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Is the behavior of fishers rational under Individual Transferable Quotas (ITQs) regimes? An Experimental Approach

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Is the behavior of fishers rational under Individual Transferable Quotas (ITQs) regimes? An Experimental Approach[†]

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Abstract
Marine resource depletion is a critical concern for humankind. Individual Transferable Quota (ITQ) regimes are among the most effective measures to tackle this problem. Employing an experimental approach, this study examines the *rationality* of fishers under an ITQ regime. In particular, this study focuses on the case where fishers can change their own vessel scales in the beginning of each period in each experiment. We find that the higher the quota price is, the more irrationally fishers behave. Moreover, vessel scales and initial allocations can influence the rationality of fishers.

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1. Introduction

Marine resources are of critical importance for the survival of humanity. Individual Transferable Quota (ITQ) regimes are considered to be one of the most effective measures for tackling the problem of over capacity and excess harvest (Costello at al., 2008). The main engine of ITQ regimes is the "market mechanism," which has also been adopted in other kinds of environmental resource management.[1] Under this regime, an authority determines the Total Allowable Catch (TAC) and the initial allocation of fishing rights/quotas. Fishers are able to transact those fishing rights/quotas in the quota market. This regime has been introduced in several countries, such as New Zealand, Iceland, and Australia, since the 1980s.[2] Under an ITQ regime, inefficient fishers gain more from selling portions of their quotas to efficient fishers than they would from harvesting by themselves. Thus, fishers under such a regime do not compete with each other to catch the most fish.

However, theoretical and empirical studies have revealed some defects of ITQs, including price instability, market power, and risk. Newell et al. (2005) found that quota prices can be unstable for the first several periods after the introduction of an ITQ system, as was the case in New Zealand. One possible reason for this instability is speculation. Fishers may expect that they will be able to resell their quotas later at a higher price. Price instability is an important issue for the *rational* behavior of fishers and, accordingly, for efficient resource management.[3]

Experimental approaches have also shed light on the functions of ITQ regimes. Anderson (2004) and Anderson and Sutinen (2005) performed basic experiments for ITQ regimes and found that quota prices may be much higher than those in the equilibrium scenario in which efficiency is achieved. Anderson and Sutinen (2006) demonstrated that the introduction of initial lease periods mitigates the problem of instability of quota prices. Anderson et al. (2008)

[1] Tradable emissions permits are among the measures that use the market mechanism.
[2] For empirical case studies and the evaluation of ITQ regimes, see, for example, Clark et al. (1988), Dupont and Grafton (2001), Eythorsson (2000), Gauvin et al. (1994), Kompas and Che (2005), Newell et al. (2005), and Weninger (1998).
[3] Bergland and Pederson (2006) considered the case in which some fishers are risk averse and proved that these fishers buy fewer quotas compared to those who are risk neutral. Moreover, Anderson (1991) demonstrated that the total cost to harvest a certain amount of fish is not minimized when some fishers have market power in the quota market. Furthermore, rational behavior has long been analyzed in the literature (e.g., Becker, 1962; Chen et al., 2006).

examined the relationship between cost structures and the situations of quota markets. Moreover, they investigated the efficiency of quota markets by comparing the realized total profit of fishers with the possible total profit when the most efficient allocation of quotas is achieved.

Whereas these prior experimental studies have focused on quota prices and efficiency, the purpose of this paper is to examine experimentally the rationality of the behavior of fishers. We define a fisher as rational when he or she chooses a harvest amount such that his or her own profit from fishing is maximized given the quota price.

In particular, this study focuses on the following points. First, we consider the case where fishers can change their own vessel scales in the beginning of each period in each experiment. The vessel scales change as time goes on under an ITQ regime in the real world, because fishers optimize their own vessels. Thus, it is important to investigate whether fishers can be rational even when vessel scales vary. Second, as pointed out in the literature, the price of quotas is likely to be biased upward and unstable. Therefore, we investigate whether or not this bias of the quota price and/or instability lead to the irrationality of fishers. Third, initial allocation can also influence the behavior of fishers, and the way of initial allocation has been controversial in the real situations. We conduct three series of experiments: the initial allocations of those series are different from each other. In addition to basic analyses of the experiment, we perform a regression on the behaviors of fishers to identify factors that significantly influence the rational behavior of fishers.

The paper is structured as follows. Section 2 describes the experimental design, including the theoretical background. Section 3 examines the results on quota prices and harvest amounts. Section 4 describes the estimation methods used to investigate the rational behavior of fishers/subjects and presents the results. Finally, section 5 provides concluding remarks.

2. Experimental Design

2.1 Theoretical background

Consider a fishery with N fishers. Each of n_S fishers engages in fishing with one small-scale vessel, whereas each of $N - n_S$ fishers engages in fishing with one large-scale vessel. These two types of fishers are referred to as type *S* and type *L*, respectively. Each fisher harvests fish stock of a single species. All vessels of a given type are identical. Moreover, all fishers use an identical fishing technique, so cost conditions are equal for all fishers with the same type of vessel.

The cost structure of each type of vessel is as follows:

$$C_i(q_i) = c_i(q_i) + F_i, \; c_i' > 0, \quad c_i'' > 0, \tag{1}$$

where q_i, c_i, and F_i denote the amount of catch, the variable cost, and the fixed cost of type $i(i = S, L)$, respectively. It is assumed that $F_S < F_L$ and $c_S' > c_L'$ for any given amount of catch. Moreover, because we assume the existence of fixed costs and increasing marginal costs, there exists a unique amount of catch that minimizes the average cost (AC) for each type, $\hat{q}_i(i = S, L)$. We assume that a large-scale fisher is more efficient than a small-scale fisher in the sense that

$$AC_S(\hat{q}_S) > AC_L(\hat{q}_L), \qquad \hat{q}_S < \hat{q}_L. \tag{2}$$

Figure 1 shows both types of cost structures.[4]

The government introduces an ITQ program for the fishery, sets a TAC (denoted by $\overline{Q}$), and determines the initial allocation to each fisher. The amount of $\overline{Q}$ and the initial allocation are constants for fishers. The demand curve for fish is downward sloping:

$$p = P(\overline{Q}), \qquad P' < 0. \tag{3}$$

Unless the government changes the TAC level, the price of fish does not change. Note that this fish price is the price of output which is different from the quota price.

Quotas are transacted between fishers in a perfectly competitive market, which means that both types of fishers are price takers in the quota market. We assume that fishers do not choose to quit fishing by selling their entire quotas. It is further assumed that new entry and exit do not take place because of the initial costs of entry and the costs of switching to other industries. Thus, a seller sells only a part of the quota he or she holds. Here, we exclude the case in which a fisher does not use part of his or her quota in an effort to manipulate the quota price.

Each type of fisher determines the amount of his or her catch and, accordingly, the amount of quotas that must be bought or sold so that the fisher's profit is maximized given the price of quotas. The profit function of fisher j with vessel type i is given by the following:

$$\pi_{i,j} = p(\overline{Q})q_{i,j} - C_i(q_{i,j}) - r \cdot (q_{i,j} - \overline{q}_j), \qquad i = S, L, \tag{4}$$

[4] In reality, larger vessels might be less efficient in some cases. However, the assumption that larger vessels are more efficient does not matter for our purposes. The opposite case can be analyzed in a similar way both theoretically and experimentally.

where r and $\bar{q}_j$ denote the price of quotas and the initial allocation for fisher j, respectively. The first-order condition is as follows:

$$p(\overline{Q}) - c_i' - r = 0. \quad (5)$$

As defined in the introduction, when a fisher is rational, which implies that he or she maximizes the profits from fishing activities given quota price, he or she catches the amount that satisfies (5).

Let $\tilde{q}_S$ ($\tilde{q}_L$) denote the amount of catch of each small-scale (large-scale) fisher in equilibrium. Then, the following conditions hold given the number of each type of fisher:

$$c_S'(\tilde{q}_S) = c_L'(\tilde{q}_L), \quad (6)$$

$$n_S \tilde{q}_S + (N - n_S) \cdot \tilde{q}_L = \overline{Q}. \quad (7)$$

The equilibrium outputs and the quota price can be represented as $\tilde{q}_i(n_S, \overline{Q})\ (i = S, L)$ and $\tilde{r}(n_S, \overline{Q})$, respectively. Thus, if all fishers are rational, the following condition is satisfied for each fisher:

$$p(\overline{Q}) - c_i'(\tilde{q}_i(n_L, \overline{Q})) - \tilde{r}(n_L, \overline{Q}) = 0, \qquad i = S, L. \quad (5)'$$

We note that the amounts of catches are not influenced by the initial allocations as long as the numbers of both types of vessels are fixed.

From (6) and the assumption that $c_S' > c_L'$ for any given amount of catch, it is clear that the amount of catch of a large-scale fisher is greater than that of a small-scale fisher for any given quota price. This relation implies that with a greater number of large-scale fishers, the total demand for quotas increases and the quota price is higher in equilibrium.[5]

2.2 Experimental design

2.2.1 Basic sessions

We conducted eight basic sessions, during which 12 subjects per session traded quotas in a computerized double auction. All subjects were under 30 years old, and they were mainly undergraduate and vocational school students. Each subject participated in one session only, and subjects were paid an average of US $30 based on an exchange rate of 100 Japanese yen = US $1.

[5] The presence of more large-scale fishers implies fewer small-scale fishers because the total number of fishers (N) is fixed.

At the beginning of each session, subjects read the instructions for about 10 minutes.[6] In this experiment, each session includes 10 periods, and each period is divided into two stages.

At the beginning of each period, each subject is given an initial allocation. In the first stage, the subject chooses between a large and a small fishing vessel. In the second stage, the subject can adjust his or her quota holdings by buying or/and selling quotas in the double auction scheme. To familiarize subjects with the experiments, we ran two training periods before beginning the paying periods.

We use technical terms specific to fisheries to describe the experimental design and results in this paper. However, terminology that is more neutral was used with the subjects. For example, we referred to a fish quota as a "coupon" and to marginal cost as marginal "production cost." After the experiment, subjects answered a questionnaire to measure their risk preferences.[7] We conducted the experiment using the University of Zurich's Z-tree program (Fischbacher, 1999).[8]

2.2.2 Choice of vessel type

In the first stage, each subject chose a method of production of either Type 1 (small-scale) or Type 2 (large-scale). The fixed cost of Type 1 was smaller than that of Type 2, whereas the marginal/variable cost of Type 1 was larger than that of Type 2 (see Figure 1). This cost structure corresponds to that in the theoretical background. In this experiment, the price of fish was fixed at 30. In other words, the revenue from selling one unit of fish was always 30. It should be emphasized that this price is not the quota price but the price of output. At the beginning of each period, each subject was given eight quotas as an initial allocation, which implies that the TAC was 96. Each subject was also given a sheet on which fixed and marginal costs of both production types were written (see Table 1 for the cost structures). From the end of the first stage through the second stage in each period, each subject could view on his or her own display the numbers of both types of vessels chosen by all subjects.[9]

The first stage was designed in this way for the following reasons. One of our purposes was

[6] The instruction manual is available upon request.
[7] See Appendix for details on the questionnaire.
[8] These sessions were conducted at the Yokohama National University in September 2009 and January 2010. Each session lasted about one and one half hours.
[9] Subjects could not identify who had chosen which type of vessel. They could see only the numbers of both types of vessels chosen in the period.

to examine whether vessel scale influences the rationality of fishers. Therefore, vessel scale and the characteristics of each subject should be independent. Subjects changed their vessel types about three times on average, and the number of subjects who changed their vessel types did not clearly decrease throughout the periods, at least until the eighth period. Figure 2 shows the average ratio of subjects who changed their vessel types in each period as compared with the previous period.[10] Therefore, we conclude that our design of the first stage worked well for our analysis.

2.2.3 Quota-trading stage

In the second stage, each subject can adjust his or her quota holdings by buying or/and selling quotas in the double auction scheme. We consider that a rational fisher maximizes his or her own profit from fishing activities. Similarly, in the controlled experiment, subjects buy and/or sell quotas to maximize their own profits from "production" activities, which are determined by (a) how many quotas the subject holds after trading and (b) how many quotas the subject buys and/or sells.

A deal was made whenever a buyer (a seller) accepted the current bid (the current ask price). After each trade, the current bid and ask price were closed and the market opened for a new set of bids and ask prices. The history of trading prices was displayed on the screen. The quota market was open for the entire period, which lasted three minutes.

2.2.4 Additional sessions and initial allocations

We conducted two more series of eight sessions, for a total of 16 additional sessions.[11] In these additional sessions, quotas were not allocated equally. We represent the first series of eight additional sessions as Allowance 1 (A1) and the second series of eight sessions as Allowance 2 (A2). In the A1 series, each of six subjects was given six quotas, and each of the other six subjects was given 10 quotas. On the other hand, in the A2 series, each of six subjects was given five quotas, and each of the other six subjects was given 11 quotas/coupons. All other details were the same as in the basic sessions, including TAC, which remained equal to 96.

We conducted these additional series for the following reasons. Under an ITQ regime, when

[10] The terms "Allowance 1" and "Allowance 2" in Figure 2 are explained in 2.2.4.
[11] These sessions were conducted at the Yokohama National University in February and March 2010.

speculation takes place, fishers do not maximize their own profits from fishing activities. They may try to gain from quota transaction itself.[12] In such a case, the amount of quotas in a fisher's possession can affect his or her rational behavior. Therefore, the effect of changes in fishers' initial allocations should be investigated.

3. Results: Quota Prices and Amounts of Harvests

Because subjects were able to choose a new type of vessel in each period, the theoretical equilibrium price (TEP), which corresponds to $\tilde{r}\left(n_L, \overline{Q}\right)$ as defined in the previous section, depended on the numbers of both types of vessels. The list of TEPs is shown in Table 2. Some of them are not integers because there is more than one possible equilibrium price. The results for basic sessions are summarized in Tables 3 and 4.

First, because the numbers of both types of vessels change in each period, we examine whether the average of actual trading prices (AATP) converges to the TEP. Figure 3 shows the average ratios of AATPs to TEPs for all sessions in the basic, A1, and A2 series. It is clear that the AATPs converged to the TEPs in all three series. This convergence implies that efficiency improves through periods when we focus on quota prices even if the vessel scales change.

Next, we ask whether subjects behaved rationally. Table 5 shows the relationship between the quota price and the harvest amount chosen by a rational fisher under that quota price. Figure 4 shows the average of the absolute values of the differences between the actual harvest amounts and the amounts that rational fishers/subjects would choose under AATPs. Hereafter, we let $DCATCH^{P}$ denote the difference. Figure 4 suggests that irrationality lingers through periods in terms of the maximization of profits from fishing activities. In other words, subjects failed in choosing their harvest amounts so that their own profits from fishing activities are maximized.

We chose to use absolute values as our measure of irrationality. In our experiment, the total allowable catch is fixed by TAC. Thus, when some subjects chose amounts greater than what would have been chosen if they had behaved rationally, the other subjects necessarily chose amounts smaller than those they would have chosen if they had behaved rationally. Therefore, the use of absolute values as the measure of irrationality is appropriate.

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[12] In the experiment, we do not consider carry-over of quotas through periods. Therefore, quotas are not long-term assets. In the present context, "speculation" means that fishers try to sell quotas at higher prices than what they bought in each period (three minutes).

We can see from Figure 4 that the values of $DCATCH^P$ of the base, A1, and A2 series differ from each other. To confirm these differences in $DCATCH^P$, we applied the Mann-Whitney test. Table 6 shows the results of Mann-Whitney tests of all possible pairs in three different series. We take $DCATCH^P$ as observed variable. The Mann-Whitney test can evaluate the hypothesis that two independent samples are selected from populations with the same distribution. The test results indicate that the value of $DCATCH^P$ in each series is significantly different from its values in all other series. Because the difference between any two series lies in the initial allocations, it can be said that the initial allocations influence the rationality of fishers' behavior in the quota market.

4. The Estimation

4.1 The method

In the previous section, we observed irrationality using the AATP and amounts of harvests. This section examines factors that cause the irrationality.

We estimate the following equation separately for each series using ordinary least squares (OLS).

$$DCATCH_{i,t}^{P} = c^{P} + \beta_1 \cdot AATP_{i,t} + \beta_2 \cdot TPV_{i,t} + \beta_3 \cdot Select2_{i,t} + \beta_4 \cdot Allocation_i + \sum_{k=1}^{4} \gamma_k \cdot risk_i^k + \varepsilon$$

where i represents the index for subjects; t represents the index for periods; $AATP$ is the average of actual trading prices; TPV represents the variance of AATP; *Select2* a dummy variable equal to 1 when a subject chooses a large-scale vessel and 0 when a subject chooses a small-scale vessel; *Allocation* is a dummy variable equal to 1 when a subject is given a smaller initial allocation and 0 when a subject is given a larger initial allocation (in the basic series, the value of *Allocation* is 0 for all fishers); and $risk^k$ represents risk preference, where the values 1–4 indicate different degrees of risk preference.[13] These values are based on the results of a pretest survey carried out before the experiments and were added to the model to control for heterogeneous risk preferences.

As noted above, we need to observe the relationship between the AATP and the rational behavior of subjects because quota prices are likely to be biased upwards, as verified in the

[13] For the meanings of the coefficients of risk factors, see the Appendix.

literature. It is likely that the larger the upward bias of the quota price is, the more transactions are made for speculation.[14] In turn, when more transactions are made for speculation, the amount of harvest of each subject becomes less rational in terms of maximizing the profit from fishing activities. Thus, β_1 is expected to be positive. When the variance of trading prices is large, it is difficult for fishers to behave rationally. Therefore, β_2 is also expected to be positive.

Moreover, from Table 5, the following relationships are considered to hold between the quota price and the amounts of harvests when subjects are price takers and choose the amount rationally[15] :

$q_L^T = 22.5 - P \quad if \;\; P \leq 22.5$, and $q_L^T = 0 \quad if \;\; P > 22.5$,

$q_S^T = 8 - 0.5 \cdot P \quad if \;\; P \leq 16$, and $q_S^T = 0 \quad if \;\; P > 16$,

where P denotes the quota price. Thus, the effect of the price change on the harvest amount is greater for a large-scale fisher than it is for a small-scale fisher. Therefore, β_3 is expected to be positive.

Finally, if speculation takes place, it is likely that as the quotas a subject has increase, so too does their incentive to dabble in speculation. Thus, β_4 is expected to be negative.

4.2 Estimation Results

Table 7 provides the results for all three series. The AATP significantly affects the irrationality of the choice of harvest amount: the higher the AATP, the greater the value of $DCATCH^P$ becomes. The upward biases of quota prices have been verified in the literature and in our experiments (see Figure 3). The estimation result suggests that these upward biases lead to irrationality of subjects. The higher the quota price is, the less likely it becomes that subjects will be able to maximize their own profits from fishing activities given the quota price. We also verify that the simple correlation between $DCATCH^P$ and (AATP – TEP) shows a positive relationship. This finding also implies that the larger the gap between AATP and TEP is, the less likely it is that subjects are rational.

Some other independent variables also affect the harvest amount significantly. As expected,

[14] See footnote 12 for the meaning of speculation in the present context.

[15] In the experiments, subjects were able to choose the units discretely.

the choices of a large-scale vessel and a larger initial allocation positively affect $DCATCH^P$. On the other hand, although TPV of series A2 has a significant influence on $DCATCH^P$, the value is very small. Moreover, no significant relationships between TPV and $DCATCH^P$ were seen in the other two series. Thus, TPV is not likely to affect irrational harvesting amounts.

One of the important factors causing irrationality is speculation. Although we assume that subjects maximized their own profits from fishing activities, when the quota price is upward biased and unstable, subjects have more to gain from speculation than from fishing activities. This factor can also influence the effect of a change in initial allocation on the gap between the actual harvest amount and the amount that a rational subject would choose given AATP. When quota prices are easily biased, initial allocations can play an important role in determining the degree of irrationality.

5. Concluding Remarks

Markets generate rationality by setting a fee on irrational behavior (Becker, 1962). Employing an experimental approach, we examined the rational behavior of fishers, because the rationality is a key to the function of ITQ regimes. We found that the upward biases of quota prices lead to irrationality of the choices of harvest amounts by fishers. Vessel scales and initial allocations can also influence irrationality significantly.

Consequently, several key points can be made about how to ensure Individual Transferable Quota (ITQ) regimes function well. First, rules that encourage the convergence of quota prices to the theoretical equilibrium prices should accompany ITQ regimes. In other words, the upward bias of quota prices should be removed as soon as possible. Second, initial allocations should be carefully chosen. In the real world, allocations are usually determined according to records of past catches. In some cases, allocations may need to be updated. Third, it may be that even vessel scales should be controlled because the vessel scale of a fisher affects her/his behavior in the ITQ market. At least, in transition periods from a non-ITQ regime to an ITQ regime, some controls on vessel scales may be justified to stabilize the quota price.

We assumed that subjects are price takers in the quota market, and we elaborated the experimental design to make subjects behave as price takers. In reality, however, some fishers may have market power, in particular, when only a small number of fishers participates in an

ITQ program. Thus, it is our goal in future studies to investigate fishers' behavior more carefully.

Another important goal for future research is to investigate what rules and controls are effective. In tackling this issue, we need to gain detailed information not only on prices and vessel scales but also on the behavior of fishers.

Appendix: Questionnaire

The questionnaire consisted of four questions on risk attitudes, which are similar to other psychological surveys related to experiments.

1) What is the lowest probability of precipitation at which you carry an umbrella?
2) If you have an appointment to meet your friends, how far ahead of time do you get to the meeting place?
3) How often do you cross the street against a red light when there is no traffic?
4) Are you usually careful with fire and secure lockup of your house? To what extent?

In Table 8, "risk 1" through "risk 4" correspond to questions 1 through 4 above, respectively. For "risk 1" and "risk 4", we process the data so that the risk lovers (risk averters) get higher (lower) scores. On the other hand, for "risk 2" and "risk 3", we process the data so that the risk averters (risk lovers) get higher (lower) scores.

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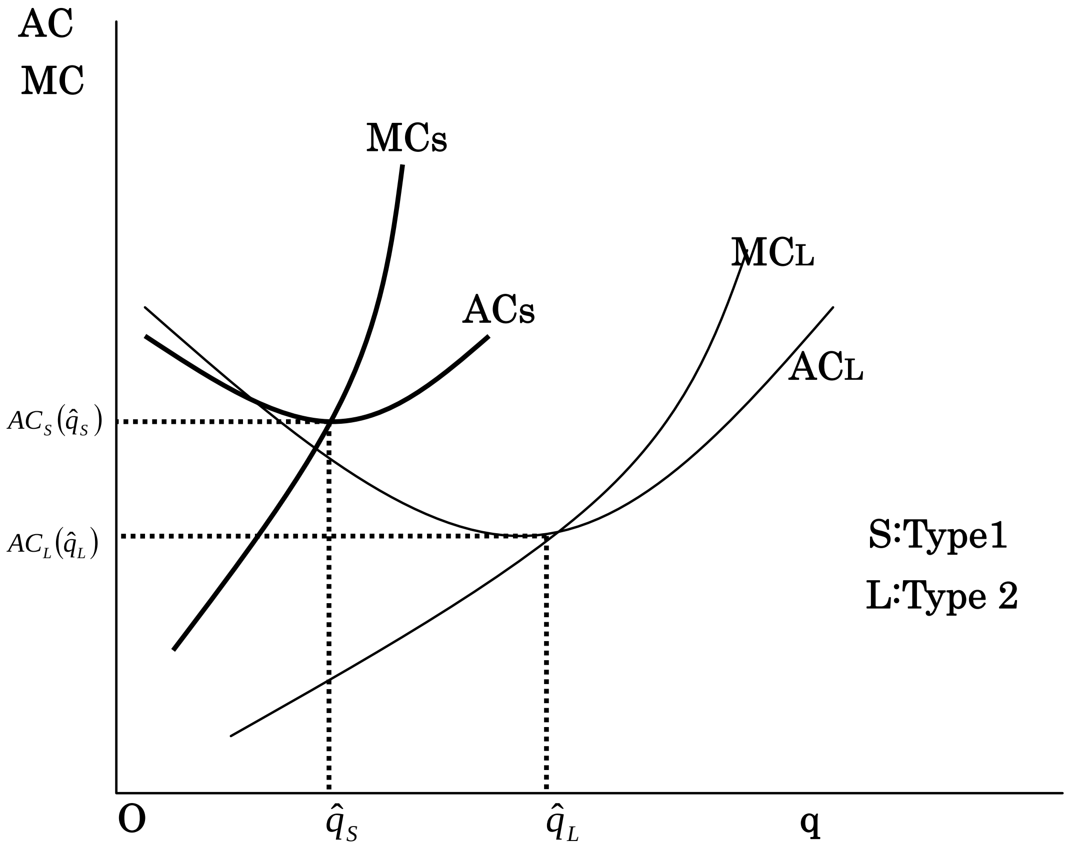

Figure 1: Cost structure

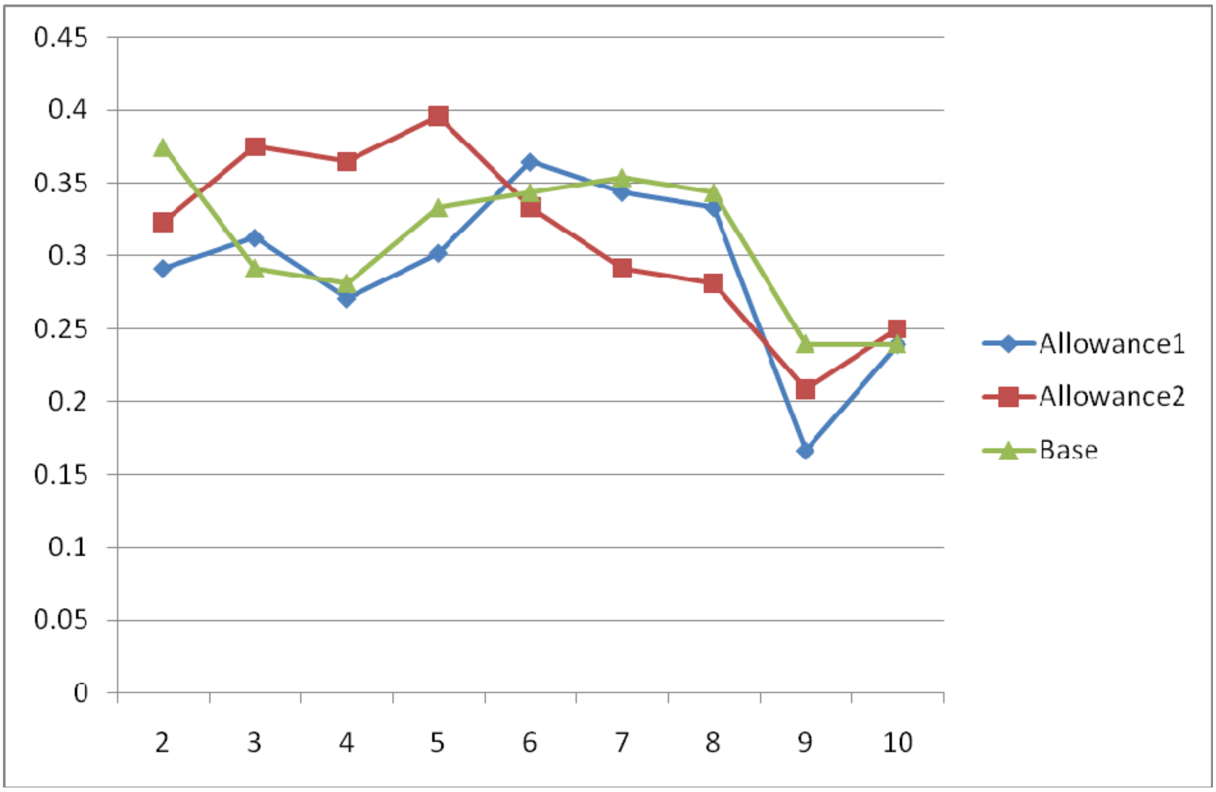

Figure 2: The average ratio of subjects who change their vessel types as compared with the previous round.

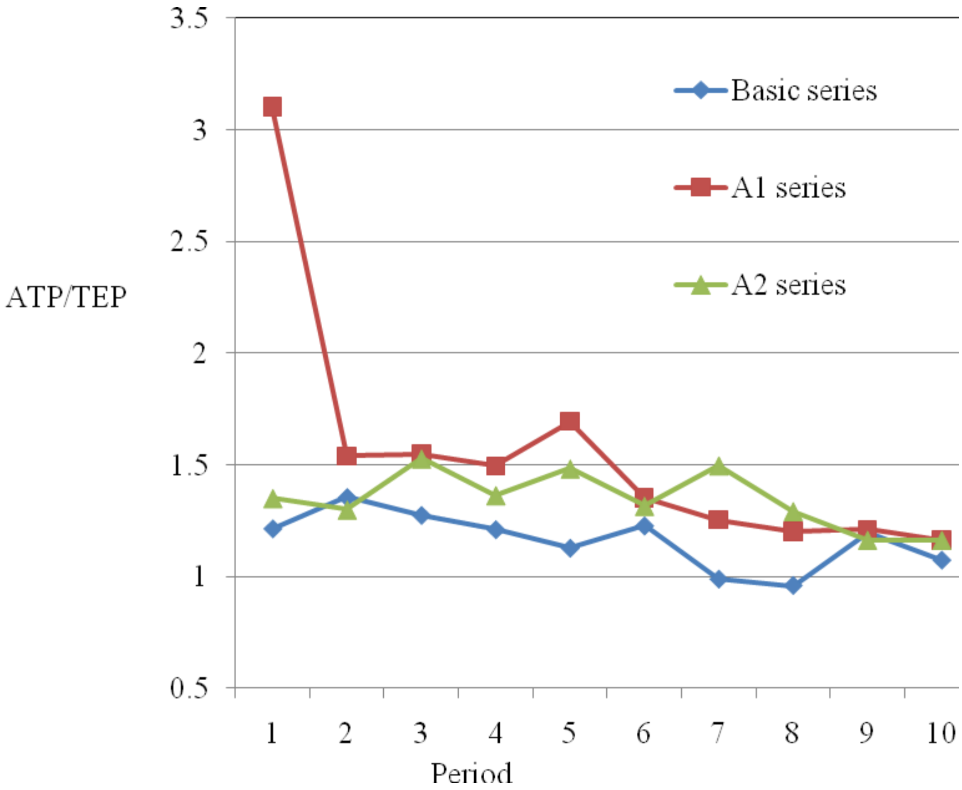

Figure 3: The average ratio of actual trading prices (ATP) to theoretical equilibrium price (TEP) in each period in Basic, A1, and A2 series

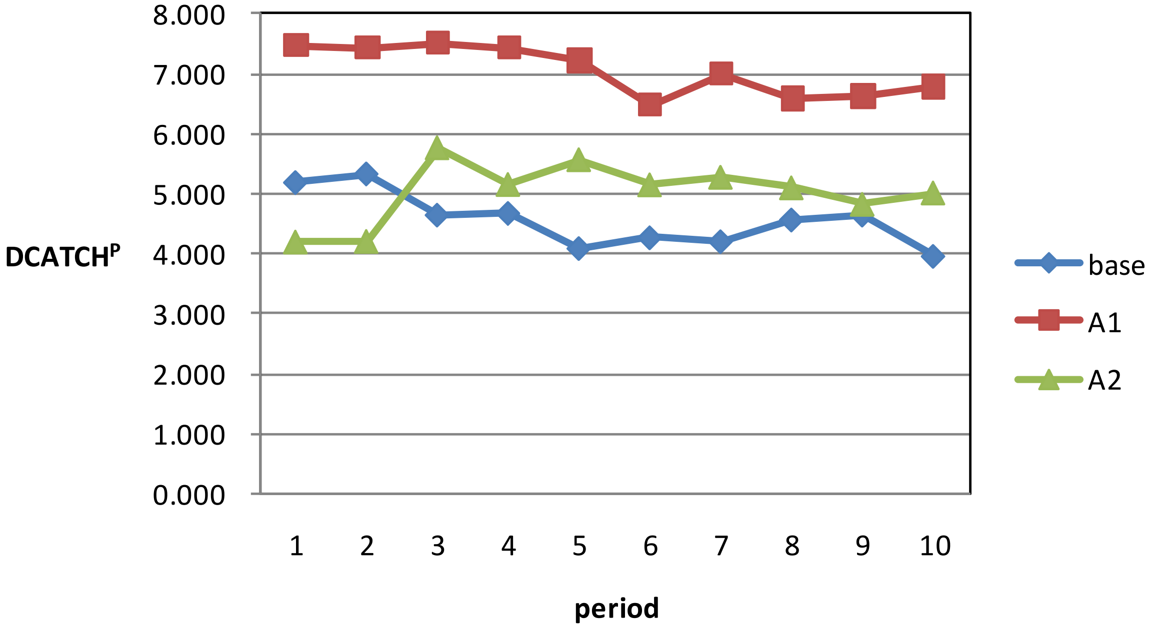

Figure 4: $DCATCH^{P}$ **(the average of the absolute values of the differences between the actual harvest amounts and the amounts which rational fishers/subjects would choose under AATP)**

Table 1: Cost structures of both types of vessels

fishing amount	Type1: Small scale		Type2: Large scale	
	Total cost	Marginal cost	Total cost	Marginal cost
0(fix cost)	20		80	
1	35	15	88	8
2	52	17	97	9
3	71	19	107	10
4	92	21	118	11
5	115	23	130	12
6	140	25	143	13
7	167	27	157	14
8	196	29	172	15
9	227	31	188	16
10	260	33	205	17
11	295	35	223	18
12	332	37	242	19
13	371	39	262	20
14	412	41	283	21
15	455	43	305	22
16	500	45	328	23
17	547	47	352	24
18	596	49	377	25
19	647	51	403	26
20	700	53	430	27

Table 2: Theoretical equilibrium price (TEP)

Number of Vessels	Theoretically Equilibrium Price (TEP)
Type1(S)=9, Type2(L)=3	5.5
Type1(S)=8, Type2(L)=4	7
Type1(S)=7, Type2(L)=5	9
Type1(S)=6, Type2(L)=6	9.5
Type1(S)=5, Type2(L)=7	11
Type1(S)=4, Type2(L)=8	11.5
Type1(S)=3, Type2(L)=9	12.5
Type1(S)=2, Type2(L)=10	13

* Some of them are not integers, since there is more than one possible equilibrium price.

Table 3: The Average of actual trading prices (AATP), variance, and numbers of vessels of each session of the basic series

Session	Average Trading Price (ATP)	Variance of price	Type 1 (S)	Type 2 (L)
1	11.64	102.25	5.1	6.9
2	10.34	18.04	4	8
3	8.10	94.58	4.5	7.5
4	11.58	40.22	5.4	6.6
5	14.31	207.19	5.8	6.2
6	9.20	56.86	4.3	7.7
7	15.48	109.93	6.2	5.8
8	15.62	1862.34	4.9	7.1
Average	12.03	311.43	5.025	6.975

Table 4: The average of actual trading prices (AATP), variance, and numbers of vessels of each period of the basic series

Period	Average Trading Price (ATP)	Variance of price	Type 1 (S)	Type 2 (L)
1	12.94	88.33	4.75	7.25
2	14.20	104.59	5	7
3	13.53	263.17	4.875	7.125
4	12.63	61.69	5.125	6.875
5	11.79	81.72	5.125	6.875
6	10.95	49.41	5.5	6.5
7	10.99	69.11	5	7
8	10.23	26.86	4.75	7.25
9	12.29	2275.77	5.125	6.875
10	10.79	93.60	5	7
Average	12.03	311.43	5.025	6.975

Table 5: The relationship between the quota price and the harvest amount when a fisher is a price taker and choose the harvest amount rationally (to maximize her/his own profit).

Quota Price	The Harvest Amount of a Large-scale	The Harvest Amount of a Small-scale
5	17.5	5.5
6	16.5	5
7	15.5	4.5
8	14.5	4
9	13.5	3.5
10	12.5	3
11	11.5	2.5
12	10.5	2
13	9.5	1.5
14	8.5	1
15	7.5	0.5
16	6.5	0

***** In the experiment, subjects were able to choose the units discretely. However, in many cases, subjects are indifferent between the alternative of two candidates of units. For example, when the quota price is 8, a large-scale fisher is indifferent between the alternative of 14 or 15. Thus, we put 14.5 in the corresponding box.

Table 6: Mann-Whitney test result: Comparing test of inefficiency/irrationality on the harvest amounts int in each series

	$DCATCH^{P}$
Base vs Allowance1	-3.402***
Base vs Allowance2	3.214***
Allowance1 vs Allowance2	3.780***

Note: *Significant at 10% level, **Significant at 5 %, ***Significant at 1% level.

Table 7: Estimation result for *DCATCH* ^{P}

	Dependent variable: $DCATCH^P$		
	base	A1	A2
AATP	0.1998***	0.7019*	0.0791**
	(4.94)	(1.82)	(2.46)
TPV	0.0002	0.0001	0.0011***
	(0.34)	(-1.42)	(2.79)
Select L	2.1994***	4.5107***	1.0729***
	(8.15)	(13.84)	(4.22)
Risk1	0.0292	-0.0813**	-0.0276
	(1.22)	(-2.52)	(-1.17)
Risk2	0.0534	-0.0217*	-0.0001
	(1.05)	(-1.96)	(-0.00)
Risk3	-2.9449***	1.310	-0.1694
	(-4.46)	(1.53)	(-0.29)
Risk4	-0.0181	-0.7952***	0.3688***
	(-0.13)	(-4.17)	(2.71)
Allocation		-1.6649***	0.0277
(small)		(-5.13)	(0.11)
c	1.8471**	6.4228***	2.5035***
	(2.29)	(5.98)	(3.09)
R^2	0.1145	0.2298	0.0428

Note: *Significant at 10% level, **Significant at 5 %, ***Significant at 1% level.