 3 shows the realized efficiency in each auction. The third column of Table 2 shows the results of a random effects tobit model of the how efficiency varies with auction design. The overall average efficiency is a very high 97.1%. None of the other variables is significant, suggesting efficiency does not systematically vary with treatment.

Effect of Secondary Market on Market Outcomes

The secondary market treatment was conducted in each auction to test the anecdotally-motivated hypothesis that large operators may be able to speculate in the initial auction and resell in the subsequent secondary market at a profit, and that their ability to do this may vary with auction institution.

Activity in the secondary market was low in the uniform price auctions, with only 13 trades observed in the five sessions of the $N+1^{st}$ price auction, and only 12 in the N^{th} price auction, with a single subject frequently being responsible for multiple sales. There were 34 secondary market transactions in the discriminative auction, with sales distributed among many subjects. Most of these sales resulted in an increase in earnings for the sellers; the speculation was successful. The increased activity in the discriminative auction could be because the more complex bidding strategy caused more misallocations of ACE after the initial auction (though without a significant effect on efficiency), or because the auction structure allowed speculators to more effectively capture ACE in the auction. These explanations are observationally equivalent.

Speculation attempts are hard to quantify, because speculative bids which do not purchase a unit, or which purchase a unit which is not successfully resold, are difficult to identify. Using a conservative measure, we count a bid as a speculation attempt if it resulted in a resale, or if it did not result in a resale, if it is over induced value, by someone who did not routinely bid over induced value, on a unit other than the first unit, and occurred in a round where resale was possible.[5] By this measure, there were 16 speculation attempts in the N+1st price auction, 34 in the Nth, and 41 in the discriminative. About the same proportion of attempts resulted in resale the N+1st and discriminative auction, but most attempts were unsuccessful in the Nth price auction.

The only measure of market performance which shows a significant effect of the secondary market treatment is 7% higher surplus capture in the N+1st price auction. This increase could arise as potential speculators increased their bids, raising the price of the extramarginal unit. It is somewhat surprising there is not significantly lower efficiency when there is more secondary market activity in the discriminative auction. Based on the efficiency measure, it would appear that an equal amount of money is left on the table in all auctions, but in only the discriminative auction is the secondary market is used to extract it. The willingness to engage in secondary market trades varies widely across sessions, with certain subjects being very active and often drawing other subjects into the secondary market. A possible explanation is that a norm of high secondary market activity arose in some sessions, and that those sessions are not evenly distributed across treatments; it is also possible that the discriminative auction rules caused subjects to think differently about the bidding problem in a way which suggested secondary market activity.

It is also surprising that the lower level of speculation in the N+1st price auction does not lead to higher efficiencies, since one can think of speculation as an effort to generate inefficiencies in the initial auction so there are still gains from trade to be had in the secondary market. One possible explanation is that the speculation in the other auctions leads to a reallocation of the marginal units, resulting in surplus changes which are small on the scale of other variations and therefore not statistically detectable. Another is that our conservative measure of speculation may not adequately characterize the speculative behavior in all the auctions. If the need to bid above value to speculate is lower in the N+1st price auction than the other institutions, then this measure may undercount speculative opportunities in this auction, identifying a difference in speculation when in fact there is none.

VALIDATION WITH INDUSTRY SUBJECTS

To validate our student subject results, we replicated three sessions each of the discriminative and Nth price auction using representatives of industry groups in several locations throughout New Zealand.[6] These experiments followed the procedures described above, except all industry group experiments were conducted with the five auctions without a secondary market before the five auctions with a secondary market, and payoffs were scaled so subjects would earn an average of NZ$50, reflecting the higher opportunity cost of time of professional subjects relative to students.

The industry subject data broadly confirms the conclusions drawn based on student subjects. Table 3 presents the models from Table 2, estimate using both student and industry data. The variable *industry* takes on the value 1 when the corresponding observation from an industry auction; it is interacted with other treatment variables to test for differences between industry and student subjects.

Table 3: Model estimates including industry data

Model	Revenue Capture AR(1) panel GLS	Market Share AR(1) panel GLS	Efficiency R.E. tobit
Average Constant	0.780	0.485	0.971
(Discriminative)	(N/A)	(N/A)	(N/A)
N+1st	-0.189	-0.027	0.008
	(-7.51)	(-0.93)	(0.86)
Nth	-0.076	0.052	0.007
	(-3.01)	(1.81)	(0.76)
Secondary Mkt	-0.005	0.005	0.006
	(-0.24)	(0.20)	(0.85)
SMkt × N+1st	0.069	0.020	0.007
	(2.06)	(0.51)	(0.74)
SMkt × Nth	0.007	0.005	0.004
	(0.20)	(0.14)	(0.46)
Industry	0.032	0.080	0.020
	(1.08)	(2.40)	(1.88)
Nth × Ind.	-0.081	-0.120	-0.028
	(-1.98)	(-2.55)	(-1.83)
SMkt × Ind.	0.049	-0.045	-0.006
	(1.26)	(-1.01)	(-0.57)
SMkt × Nth × Ind.	-0.044	0.039	0.011
	(-0.81)	(0.61)	(0.72)
Wald(14)	12506.72	4808.54	131207.84

Asymptotic z-statistics are in parentheses

In the revenue capture model, the industry indicator variable is insignificant (*p*=0.279), indicating that there is no cross-auction tendency for revenue capture to differ when industry subjects are used. However, the industry indicator interacted with the Nth price auction is significantly negative, representing that industry subjects have significantly lower revenue capture in the Nth price auction than student subjects (*p*=0.048). This suggests that industry subjects may bid more aggressively in the uniform price auctions, but not enough so that the industry Nth price auction eclipses the low revenue capture in the N+1st price auction with student subjects. Although the magnitude of the treatment effects change, the ordering of the auction mechanisms is robust to the different subject pool.

In the market share model, the industry indicator variable is significantly positive (*p*=0.016). However, for the Nth price auction, this significant increase in the industry treatments is offset by a larger significant decrease. Thus, while the large operators in the two subject pools have similar market shares in the Nth price auction, 53.7% with student subjects and 49.7% with industry subjects, they differ significantly in the discriminative auction, where industry subjects have market shares of 56.5% compared to 48.5% with students. Thus, there is a difference in bidding patterns between the student and industry subject pools in the strategically complex discriminative auction.

The industry indicator variables is borderline significantly positive in the efficiency model (*p*=0.060), but like in the market share model, the effect is offset by an equally significantly negative effect of the Nth price auction treatment with industry subjects. Thus, the net effect is that the industry subject pool achieved higher efficiency in the discriminative auction than did the students in the same auction. This is the only subject pool/treatment combination that realized a significant difference in efficiency.

Overall, the industry subject pool validated the overall impression of each auction based on student subject results. There were no differences between the two subject pools in reaction to the secondary market, and strong rankings observed in student experiments were robust to industry subjects. However, there the industry subjects responded differently to the discriminative auction, bidding so that they achieved a higher level of efficiency, and a correspondingly higher market share for the large operators.

DISCUSSION

These experiments confirm that in an environment with demand features similar to those likely to occur in upcoming auctions for annual catch entitlement, different auction institutions significantly affect market outcomes. Perhaps surprisingly, the largest differences in the auctions did not emerge through speculation designed to leverage the secondary market, but rather through differences in bidding strategies in the different auctions. Although intuition suggests that participants in the discriminative auction have an incentive to reduce their bids, giving up some probability of winning to increase the surplus they receive conditional on winning, to maximize their expected surplus, we find that participants bid sufficiently high to yield significantly higher revenues to the seller in the discriminative auction than in the other two institutions. Revenues were second highest in the N^{th} price auction, and lowest in the $N+1^{st}$ price auction.

Despite this variation in revenue, there was relatively little variation in efficiency, with the only significant difference being industry subjects in discriminative auction, who were able to achieve slightly higher efficiencies than student or industry participants in the other auctions. Interestingly, this higher efficiency corresponded to higher market shares for the large operators, suggesting it is they rather than the smaller operators who lose out in less efficient auctions. This could be because small operators bid more aggressively for the marginal unit because it constitutes a larger portion of their income, even at a lower level of surplus.

In selecting an auction for policy purposes, the student data suggest that the choice can be made based exclusively on distributional considerations, both between the industry and the Crown (revenue capture) and among quota holders (market share). The industry data, in contrast, hint that there may be a small efficiency price to selecting a discriminative auction. Depending on policy objectives, however, the price for the discriminative auction may be too high, as it has by far the highest revenue capture, and its strategic complexity led to greater secondary market activity than the other auctions. The uniform price auctions had comparable levels of efficiency and, correspondingly, secondary market activity, but the N^{th} price had lower revenue capture and higher market share for the large operators.

While this experiment has helped characterize differences between auction institutions under consideration for use in upcoming annual catch entitlement auctions, it has also highlighted the role that institutions play in determining outcomes. Most of economic theory is agnostic to institutions, and although auction theory does consider features of different institutions, the revenue equivalence theorem suggests further reinforces the economists' perception that institutions do not matter. Although the lack of theoretical result establishing the equivalence of the multi-unit auctions considered here was a motivating factor for these experiments, the lesson that institutions affect outcomes can be construed more broadly. This imposes a new responsibility on the policy-oriented economist, as she must now consider the rules of trade in addition to market fundamentals when analyzing a policy designed to achieve certain objectives. However, it also provides a powerful new degree of freedom in selecting among institutions whose outcomes have systematically different properties. Thus, secondary policy goals can be advanced through careful selection of the institution, in addition to simply achieving allocative efficiency. However, without a theory or model of how institutions affect outcomes, controlled experimentation must remain a critical component of this analysis, for in the lab—perhaps only in the lab—can the variables necessary to compare markets on measures such as efficiency, and revenue capture be known.

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ENDNOTES

[1] Note that a discriminative auction is a first price auction when only one unit is for sale.

[2] Diminishing marginal value would result if the marginal cost of reducing incidental catch rises as total incidental catch is reduced. Small reductions of incidental catch may be relatively easy to achieve but further reductions can be expected to become increasingly difficult and costly.

[3] See Anderson and Sutinen (forthcoming), Smith (1976, 1994), Plott (1994), Davis and Holt (1993), *inter alia*, for more detailed discussions of experimental methods.

[4] Because this chart represents ratios of small integers, there are limited number of values which can be observed in each auction. This leads to many overlapping observations. This graph has had a random number on [-0.035,0.035] added to each observation to give a more accurate impression of the data.

[5] Some subjects, especially in the uniform price auctions, adopted bidding strategies where they bid above their induced value for some or all units, even when resale was not possible. We conservatively excluded subjects with this strategy from our analysis of speculation because it is impossible to distinguish speculative bidding from obviously non-speculative behavior. The presence of this strategy reflects that we did not provide subjects with any strategic advice, and that the rules of uniform price auctions do not usually punish this behavior on non-marginal units. This suggests that, if a uniform price auction is adopted, some basic strategic explanations may help participants.

[6] Care must be taken in interpreting differences between student and industry subject pools when analyzing policy experiments. There is a common intuition that expert subjects (here, industry participants) have well-developed

strategies which differ from those of inexperienced subjects and enable them to better respond, or more realistically respond, to the incentives provided. However, expert subjects may have developed habits rather than strategies, and thus not be responsive to features of the experimental environment—such as the potential policies being evaluated—which differ from those presently used; the scale of experimental payoffs may not be sufficient to motivate re-evaluating a habitual response in the same way as would a change in the natural environment. In addition, in policy experiments in particular, expert subjects may have opinions about the best policy and may attempt to manipulate the experimental outcome to provide evidence for their position, forgoing some experimental earnings in hopes of a favorable policy. These reasons suggest the opposite intuition, that inexperienced, disinterested non-expert subjects will have greater external validity than a pool of experts. See Anderson and Sutinen (fothcoming) for considerations in using student and industry subjects in policy experiments.