Voluntary Approaches to Transitioning from Competitive Fisheries to Rights-Based Management: Bringing the Field into the Lab

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This paper describes a novel experiment designed to examine how rent dissipation may occur in fisheries in which the right to participate is limited and fishermen compete amongst themselves for shares of an exogenous total allowable catch. We demonstrate that rent dissipation may occur through multiple mechanisms, and that the heterogeneity of fishermen has important implications for how rent dissipation occurs and the extent to which different individuals may benefit from the implementation of rights-based management. We apply this approach to investigate the concept of voluntary rights-based management under which managers divide the total allowable catch between two separate fisheries, and fishermen may choose between fishing for a guaranteed individual harvest quota and competing for a share of the total catch in a competitive fishery.

Key Words: experimental economics, fisheries, rights-based management, IHQ

More than fifty years ago, H. Scott Gordon (1954) described the problem of rent dissipation in fisheries in which fishermen do not have clear rights to the fish they catch. This absence of well-defined property rights can lead to excess investment in inputs, which dissipates potential rents from fishing. Since then economists have extensively examined and documented rent dissipation in fisheries, expanded the understanding of its causes and extent, and proposed a wide variety of regulatory approaches to addressing it (Wilen 2004, Homans and Wilen 2005). Many of these approaches are based on the creation of individual property rights to harvest shares of the total allowable catch.

This paper describes a novel experiment designed to examine how rent dissipation may occur in fisheries in which the right to participate in the fishery is limited and fishermen compete amongst themselves for shares of an exogenous total allowable catch. We demonstrate that rent dissipation may occur through multiple mechanisms, and that the heterogeneity of fishermen has important implications for how rent dissipation occurs and the extent to which different individuals may benefit from the implementation of rights-based management. We apply this approach to investigate the concept of voluntary rights-based management under which managers divide the total allowable catch between two separate fisheries, and fishermen may choose between fishing for a guaranteed individual harvest quota and competing for a share of the total catch in a competitive fishery.

Mechanisms of Rent Dissipation in Fisheries

It is important to distinguish between three different mechanisms of rent dissipation in fisheries,

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Financial support from Flint Hills Resources is gratefully acknowledged. Peter Bradley provided outstanding research assistance. Special thanks to Ned Murphy for his efforts in pre-testing the initial designs of the beans game. The authors assume complete responsibility for the final contents of this paper.

This paper was presented as a selected paper at the workshop "The Use of Experimental Methods in Environmental, Natural Resource, and Agricultural Economics," organized by the Northeastern Agricultural and Resource Economics Association (NAREA) in Burlington, Vermont, June 9–10, 2009. The workshop received financial support from the U.S. Environmental Protection Agency, the USDA Economic Research Service, and the Farm Foundation. The views expressed in this paper are the authors' and do not necessarily represent the policies or views of the sponsoring agencies.

Agricultural and Resource Economics Review 39/2 (April 2010) 245–261

all of which derive from lack of clear rights to fish, but which differ in the extent to which they are addressed by regulatory policies.

Resource-driven. Without clear rights to fishery resources, individual fishermen do not receive the full benefits to society that derive from foregoing current harvests. As a result, they may harvest too many fish in the short run, resulting in lower long-term biomass levels, harvests, and rents. Resource-driven rent dissipation—Hardin's much-cited "Tragedy of the Commons" (1968)—has received the greatest attention from environmentalists, the public, and regulators—some of whom perceive it to be the *only* problem of fisheries management.

Cost-driven. Even if managers successfully address the problem of resource-driven overfishing by limiting total harvests, without resource rights fishermen seeking to capture resource rents will tend to use higher-than-optimal inputs that lead to higher-than-optimal costs. As described by Wilen (2004, p. 51), "the rent generation capacity of the natural resource will be squandered. By attracting too many inputs…the output produced will not generate any surplus returns.... As a result, we witness the paradoxical situation of a system with reasonably healthy biological resources producing virtually zero or even negative economic returns." Cost-driven rent dissipation may take a variety of forms, such as overcapitalization, gear loss, and interference of vessels in each other's fishing operations.

Value-driven. Recently economists have recognized a third type of rent dissipation driven by the more subtle mechanism of the failure of fisheries without rights to capture the full market value potential of fish. As described by Homans and Wilen (2005, p. 383), "the character of modern fisheries on both its market and production side is heavily influenced by the nature of regulations and the manner in which these unfold over time. Importantly, regulations are influenced by, and have impacts on, product attributes and quality. …Rent dissipation and distortions on the marketing side of the ledger may be as important as distortions on the production or cost side of the ledger." After individual transferable quota were implemented in the British Columbia halibut fishery, *ex vessel* prices increased over 50 percent in the first few years as the market for fresh halibut expanded. Similar price increases after quota implementation were observed in the Australian southern bluefin tuna and south Atlantic wreckfish fisheries (Homans and Wilen 2005).

This paper is motivated by the competitive—or derby—salmon fisheries in Bristol Bay, Alaska. Harvesting in the fishery is limited to a fixed number of permit holders. These permits convey only the right to participate in the fishery; they do not allocate individual property rights to a particular quantity or share of total allowable catch. In Bristol Bay and other Alaska salmon fisheries, the resource-driven problem of overharvesting has been addressed by limits on when permit holders may fish. Fishery managers "close" fishing periodically to ensure that sufficient returning salmon "escape" the commercial harvest to enter their rivers of origin to spawn. In limited entry fisheries for other species, the aggregate harvest is capped at a total allowable catch (TAC) determined by fishery managers based on annual biomass projections, and managers close the fishery once this TAC is reached.

In these competitive limited entry fisheries, although the resource may be protected by limits on when fishermen may fish or how much they may catch, the absence of clearly defined rights to shares of the harvest can still lead to cost-driven and value-driven rent dissipation through both overcapitalization and a highly competitive, derby-style "race for fish." (Fishermen and managers use the term "derby" to describe intensely competitive fisheries in which fishermen fish aggressively to harvest the total allowable catch in a short period of time.) The focus of this paper is on these latter two mechanisms of rent dissipation. In particular, we seek to understand how and why input choices and fishing behavior of heterogeneous fishermen affect individual and aggregate costs and value—and in turn the extent of individual and aggregate benefits from adoption of rights-based management.

Overview of Experiment

Our experiment is intended to parallel—in a simple way—physically harvesting fish under different management regimes. The "fish" were beans in a large common bowl on a table. For fishing "gear," subjects used metal kitchen measuring cups, or "scoops," to harvest beans from the bowl into plastic pitchers on the floor. Subjects harvested under three different management regimes or treatments. The "Skill" treatment was intended to test for heterogeneity among subjects in their harvesting skill in a competitive fishery. In this treatment, eight subjects harvested simultaneously from one bowl using identically sized scoops until all the beans were harvested. Individual earnings were proportional to the amount of beans harvested. We observe wide differences in individual harvests, which are highly correlated across successive fishing "seasons" (experiment rounds).

The "Derby" treatment was intended to mimic conditions in a fishery in which both the total catch and the right to participate in the fishery is limited, but fishermen compete among themselves for shares of the total catch. Eight subjects harvested simultaneously from one bowl. At the start of each round, subjects had to choose one of seven scoops with which to harvest, ranging in size from ⅛ cup to 1 cup. As in the Skill treatment, subjects were paid a fixed price that was proportional to their individual harvest, but they also had to pay a rental cost for their scoops that was proportional to the scoop's size. Costs would be minimized and rents maximized if all subjects chose the least-cost ⅛-cup scoop.

Fishing under these rules, subjects regularly exhibited competitive behavior characteristic of a classic derby fishery. Not surprisingly, they chose scoop sizes much larger than ⅛ cup, realizing (correctly) that those with larger scoops capture a much larger share of the harvest. This added to total costs without adding to total revenues, resulting in cost-driven rent dissipation. An unanticipated and interesting result of the experiment is that in harvesting aggressively to scoop beans out of the bowl and toss them into their pitchers as fast as they could, subjects spilled a significant share of the total harvest onto the floor rather than successfully transferring the beans to their pitchers. This is an example of value-driven rent dissipation because the value subjects received for the beans they harvested from the bowl was less than the full potential value they would have received had they handled their harvested beans more carefully.

Thus, as a result of the combined effects of cost-driven and value-driven rent dissipation, a large share of the potential profits in the Derby treatment were dissipated (92 percent), and most subjects earned little or no profits. Importantly, subjects' scoop choices and catches in the Derby are correlated with their "skill" as measured in the Skill treatment, suggesting that heterogeneity in skill affects individual subjects' gear use, catches, profits, and aggregate rent dissipation in the derby fishery.

After subjects experienced the competitive derby fishery for multiple rounds, in subsequent "Individual Harvest Quota" (IHQ) treatments they were given the option to switch to an individual quota fishery, in which each subject received an individual quota that he could harvest at his own pace. For those subjects who chose the IHQ fishery, the change in behavior was dramatic. They harvested slowly and carefully using the efficient, lowest-cost ⅛-cup scoop, and spilled almost no beans. Thus the experiment demonstrates—quite dramatically—the predicted result that competitive fishing leads to rent dissipation, and that quota-based management ends this rent dissipation. Although this result is well-known, the experiment provides a particularly effective way of demonstrating it using a unique design.

The focus of the remainder of this paper is on research applications of the experiment: to examine implications of heterogeneity in competitive fisheries, and to examine factors influencing subjects' choices over time between the option to fish competitively and a guaranteed individual quota. In addition, the experimental approach also has great potential for teaching and demonstration applications.

Voluntary Transition to Rights-Based Management

By addressing the fundamental causes of rent dissipation, rights-based fisheries management offers significant potential economic advantages over competitive fisheries. Various approaches to rights-based management have been implemented in numerous fisheries worldwide. One form is individual fishing quotas (IFQs), under which governments allocate rights to individuals to harvest shares of the total allowable catch (TAC). Another approach is for governments to allocate rights to all or part of the TAC to harvester cooperatives, which may then allocate harvesting rights among their own members (Townsend, Shotton, and Uchida 2008). Despite potential advantages of rights-based management over competitive fisheries, there is often significant resistance to rights-based management from many fishermen (e.g., Grader 2002). This resistance has slowed or stopped the adoption of rights-based management in many fisheries. For example, opposition from fishermen led to a Congressional moratorium on the establishment of new individual quota systems in U.S. federally managed fisheries between 1996 and 2002. Fishermen may oppose rights-based management for many reasons. These include but are not limited to the following:

- They may not understand the reasons for which economists believe rights-based management would make them better off.
- They may doubt that rights-based management will work in practice like economists think it will.
- The proposed method of allocation of rights may reduce their expected future catches and profits.
- If they are risk-seeking, they may prefer the chance to strike it big with a highly profitable season to a lower guaranteed catch in a rights-based fishery.
- They may enjoy fishing competitively.

Voluntary transition to rights-based management may help to overcome political resistance to rights-based management by addressing these concerns. It provides an opportunity to demonstrate the benefits of rights-based management for those who do not understand the concept or doubt that it will work as intended. It provides an opportunity for fishermen who prefer to fish competitively to continue to do so.[1] In this paper, we apply our experimental methodology to examine the following approach to voluntary transition to rights-based management:

- Entry to the fishery is limited so that new entrants are not attracted as rents increase.
- The total quota is allocated between two separate fisheries: a rights-based fishery, in which harvesters fish for equal individual shares of the total rights-based quota, and a competitive derby fishery, in which harvesters compete for the total competitive quota. The two fisheries may be divided temporally (fishing occurs at different times), spatially (fishing occurs in different areas), or in some other way.
- Harvesters may choose annually whether to participate in the rights-based fishery or the competitive fishery.
- The annual allocation of the aggregate quotas between the two fisheries depends upon the number of harvesters choosing to participate in each fishery.
- The average allocation per harvester is greater for the competitive fishery than for the rights-based fishery.

The rationale for this approach is as follows. The new rights-based fishery generates higher rents per fish than the original competitive fishery. Thus, even if those harvesters who choose the rights-based fishery are given a lower average allocation of fish than their average harvests in the original fishery, they can earn higher rents per fish—giving them an incentive to choose the rights-based fishery. But by giving the rights-based fishery a lower per capita allocation, harvesters who choose the competitive fishery can be given a higher average allocation than average catches in the original fishery—potentially making them also better off.[2] Thus both the fishermen who prefer a rights-based fishery and those who prefer a competitive fishery can be potentially made better off—a "win-win" opportunity that gives both groups an incentive to support the change from a fully competitive fishery.

This approach to voluntary transition is similar to that which was adopted in the Alaska Chignik salmon fishery between 2002 and 2005. The Chignik salmon fishery is a major Alaska sockeye salmon fishery with approximately 100 limited entry permit holders. Permit holders recognized the potential for substantial cost savings from a harvesting co-op which would harvest the fish using a much smaller number of boats and share the profits among permit holders. However, advocates of a harvesting co-op were unable to gain a consensus among permit holders as to how the profits would be distributed. To overcome this

[1] We do not argue that voluntary transition addresses *all* of the reasons for which fishermen may oppose rights-based management. Examples of reasons for which fishermen may oppose rights-based management which would *not* be addressed by voluntary transition include loss of employment opportunities for crew as fleets consolidate; increased cost of entry to the fishery for young people who do not receive initial allocations of quota; decline in return to competitive fishing skills such as the ability to fish continuously without resting; and effects on fishing communities due to changes in the geographical distribution of where fish are landed, where fish are processed, and where fishermen live. Thus we do not argue that rights-based management is a panacea that will smooth all objections to rights-based management, but rather that it may be a practical method of addressing some concerns and capturing some of the potential benefits of rights-based management.

[2] Whether they are in fact better off depends on what their aggregate catch share would have been in the original fully competitive fishery.

impasse, in 2002 a group of permit holders asked the Alaska Board of Fisheries to allocate part of the Chignik sockeye harvest to a voluntary harvesting cooperative. The size of the allocation would depend upon how many permit holders chose to join the co-op. Other permit holders could harvest the remaining fish in a traditional competitive derby fishery that would receive the remaining allocation of the sockeye harvest. The co-op fishery and competitive fisheries would be conducted sequentially, alternating fishing opportunities over the course of the salmon season. (Knapp 2008).

The Board of Fisheries granted the allocation, and over the following four years (2002–2005) more than three-quarters of Chignik permit holders joined the co-op. The co-op hired about 20 members to fish the co-op's catch allocation. All co-op members were paid equal shares of the co-op's profits. By greatly reducing the number of vessels participating in the fishery, the co-op achieved significant cost savings, while also implementing a variety of quality improvements. The Chignik co-op, which ended after four seasons because the Alaska Supreme Court found that it was inconsistent with Alaska's limited entry law, clearly demonstrated the potential of rights-based management to generate substantially higher salmon rents in an Alaska salmon fishery. Perhaps more importantly, however, it demonstrated the potential for a voluntary approach to facilitate the implementation of rights-based management. It is almost certain that the Board of Fisheries would not have approved the creation of a mandatory co-op.

Experimental Design

Many social dilemma experiments with nonlinear payoff functions, such as most common-pool resource and some public goods experiments, give subjects a large payoff table that presents individual earnings as a function of the subject's own choice and those of the fellow group members.[3] To examine the concept of a voluntary transition to rights-based management, rather than use payoff tables, a unique feature of these experiments is that subjects actively participated in an actual harvesting activity—scooping beans from a large bowl.

The rationale behind using this hands-on approach was to have not only the decisions, but also the actions, of the experiments be more natural and more closely parallel those in the fisheries that motivate the research. The use of a payoff table detailing all the possible choices and outcomes may be too abstract for some subjects, even when the game is framed in non-neutral language. Moreover, the payoff table masks the process through which the values arise and implies a particular approach for thinking about the problem and developing a decision making strategy. Using the taxonomy of Harrison and List (2004), this experiment would be classified as a framed field experiment in which we use a neutral frame, but the lab task is comparable to the field task under investigation. In essence, we bring the field into the lab.

A total of 96 subjects were recruited from the general student population at the University of Alaska Anchorage. There were a total of four treatments, presented to subjects in one of three possible sequences. Each sequence was implemented in four separate sessions, for a total of 12 sessions with 8 subjects per session. We begin by first describing the treatments, and then we explain the sequences.

Skill Treatment

Every session, regardless of sequence, began with an unpaid practice round followed by three real money rounds in the Skill treatment. A group of $n = 8$ subjects stood around a table with a large bowl containing a total of 20 cups of pinto beans (2.5 cups per person). The harvesting technology was a ¼-cup stainless steel measuring cup referred to as a "harvesting scoop." Subjects received a price of $p = \$1$ for each cup of beans harvested from the common bowl into their individual pitchers, which were placed on the floor about three feet from the table. There were no costs associated with harvesting in the Skill treatment. The restrictions imposed upon harvesting activities included: no intentional interference with the harvesting of others, no talking with the other participants, the scoop had to be held by the

[3] There is a vast experimental literature that focuses on common pool resources and resource-driven rent dissipation; see Ostrom (2006) for a synthesis of some key lessons learned. For an example of a nonlinear public goods experiment, see Isaac and Walker (1998).

handle, and beans spilled on the floor could not be picked up. Harvesting was simultaneous and continued until all the beans were removed from the bowl.

After harvesting was completed, the beans in the pitchers were then delivered to the experimenter and results were tallied. For quicker and more accurate measurements, all deliveries were weighed and converted from grams to cups using the conversion ratio of 190 grams of beans per cup. Results were input into a spreadsheet that was displayed with a laptop projector for all to see. The public information included individual scoop sizes, deliveries, costs, and earnings.

The purpose of the Skill treatment was twofold. First, since all subjects were required to use the same ¼-cup harvesting scoop, any observed differences in individual deliveries may be attributable in part to unobserved individual characteristics, which we refer to as relative skill, which affect individual harvests in the same way across periods. As discussed below, we use the Skill treatment to estimate subjects' relative skill, which we then use in estimating a production function for deliveries in other treatments. Second, pilot experiments suggested that our hypotheses about rent dissipation were likely to be supported in the Derby treatment described below. In addition to providing data about relative skill, the Skill treatment also provided a salient way to increase earnings and maintain interest in the experiment.

Derby Treatment

After the Skill treatment, the rules for the Derby treatment were explained and were in effect for rounds 4–7 of each session. The Derby treatment proceeded in much the same way as the Skill treatment with two exceptions. First, subjects were no longer required to use the ¼-cup harvesting scoop. Instead, each subject had his or her own complete set of seven stainless-steel measuring cups, referred to as "harvesting scoops," ranging in size from ⅛ to 1 cup. Each subject's set of seven harvesting scoops was placed on the floor next to the pitcher. When period t began, each subject selected one scoop, x_{it}, from his or her set to be used for harvesting during the entire round. Subjects could not switch scoops during a round, but could use a different scoop in subsequent rounds. Second, harvesting was no longer costless. As shown in Table 1, the rental cost, $c(x_{it}) = 4.375x_{it}$, was a linear function of the individual's harvesting scoop size. The cost was explained to subjects as follows:

Table 1. Scoop Sizes and Costs

Scoop Size (cups)	Scoop Cost [a] (cups)
⅛	0.55
¼	1.09
⅓	1.46
½	2.19
⅔	2.92
¾	3.28
1	4.38

[a] Scoop cost = 4.375 × scoop size.

> To pay for your harvesting scoop, we will subtract 4.375 scoops from your harvest using the same scoop that you used for harvesting. This means that smaller harvesting scoops cost less, and larger harvesting scoops cost more. The table here [a large poster on the wall] shows the cost of each harvesting scoop.

This game is essentially a social dilemma with a nonlinear payoff function in which individuals are competing for a share of a fixed quantity of beans. Suppose an individual's quantity delivered, q_{it}, is a function of his scoop size, x_{it}, relative to the scoop size choices of the others, adjusted by a constant exogenous relative skill parameter, α_i, which reflects all individual characteristics, such as agility and motivation, that could affect harvesting by individual i. (Note that although we use the term "skill," we cannot distinguish between physical ability to harvest beans quickly and the motivation to do so.) Under these assumptions, an individual's earnings would be

$$\pi_{it} = pQ\frac{\alpha_i x_{it}}{\sum \alpha_j x_{jt}} - c(x_{it})\,, \qquad (1)$$

where $Q = 20$ is the total quantity of beans in the bowl, $p = \$1$, and $c(x_{it}) = 4.375x_{it}$. Because the total revenue for the group, pQ, is fixed, aggregate earnings are maximized when costs are minimized, which occurs when each of the $n = 8$ group members selects the smallest possible scoop, x_{it} = ⅛ cup. In this case, average individual harvests would be Q/n = 2.5 cups, with a cost of 0.55 cups and average earnings of 1.95 cups at the social optimum. For efficiency, the essential ingredient is that all subjects choose ⅛ cup. With heterogeneous subjects, variability in individual harvests and earnings is expected and has no impact on efficiency.

However, as in any social dilemma, this limited-entry or derby fishery creates a divergence between group and individual interests as people compete for the fixed pool of revenue ($pQ = 20$). If all subjects were homogeneous ($\alpha_i = 1$ for all i), then the symmetric Nash equilibrium would entail all subjects choosing a scoop such that

$$\text{(2)} \quad x_{it} = \frac{Q}{n}\frac{p}{c'}\left(\frac{n-1}{n}\right) = \frac{20}{8}\frac{1}{4.375}\left(\frac{8-1}{8}\right) = \frac{1}{2}.$$

In this case, average harvests would still be Q/n = 2.5 cups, but average earnings would now be 0.31, which is only 16 percent of the social optimum. Put differently, if all subjects were homogeneous, we would expect most but not all rents to be dissipated.

Our experiments show that people are not homogenous. They make different cup choices and deliver different volumes even if they choose the same cup. For our purposes, the key measures of rent dissipation are (i) whether all subjects chose the efficient ⅛ cup, (ii) the quantity of beans that were spilled, and (iii) whether individual earnings approached zero.

Individual Harvest Quota Treatments (IHQ40 and IHQ80)

At the start of each round in the two voluntary individual harvesting quota (IHQ) treatments, subjects were given the choice of harvesting in either the competitive derby (Bowl 1) or a quota fishery (Bowl 2) in which the competitive elements were eliminated by guaranteeing each participant a fixed harvest.[4] Subjects had to commit to harvesting from a single bowl for the entire round, but could switch between bowls in a subsequent round. The instructions for this choice were as follows for the IHQ40 (IHQ80) treatment:

> We will now divide the beans into two separate bowls. Before each round, you must decide the bowl from which you want to harvest. The amount of beans in each bowl will depend upon how many people choose to harvest from each bowl. The beans will be divided such that Bowl 1 always has 2½ [1¼] times as many beans per person as Bowl 2. The rules for harvesting at each bowl are also different. In Bowl 1 the rules will be exactly the same as the previous stage [the Derby treatment]. The only differences may be the number of people harvesting from this bowl and the amount of beans in the bowl. In Bowl 2, the rules will be different. Each person who harvests from Bowl 2 will be assigned a personal harvest quota. If you choose to harvest from Bowl 2, your harvest is limited to your personal quota; you may not harvest more than your personal quota.

Each round, decisions about which bowl to harvest from were made simultaneously and in private. Leaving the derby to harvest in the IHQ came at a cost in that there were always fewer beans per person available in the IHQ than in the derby. Let Q^1 denote the total quantity of beans in Bowl 1 (derby) and Q^2 denote the total quantity of beans in Bowl 2 (IHQ). Let n^1, n^2 denote the number of subjects who chose to harvest from Bowls 1 and 2, respectively. Of course, $n^1 + n^2 = 8$ and $Q^1 + Q^2 = Q = 20$. In the IHQ80 treatment, the cost of switching was relatively low—the number of beans per person available in Bowl 2 was 80 percent of Bowl 1. That is, $(Q^2/n^2)/(Q^1/n^1) = 0.80$. In the IHQ40 treatment, the cost of switching was high—the number of beans per person available in Bowl 2 was only 40 percent of Bowl 1: $(Q^2/n^2)/(Q^1/n^1) = 0.40$. Table 2 summarizes, for each treatment, the availability of beans in each bowl for each potential combination of subjects choosing each bowl.

The guaranteed harvest quantity in Bowl 2 depends upon the total number of harvesters who choose to switch (columns 6 and 10 in Table 2). With individual harvest (and therefore total revenue) guaranteed, there is no longer competition for a fixed resource stock and this is no longer a social dilemma. Instead, IHQ participants need to decide only which harvesting scoop to use. In this environment, the Nash equilibrium and efficient choices align, and each person should choose the smallest possible cup (⅛) to minimize costs.

Sequences of Treatments

There were three possible treatment sequences (A, B, and C), shown in Table 3. All three se-

[4] In the Chignik fishery that motivated the voluntary transition to IHQ treatment, at the start of each season fishermen were given the option of harvesting in the derby or the cooperative fishery.

Table 2. Availability of Beans in Each Bowl in IHQ Treatments

Number of Harvesters		IHQ80				IHQ40			
		Total Cups in Bowl		Avg Cups per Person		Total Cups in Bowl		Avg Cups per Person	
Bowl 1 (derby)	Bowl 2 (IHQ)	Bowl 1 (derby)	Bowl 2 (IHQ)	Bowl 1 (derby)	Bowl 2 (IHQ)	Bowl 1 (derby)	Bowl 2 (IHQ)	Bowl 1 (derby)	Bowl 2 (IHQ)
8	0	20.0	0.0	2.5	--	20.0	0.0	2.5	--
7	1	17.9	2.1	2.6	2.1	18.9	1.1	2.7	1.1
6	2	15.8	4.2	2.6	2.1	17.6	2.4	2.9	1.2
5	3	13.5	6.5	2.7	2.2	16.1	3.9	3.2	1.3
4	4	11.1	8.9	2.8	2.2	14.3	5.7	3.6	1.4
3	5	8.6	11.4	2.9	2.3	12.0	8.0	4.0	1.6
2	6	5.9	14.1	2.9	2.4	9.1	10.9	4.6	1.8
1	7	3.0	17.0	3.0	2.4	5.3	14.7	5.3	2.1
0	8	0.0	20.0	--	2.5	0.0	20.0	--	2.5

Table 3. Sequence of Treatments

	ROUND																
Sequence	*Practice*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	*Skill*	Skill			Derby				IHQ40								
B	*Skill*	Skill			Derby				IHQ80								
C	*Skill*	Skill			Derby										Skill		

quences began with a practice round that followed the rules for the Skill treatment. This was followed by 3 rounds of the Skill treatment and 4 rounds of the Derby treatment. Hence, the first 7 rounds were identical across all three sequences. Consistent with the policy problem of interest, this provides all subjects with experience in a competitive derby fishery before being given the opportunity to switch to an IHQ.

For sequences A and B, in rounds 8–16 subjects were given the option to choose the bowl from which they would harvest. Those who chose Bowl 1 continued to harvest following the rules of the derby. Those who chose Bowl 2 were allowed to harvest the individual quota shown in columns 6 and 10 of Table 2. In sequence C, subjects were not given a choice. They continued to harvest in a derby fishery through round 13. The last 3 rounds of sequence C returned to the Skill rules (must use ¼ cup) to allow us to test whether those who harvested the most in rounds 1–3 were equally successful in rounds 14–16.

Results

We begin our discussion of our experimental results by reviewing and comparing results for each treatment averaged across all sequences, rounds, and subjects. We then discuss, in turn, heterogeneity of subjects and estimation of relative skill, estimated production functions for competitive fisheries, and choices between competitive and quota fisheries.

Comparison of Results across Treatments

Table 4 summarizes the results for each treatment, averaged across all sequences, rounds, and subjects. The top three rows of the table provide some benchmarks for evaluating outcomes: the maximum potential earnings or rents, calculated as maximum potential value minus minimum potential cost. The next two rows summarize average group sizes (n) and scoop sizes (x_{it}). The three rows after that show the calculation of actual average earnings or rents. The last few rows of the table show average rent dissipation or the difference between maximum potential rent and observed average rent. We distinguish between value-driven rent dissipation (the difference between maximum potential value and actual average value) and cost-driven rent dissipation (the difference between actual average costs and minimum potential costs).

Consistent with naturally occurring derby fisheries, behavior in both the skill and derby treatments is highly competitive. The prohibition on verbal communication, combined with the speed with which the resource is exhausted (as little as 16 seconds), leaves little opportunity for subjects to coordinate choices. In both the Skill and Derby treatments, although there were 2.5 cups of beans per person in the common bowl, average value or deliveries per person are substantially below this (1.93 cups in Skill and 1.81 in the Derby). The harvesting frenzy that emerges in these competitive fisheries causes participants to spill roughly one-quarter of the beans in each treatment rather than taking the time to empty the beans carefully into their pitchers. This is an example of value-driven rent dissipation. Because total deliveries are significantly less than the maximum potential value, the value that participants derive from harvesting the resource is less than would be possible if subjects handled the resource with greater care.

Our observation of significant value-driven rent dissipation illustrates an important advantage of physically simulating the conditions of an actual fishery: it allows us to observe important but unanticipated effects. In designing the experiment, our focus was on cost-driven rent dissipation. We had not expected to observe value-driven rent dissipation and would not have observed it in a computer-based experiment using payoff tables. Moreover, this value-driven rent dissipation through spillage is not an explicit choice; instead, subjects typically described it as a necessary response to the real-time, competitive environment.[5]

In the Skill treatment, because there is no cost to harvesting, there is no cost-driven rent dissipation. In contrast, in the Derby treatment, significant cost-driven rent dissipation occurs as subjects choose scoops with average size of 0.38 cups, well above the cost-minimizing size of ⅛ cup. The average gear cost is 1.66 cups, compared with the minimum potential cost of 0.55 cups, resulting in average cost-driven rent dissipation of 1.11 cups, or 57 percent of total potential rent. Thus, in the Derby treatment the combination of value-driven rent dissipation (spills) and cost-driven rent dissipation (larger-than-necessary cups) results in dissipation of almost all (92 percent) of potential rents. Alternatively, efficiency in the Derby was only 8 percent.

In the two IHQ treatments, there continues to be significant rent dissipation in Bowl 1 (the derby). The percentage of beans spilled is similar to that observed in the Skill and Derby treatments—on average about one-quarter of the total quantity of beans available wind up on the floor. The experiments were parameterized using equation (2) such that, if all subjects were homogeneous, average scoop sizes and costs at Bowl 1 (derby) should increase in IHQ40 relative to the Derby treatment, and decrease in IHQ80, but both would lead to higher earnings vis-à-vis the Derby treatment. What we observe is a decrease in average scoop size for both treatments, although the average scoop in IHQ80 is slightly smaller than IHQ40. In both IHQ treatments, those who voluntarily remained to harvest in a competitive derby earned more on average than in the Derby treatment, when all subjects had to harvest competitively.

Put differently, while there is significant rent dissipation in the competitive Bowl 1 for both the IHQ40 and IHQ80 competitive treatments, there is considerably less rent dissipation than in the Derby treatment, and subjects earn significant positive rents. It is an interesting question why those subjects who choose to fish competitively

[5] Note that while we were able to measure subjects' collective value-driven rent dissipation (we measured total spills as the difference between the total harvested volume of beans and the total delivered volume of beans), we were unable to measure the volume of beans spilled by individual subjects, or individual value-driven rent dissipation.

Table 4. Experiment Summary Statistics (per person per round)

Treatment	Skill	Derby	IHQ40	IHQ80	IHQ40	IHQ80
Bowl	1	1	1	1	2	2
Type of fishery	Competitive	Competitive	Competitive	Competitive	Quota	Quota
BENCHMARKS						
Maximum potential value[a]	2.50	2.50	3.32 (0.54)	2.89 (0.09)	1.42 (0.22)	2.33 (0.07)
Minimum potential cost	0.00	0.55	0.55	0.55	0.55	0.55
Maximum potential rent[a]	2.50	1.95	2.77	2.34	0.87	1.78
OBSERVED						
Average group size	8.0	8.0	5.0	2.6	3.0	5.4
Average scoop size	0.25 (0)	0.38 (0.25)	0.31 (0.09)	0.27 (0.15)	0.13 (0.05)	0.13 (0.07)
Average value (deliveries)	1.93 (0.47)	1.81 (0.92)	2.41 (0.67)	2.17 (0.74)	1.42 (0.22)	2.33 (0.07)
Average costs	0	1.66 (1.11)	1.37 (0.37)	1.17 (0.66)	0.58 (0.22)	0.59 (0.32)
Average rent	1.93 (0.47)	0.15 (0.68)	1.04 (0.56)	1.00 (0.78)	0.84 (0.29)	1.74 (0.34)
RENT DISSIPATION						
Value-driven (avg)	0.57	0.69	0.91	0.72	0.00	0.00
Cost-driven (avg)	0.00	1.11	0.82	0.62	0.03	0.03
Total (avg)	0.57	1.80	1.73	1.34	0.03	0.03
RENT DISSIPATION AS A SHARE OF MAXIMUM POTENTIAL RENT						
Value-driven (avg)	23%	35%	33%	31%	0%	0%
Cost-driven (avg)	0%	57%	30%	27%	4%	2%
Total (avg)	23%	92%	63%	58%	4%	2%

[a] Maximum potential value and earnings varies each period in IHQ treatments based on number of subjects choosing each bowl. Standard errors in parenthesis.

in Bowl 1 do not dissipate most of the potential additional rents from higher average allocations by increasing their scoop sizes. We may speculate as to several possible answers. If some subjects initially continue with the same cup choices as during the Derby treatment, their profits will likely increase—providing less incentive to experiment with an alternative cup size. Moreover, because they are competing with fewer other subjects, they may be less comfortable selecting a large cup size choice, and may recognize the risk of provoking a collective response of larger scoop size choices from other participants. In any case, it is desirable that subjects choosing to fish competitively from Bowl 1 should earn positive rents. Recall that this is part of the logic of a voluntary transition scheme: to provide a win-win option so that those who prefer to fish competitively will not oppose giving those who wish to fish for a fixed quota the option to do so.

As expected, in the quota fisheries of the two IHQ treatments, there is minimal rent dissipation. When the competition for a fixed resource is removed, average scoop choices in Bowl 2 approach the smallest option (⅛ cup) and there is almost no spillage, leading to almost perfectly efficient outcomes.

Heterogeneity of Subjects and Estimation of Relative Skill

The above discussion focuses on average cup choices, deliveries, and earnings. In the competitive treatments, these averages conceal significant differences among subjects in their cup choices, deliveries, and earnings.[6] These differences are illustrated in Figure 1, which shows the distribution of individual earnings per period in the Derby treatment. Although there are instances in which subjects were able to earn over \$1, this is uncommon relative to the frequency with which subjects were losing money. In fact, total group earnings were negative in nearly one-third of the Derby treatment periods.

In any period of the Derby treatment or Bowl 1 (derby) of the IHQ treatments, there are three potential explanations for differences in subject earnings: (i) differences in cup choices, (ii) differences in individual characteristics, which we refer to as relative skill, which persist across periods, and (iii) random factors that are independent across periods.[7]

We use the results of the Skill treatment to estimate individuals' relative skill. We define estimated relative skill as the ratio of the total quantity harvested by individual i in the three periods of the Skill treatment to the total quantity harvest by the entire group:

$$RelativeSkill_i = \sum_{t=1}^{3} q_{it} \Big/ \sum_{i=1}^{8} \sum_{t=1}^{3} q_{it} \,,$$

where q_{it} is the amount harvested by individual i in period t. Figure 2 shows that, not surprisingly, there is heterogeneity in estimated relative skill. The mean is 0.13 ($\sigma = 0.02$), and ranges between 0.07 and 0.18. This heterogeneity of estimated relative skill among subjects is not random as there is positive correlation between an individual's harvest shares among all periods of the Skill treatment.[8] Moreover, relative skill is robust across the start and end of the experiment. In sequence C, subjects participated in the Skill treatment in periods 1–3 and again in periods 14–16. The harvest shares for these two time segments are again positively correlated (0.60).

Estimated Production Functions for Competitive Fisheries

The estimated relative skill parameter is useful in estimating a simple production function for individual deliveries (q_{it}). Table 5 presents the estimation results for a linear random effects model of the form $q_{it} = \alpha + x_{it}\beta + v_i + \varepsilon_{it}$ for subject i, in periods $t = 4...7$ (i.e., the Derby treatment); the individual random effects are $v_i \sim N(0, \sigma_v^2)$, and $\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$ is the idiosyncratic error term. The positive and significant coefficient on estimated *RelativeSkill*$_i$ confirms that harvesting success in the Skill treatment carries over into the Derby and that this skill parameter successfully reflects subject heterogeneity. In addition to *RelativeSkill*$_i$, the other two dependent variables in the delivery production function are different measures of input choices: x_{it} is the individual's cup choice for harvesting, and

$$CapacityShare_{it} = x_{it} \Big/ \sum_i x_{it}$$

is the individual's cup size relative to the cup size choices of the entire group. As one might expect, all else equal a larger cup will yield a larger delivery ($x_{it} > 0$).

Because the derby is a social dilemma, harvesting success depends not only on one's own input choice, but also the input choice of the other group members. The positive coefficient on *CapacityShare* shows that it is important to not only have a "large" harvesting capacity, but also to have a "large" harvesting capacity relative to the group members. This captures the essence of the cost-driven rent dissipation problem or "keeping up with the Joneses"—individuals in a derby compete by increasing their share of the total har-

[6] Although we were able to measure aggregate harvests and aggregate spills (the difference between total harvests and total deliveries), we were not able to measure individual harvests and individual spills—only individual deliveries.

[7] Note that we use the term "relative skill" rather than simply "skill" because the effects of these individual characteristics on an individual's catch share and earnings depend in part on the characteristics of other subjects with whom the individual is competing. A subject who is very good at scooping beans will do better if all the other subjects are not very good at scooping beans than if all the other subjects are as good or better at scooping beans.

[8] The correlation in the individual share of the total harvest between periods 1 and 2 is 0.69, between periods 2 and 3 is 0.66, and between periods 1 and 3 is 0.60.

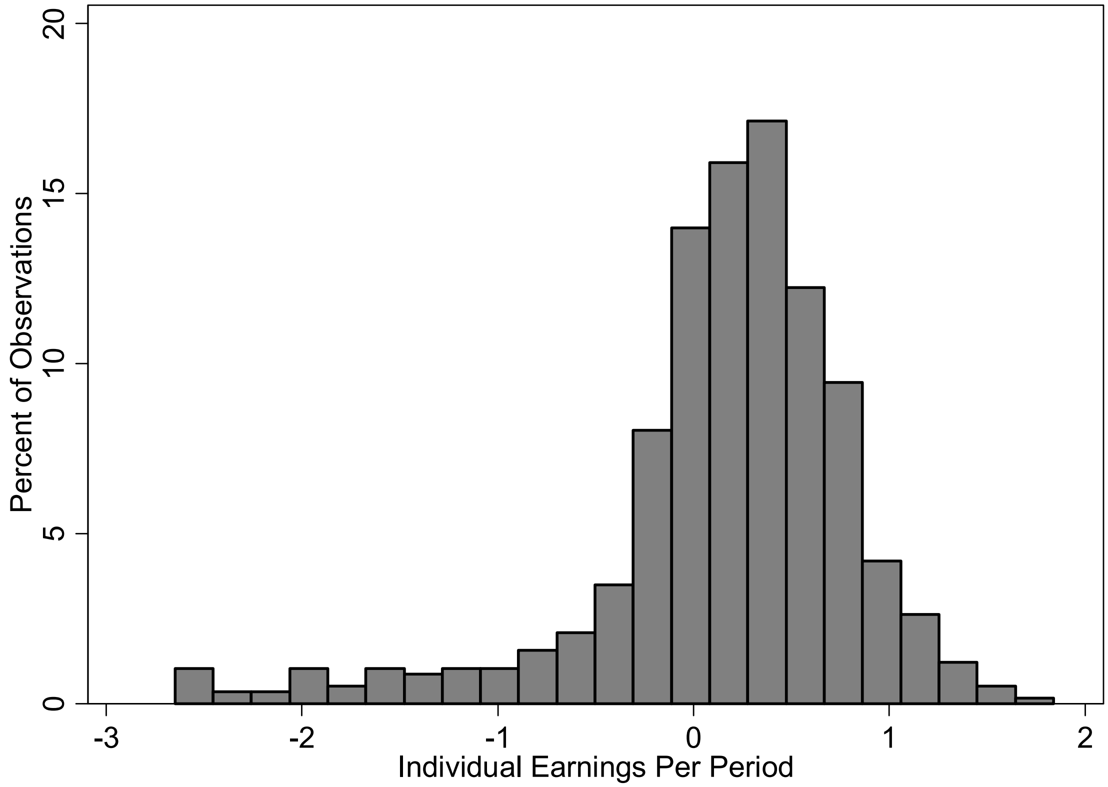

Figure 1. Distribution of Individual Earnings per Period in the Derby Treatment

vesting capacity until all the rents have been dissipated.

In our environment, with a linear cost function and output price set at one, the difference in deliveries and earnings is simply the input cost, $c(x_i) = 4.375x_i$. Because the cost of inputs is increasing, harvesting more does not necessarily translate to higher profits. In fact, on average, the three largest cup sizes all have negative average earnings in the Derby treatment.

Aggregate Choices Between Competitive and Quota Fisheries

We turn next to experiment results related to subjects' choices between competitive and quota fisheries in the two IHQ treatments, in which subjects are given the option of fishing competitively (Bowl 1) or in a quota fishery (Bowl 2). We first discuss trends over time in the total number of subjects choosing each fishery. We then discuss factors affecting which subjects choose each fishery.

Figure 3 shows the average number of subjects choosing the quota fishery in rounds 8–16 of the IHQ80 and IHQ40 treatments. Although all subjects would be better off on average if everyone were to switch to the quota fishery (Bowl 2), in both treatments at least some subjects choose to remain in the derby. Fewer subjects switch to the quota fishery in IHQ40 due to the higher costs of switching [for any given number of quota harvesters, the individual quota per person in IHQ40 is less than IHQ80 (see Table 2)].

Neither treatment has a discernible trend towards full adoption of the quota fishery over time. Instead, on average the distribution of participants between the two fisheries appears relatively stable over time. This would suggest that the derby fishery is not likely to be fully voluntarily phased out over time.

One reason we might expect this is that under the allocation formula between the two fisheries,

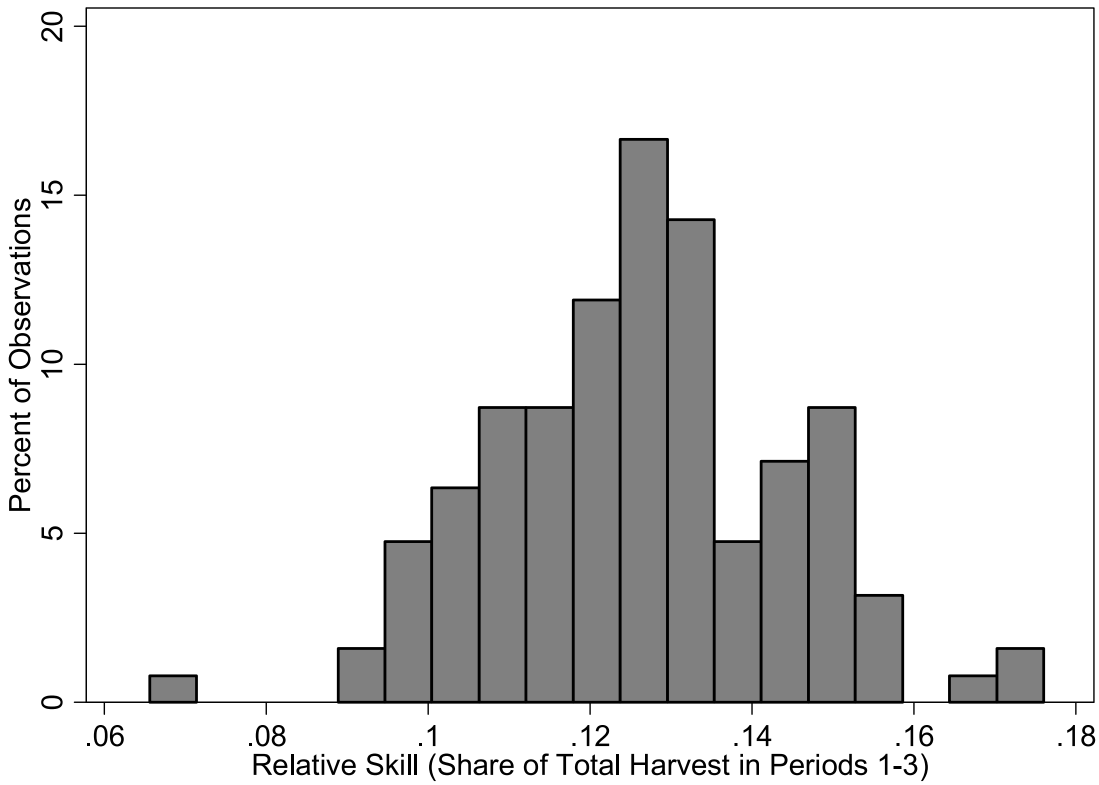

Figure 2. Distribution of Relative Skill

an "end-game" problem arises. As can be seen in Table 2, as the number of subjects choosing the competitive fishery becomes smaller, the average allocation increases, giving subjects an increasing incentive to remain in or return to the competitive fishery. There is never an incentive for the last subject to join the quota fishery: as the sole participant in a "competitive" fishery he would in effect be fishing for a guaranteed but higher quota than in the quota fishery.

We also observed that over the course of the IHQ80 and IHQ40 treatments, some subjects who had chosen the quota fishery subsequently switched back to the competitive fishery in later periods. This suggests that the optimal choices for individual subjects are not necessarily obvious or stable. Individual subjects' expected catches in a competitive fishery depend in part on not only their own skill and cup choices, but also the relative skill and cup choices of the other subjects choosing the competitive fishery. As subjects leave or enter the competitive fishery, they change the expected catches of the other subjects choosing the competitive fishery, and their optimal choices between fisheries.

Table 5. Linear Random Effects Models for Derby

Variable	Model 1: Harvest (q_{it})
x_{it}	0.93*
	(0.16)
$CapacityShare_{it}$	7.99*
	(0.60)
$RelativeSkill_i$	11.08*
	(1.79)
Constant	–0.92*
	(0.23)
R^2	0.76
Wald $\chi^2(3)$	1221.1
p	0.00

Note: Includes data from all sessions for the derby in periods 4–7. Standard errors are in parentheses. * indicates $p \leq 0.01$.

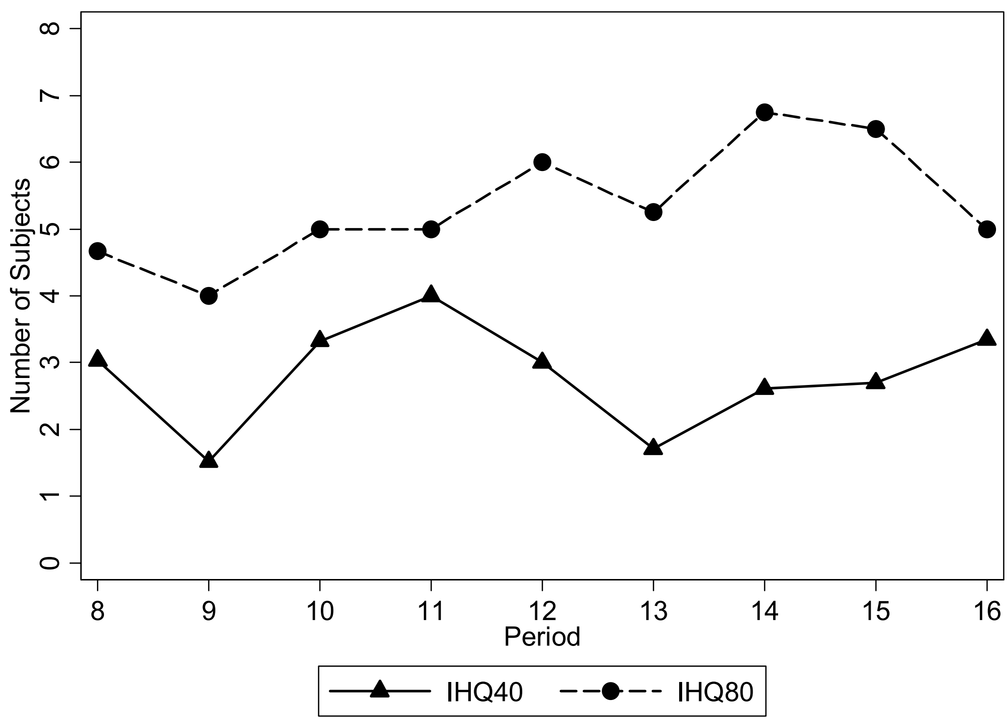

Figure 3. Number of Subjects Choosing to Harvest an Individual Quota (Bowl 2)

Figures 4 and 5 show that for both IHQ treatments, average earnings were higher in both the quota fishery (Bowl 2) and the competitive fishery (Bowl 1) than in the preceding Derby treatments. This result lends support to an important premise of the rationale for voluntary transition: that it offers the opportunity to make both groups better off on average: not only those who choose the quota fishery, but also those who choose the competitive fishery.

Individual Choices Between Competitive and Quota Fisheries

We next examine factors affecting *which* individuals choose the competitive and quota fisheries. These same factors may also affect the extent to which individuals would oppose or support the mandatory imposition of a quota system. As discussed above, in both our experimental environment and the naturally occurring derby fisheries of interest, there can be substantial heterogeneity among the harvesters. This can manifest itself in individual choices between competitive and quota fisheries in a number of ways, which are not entirely independent. First, those harvesters who are able to catch a relatively larger share of the fixed resource might be inclined to remain in the derby. This could be driven in part by the prestige associated with harvesting success, independent of profitability. Some individuals may harvest less, but perhaps due to skill and lower input costs, are able to do so more profitably than those harvesting more. Whether these individuals switch to an individual quota depends upon whether the quota offers greater expected profits. Finally, some individuals may simply enjoy the competitive nature of the derby.

In the experiments, subjects in Sequences A and B had the choice of remaining in the derby or voluntarily switching to a non-transferable individual harvest quota. There are at least three observable sources of heterogeneity that could affect this choice: relative skill, derby earnings, and derby harvests. We use a random effects logit model (with the panel defined over the individual) to estimate the individual decision about whether to switch to the individual harvest quota

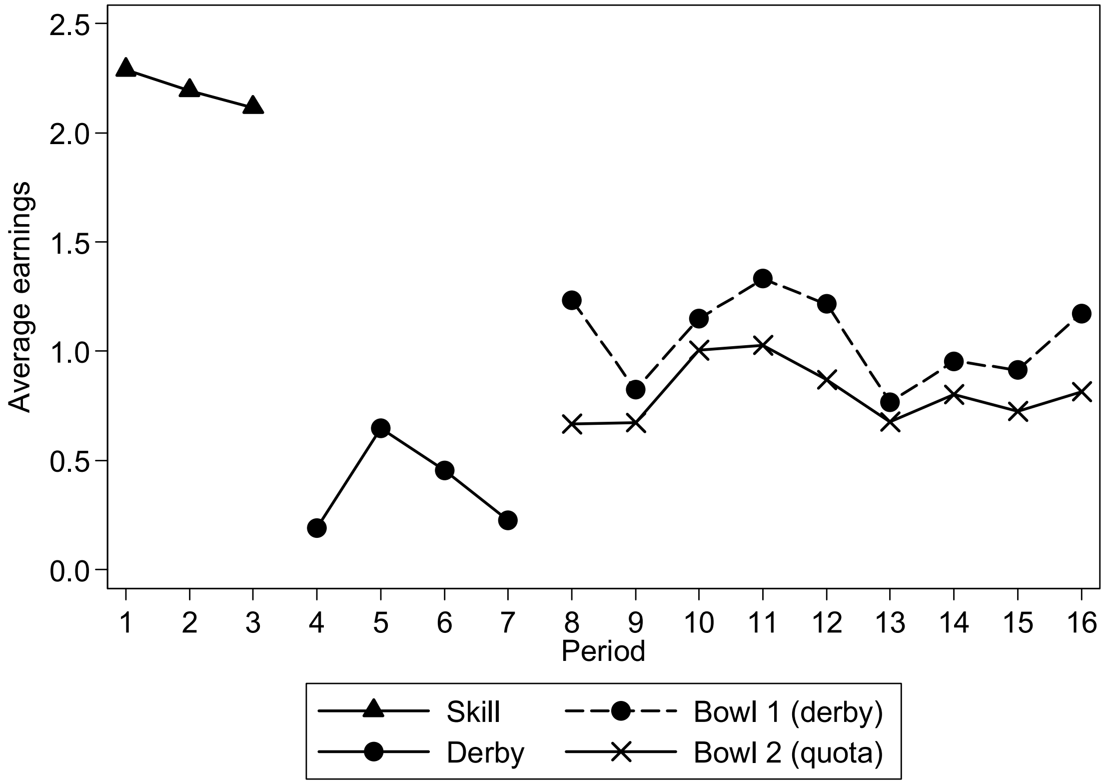

Figure 4. Average Earnings by Period for Sequence A (IHQ40)

(subjects made this decision at the start of each period). In Table 6, the dependent variable, IHQ_{it}, equals 1 when the subject chooses the individual quota (bowl 2) and 0 when the subject harvests in the derby (bowl 1).

$$DerbyEarningsShare_i = \sum_{t=4}^{7} \pi_{it} \Big/ \sum_{i=1}^{8} \sum_{t=4}^{7} \pi_{it}$$

is the total amount earned by an individual during the Derby treatment as a share of total earnings by the group; $DerbyHarvestShare_i$ is defined similarly, using x_{it} rather than π_{it}.

The results in Table 6 indicate that those with more skill and those who harvested more are less likely to switch to the individual quota. We hypothesized that those who earned the most in the derby might be less likely to switch to the quota, but estimation results suggest that relative earnings in the derby do not have a significant effect. This also suggests that skilled harvesters may be more likely to oppose implementation of a mandatory quota system, particularly one with equal quota shares as in these experiments, because they are generally able to harvest a larger share of the resource in the competitive derby environment. This skill advantage has no value with the individual quota.[9]

In addition, those who were able to harvest relatively more in the derby (this could be due to skill or choice of cup size) may be reluctant to switch in the expectation that their harvesting success will continue. A large harvest alone does not necessarily translate into success in the derby—the individual must also make a smart choice of cup size to ensure profitability. The results in Table 6 show that relative earnings in the derby are not a significant factor in the decision to switch to the IHQ. The estimation results show that an individual's willingness to

[9] The primary return to skill would be if the quota were allocated based on historical catch in the derby.

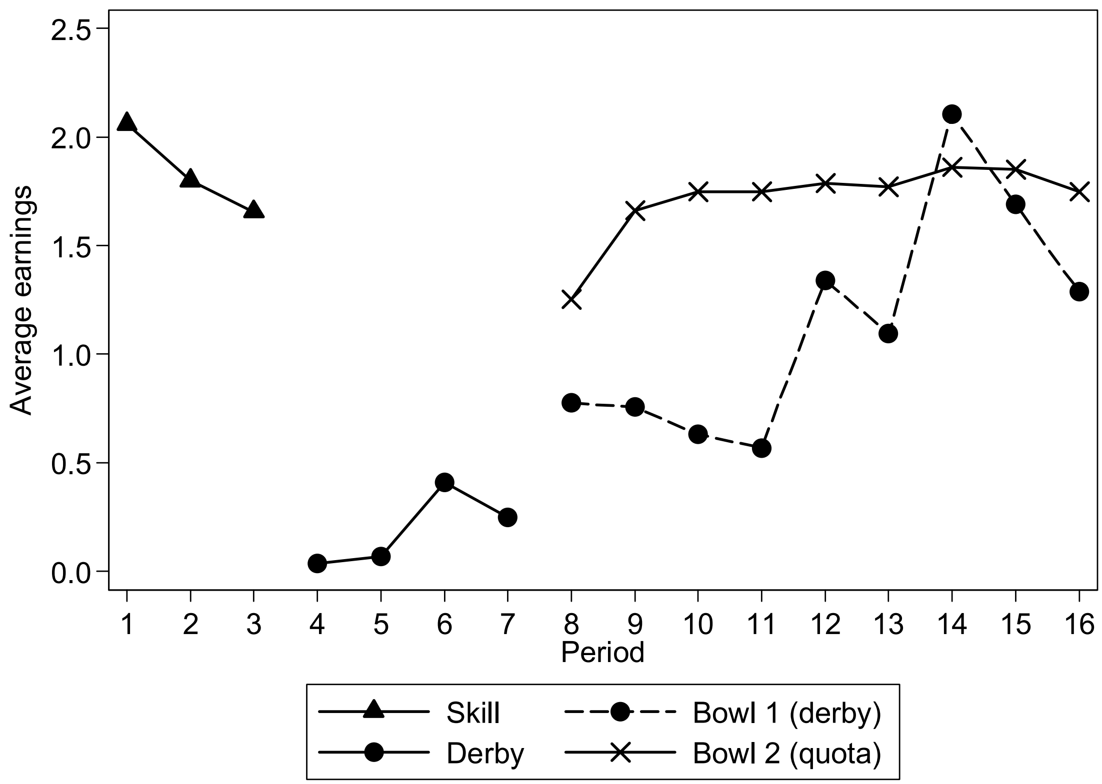

Figure 5. Average Earnings by Period for Sequence B (IHQ80)

switch will depend upon how much it "costs" to leave the derby. Recall that, unless everyone switches to the IHQ, there will always be more beans per person in the derby (see Table 2). The costs of switching are greater in the IHQ40 treatment; hence, individuals are less likely to switch than in the IHQ80 treatment. This is shown in Figure 3, and in the negative coefficient on IHQ40 in Table 6.

It is not necessarily the case that everyone is "losing" money in the derby even if rents are dissipated in aggregate. More importantly, our results show that not everyone will voluntarily switch to the IHQ when given a chance—and this decision to remain in the derby is not entirely irrational. When the costs of switching are low (IHQ80), Figure 5 shows that average derby earnings (Bowl 1) are lower than in the quota (Bowl 2), although the earnings difference is smaller in the later periods. More importantly, when the costs of switching are high (IHQ40), those in the derby actually earn more on average than those who switch to the quota (Figure 4).

Table 6. Random Effects Logit Model

Variable	Switch to Quota (IHQ_{it})
$RelativeSkill_i$	–24.40 *
	(14.49)
$DerbyHarvestShare_i$	–19.32 **
	(7.51)
$DerbyEarningsShare_i$	0.70
	(0.45)
$IHQ40_t$	–1.37 **
	(0.39)
Constant	6.26 **
	(1.67)
Wald $\chi^2(4)$	31.58
p	0.00

Note: Includes sequences A and B only, periods 8–16. Standard errors are in parentheses. * indicates $p \leq 0.10$, ** indicates $p \leq 0.01$.

Conclusions

This paper presents the results of a unique experiment that, in essence, brings the field into the lab. The hands-on approach provides a simple and more natural experience for subjects and may be particularly amenable to field situations in which education and literacy might affect a subject's ability to understand the experiment. The experimental results for the competitive treatments help to confirm and illustrate basic but important points about rent dissipation in competitive fisheries, as well as the political economics of changes to fisheries management. Key results include:

- Significant rent dissipation may occur in competitive fisheries, but not all rents are necessarily dissipated.
- Competitive fisheries may exhibit both cost-driven and value-driven rent dissipation.
- Fishermen may be heterogeneous with respect to fishing skill, which may in turn affect their optimal gear choices in a competitive fishery.
- Heterogeneity of both fishing skill and gear choices may contribute to heterogeneity of harvests and earnings. The fact that fishermen may be earning low rents on average does not necessarily mean that all fishermen are earning low rents, or stand to benefit equally from management changes.

Theory, experimental evidence, and practical experience all suggest that offering fishermen a choice between participating in a rights-based fishery and continuing to fish competitively may be an effective approach to facilitate transition to rights-based fishing. Voluntary transitions may become a "win-win" approach under which both groups become better off.

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