# Individual transferable quotas versus auctioned seasonal quotas, an experimental investigation

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**Abstract**

Fishery policies have largely developed in response to experienced problems. The last major change is the introduction of individual transferable quotas, ITQs. This seems to be a promising policy instrument compared to previous policies. Extrapolating from previous experiences, however, a further investigation of the ITQ system may reveal weakness of this instrument as well and may help improve the policy or stimulate the development of alternative policies. One such alternative may be auctioned seasonal quotas, ASQs. A laboratory experiment of a market with seven fishing firms is used to compare the ITQ and ASQ systems. Compared to traditional laboratory experiments of market institutions, this experiment allows for more realistic dynamic adjustments over time. In this setting, none of the policies are as perfect as economic theory may suggest. The ASQ system provides an automatic taxation of the resource rent, and surprisingly, it may also be the system with the lowest risk of bankruptcy for fishers.

## 1. INTRODUCTION

Historically, contemporary problems have to a large extent driven the development of fishery management practices. Overfishing led to various policies to curtail fishing effort, while three were no restrictions on capacity. Overcapacity led to licensing schemes, however with limited regard for efficiency. Finally, low efficiency has lead to the implementation of individual transferable quotas (ITQ) in a number of fisheries. By extrapolation, it seems pertinent to ask what problems may follow the implementation of ITQs. The earlier fishery authorities detect and correct possible problems, the smaller the problems and the higher the probability that ITQs or modifications of this system will be used to manage renewable resources around the world. It is the purpose of this paper to investigate some potential future problems with the ITQ system. To do so we use a laboratory experiment. We investigate both the ITQ system and an alternative market based system: auctioned seasonal quotas (ASQ). In the latter system the total seasonal allowable catch (TAC) is sold in yearly auctions.

According to now standard economic analysis, ITQs ensure efficiency in renewable resource management. Fishers are free to bid for quotas and fishing capacities, and are hence free to seek profit maximising combinations of these two factors of production. Efficiency should be ensured in that only low cost firms will afford to pay market prices for quotas and capacity. Hence ITQs prevent frequently observed tendencies towards overcapacity. In accordance with theory, efficiency has increased in fisheries where ITQs have been implemented, Kompas and Che (2005), Newell et al. (2005), Dupont et al. (2005), Waitt and Hartig (2000), Sinclair et al. (1999), and Hatcher et al. (2002).

While the ITQ system is well known, the system of ASQs is hardly ever mentioned with one notable exception, Trondsen (2004)[1]. This may seem surprising since auctioning of other scarce public resources has gained popularity over recent years, for instance to allocate radio frequencies, landing slots, water, import quotas etc. It is also surprising since leasing of seasonal quotas has become commonplace where the ITQ system has been implemented. Over recent years more than 40 percent of the ITQs in Iceland and New Zealand have been leased to fishermen who are willing to pay to obtain seasonal quotas. Hatcher et al. (2002) report that in general, traded volumes in seasonal quotas exceed by a large amount the volumes traded in ITQs. This suggests that seasonal quotas represent a more flexible instrument for short term adjustments than ITQs. There are however two main differences between the ongoing leasing of seasonal quotas and the ASQ system discussed here. In the ASQ system all seasonal quotas are sold in one open auction, and the seller is a public institution rather than private ITQ owners.

Fishers know and are used to auctions from fish markets. According to standard economic analysis ASQs have the same basic properties as ITQs when it comes to efficiency. However, this does not rule out the need for further investigations. Our experiment is designed to test the effects of the ITQ and the ASQ systems in a more complex environment than that included in standard economic analyses and in previous laboratory experiments of static markets. Notably, we keep track of capacities and ITQ holdings and update these from year to year.

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1 Weitzman, M.L. (2002). "Landing Fees vs Harvest Quotas with Uncertain Fish Stocks." *Journal of Environmental Economics and Management* **43**:325-338. analyses a dual system to ASQs, landing fees. He finds fees to be preferable to ITQs under uncertainty.

A number of historical and potential problems with the ITQ system have been described by Orebech (2005), Bradshaw (2004), Gylfason and Weitzman (2003), Eythórsson (2000), and Sinclair et al. (1999). For natural reasons, we have not found descriptions of problems with the ASQ system. Our focus is on the following key issues.

1. Efficiency. How efficient are the systems in reducing initial overcapacity, and in replacing high cost firms with low cost firms? At times the ITQ system has been supplemented with buyback schemes, e.g. in Iceland, suggesting that the ITQ system has not been as efficient as hoped for. On the other hand, considerations of dynamics and uncertainty may explain sluggish capacity reductions, Just and Weninger (1997), Grafton (1996), Linder et al. (1992), and Anderson (2000). If at the outset one considers the ASQ system to be the tougher of the two systems, one may expect ASQ to be the most efficient system in removing inefficient capacity.

2. Prices and risk. At the outset, the ASQ system may be thought to produce highly volatile prices for seasonal quotas. In years with low TACs, prices will be high, and in years with high TACs, prices may approach zero. Fisheries will resemble industries with strongly fluctuating raw material prices. Since ITQ owners do not pay to fish, their profit stream should be considerably more stable. On the other hand, ITQ owners face the risk of volatility in ITQ prices. Since the price of an ITQ is considerably larger than the price of an ASQ, the effect on firm equity may be significant. The risk of negative equities increases with the price fishers have paid for their ITQs in the first place. Since ITQs are assets, one cannot rule out speculation and price bubbles, Smith et al. (1988). A tendency towards bubbles and crashes have been detected in a laboratory experiment where ITQs have a limited lifetime of four years, Anderson and Sutinen (2005). We will investigate ITQs with infinite lifetimes. Thus, an interesting question is what system produces the highest risk to fishers.

3. Concentration. Concerns have been raised about concentration in terms of fleet ownership, ITQ ownership, and geographical location, Eythórsson (2000). According to economic arguments, Hatcher et al. (2002), the industry concentration will develop in whatever direction economic efficiency predicts. Hence, the major effects of the ITQ system should in theory depend on the starting point. In the experiment we split the industry in two segments with different efficiencies. The high cost producers should disappear over time. In the remaining group, with identical and low costs, there are no cost reasons for concentration to take place. We may observe concentration for other reasons pertaining to personal characteristics of the decision makers.

4. Fairness. The ITQ system we investigate starts out with grandfathered quota rights. This is the typical starting point for ITQ systems, and a major reason for opposition to the system, confer e.g. Supreme Court cases in Iceland, Gylfason and Weitzman (2003). We assume there is no resource tax included in the ITQ system. This is in line with most ITQ systems around the world, Hatcher et al. (2002). The ASQ system collects a resource tax through yearly auctions. To make the two systems more similar in net present value terms, we assume that initially, a public agency pays fishers for the established customs or previous investments in ITQs. We compare the financial outcomes for fishers and the public in the two regimes.

Section two presents the details of the experiment. The next section presents the hypotheses and provides benchmarks. The ensuing section shows results, tests hypotheses, and considers field data for each of the hypotheses, one by one. The most striking results are a slow and limited removal of high cost fishing capacity and of overcapacity, a tendency to bid up the price of ITQs well above the benchmark price, and lower risks to fishers in the ASQ system than in the ITQ system. The final section concludes and suggests further research into auctioned seasonal quotas (ASQs) as an alternative to ITQs.

## 2. THE EXPERIMENTAL DESIGN

First we present the task and underlying model for the ITQ treatment. Next we point out the differences between the ITQ and ASQ treatments. Then we discuss the hypotheses, benchmarks, and finally some practical issues.

### 2.1. The ITQ treatment

Different from earlier experiments (e.g. Plott (1983), Bohm and Carlen (1999), Soberg (2000)), our experiment is dynamic in that both capacity and ITQs are traded once a year and accumulate over a period of 30 simulated years. We observe how market prices for ITQs and capacity develop over time, how total fishing capacity develops, and how ITQs and capacity are distributed among the players. The initial situation is one of overcapacity, a typical starting point when implementing an ITQ system. In each market with seven players, three players will have higher operating costs than the others. This is the only difference between the players. Initially all players are endowed with the same fishing capacity and the same amount of ITQs. Total allowable catch

(TAC) varies randomly and with no trend over time. There is no coupling to an underlying fish stock. The players are asked to maximise equity and are paid according to performance. The participants received all the information given below, with the exception of the expected variable operating costs.

Figure 1 shows the computer screen. On the left hand side we find the last year's account, the balance sheet, some additional data, and the payoff (only shown when the game is over). Last year's quota is given by the firm's quota share times the TAC. Last year's harvest is the minimum of capacity and quota. Income is given by harvest times fish price, which is distributed uniformly over the range 9.6 to 14.4 NOK/kg (iid). Variable operating costs equal harvest times unit variable costs, uniformly distributed from 5.6 to 8.4 NOK/kg for the four low cost firms, and from 6.6 to 9.4 NOK/kg for the three high cost firms (iid). Fixed operating costs equal capacity times unit fixed operating costs of 2 NOK/kg/year. Depreciation equals capacity (aggregated into one age class) divided by a 15 year average lifetime of capacity and multiplied by the current price of capacity in the market. Results after interest payments and tax equals results before interest payments minus interest payments (6 % p.a.) and taxes (28 % of positive results after interest payments). Capacity value reflects capacity valued at the current capacity price in the market. Quota value reflects the quota holding valued at the current quota price. When the firm has net debt, this is shown as debt, otherwise the bank deposits will show a positive value. Equity makes assets and liabilities balance. The payoff varies with the final year equity from NOK 50 to NOK 300 (from 0.5 to 3 times a typical hourly wage for students).

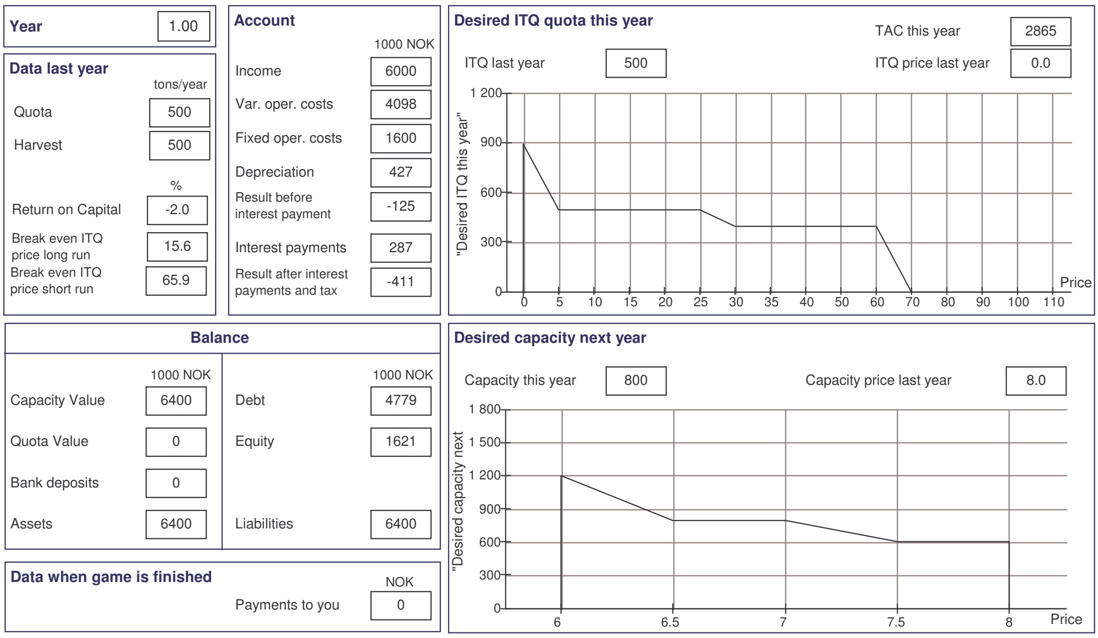

Figure 1: PC-screen for the ITQ treatment

The markets for fishing capacity and ITQs can be described with the following analogy. The owners of the fishing companies give their reservation prices to a broker, who operates in the market. A server module of the program mimics the market, calculates the equilibrium prices of capacity and quotas each year, and feeds back information about realised prices and obtained quantities to the participants.

On the right hand side are the two graphs that the players use to make decisions about market operations. To simplify, the players trade "expected quotas" rather than shares of the TAC. The TAC varies uniformly from 1750 to 5250 tons per year (iid). The expected TAC is 3500 tons per year, such that an ITQ holding of 500 (the initial value) is equivalent to a TAC share of 1/7.

The players can change the shape of the graph by the computer mouse to set the desired ITQ holding for the current year and desired capacity for the next year. Note that the desired ITQ holding is given as a function of the quota price and similarly the desired capacity is given as a function of the capacity price. When all players have pushed "Accept decisions" in a popup window, the computer calculates bids or offers at different prices (desired amount minus current holding) for each player. The computer then sums all the bid/offer-curves and finds equilibrium prices. To ensure that an equilibrium can be found, and to guard against logical errors, only monotonically decreasing curves for desired capacity and desired ITQs are accepted by the program.

The ITQ market equilibrium obtains where the sum of bids equals the sum of offers. The graph limits the ITQ price to the range from zero to 110 NOK/kg/year. For the capacity market there is a similar equilibrium for capacity prices between a lower and an upper limit, 6 and 8 NOK/kg/year. The lower limit denotes the price at which capacity can be sold out of the TAC-area, and the upper limit denotes the price of limitless amounts of new capacity.

The two decisions are made simultaneously. However, it is natural to decide on the desired ITQ holding first since both the TAC for the coming year and the available capacity is known and fixed. Capacity is adjusted after a one year delay reflecting real life delays due to planning, bargaining, retrofitting or building.

Finally, the players get some extra information to reduce the need for calculations. Here we explain these by the exact wording from the instructions:

"<u>Return on capital</u> is the "result before interest payment" as a percentage of the total book value (sum of year end capacity value and ITQ value). If your return on capital is less than the market interest rate of 6 percent per year, you would get a higher return by selling ITQs and capacity and thus increase your bank deposits. This is not necessarily correct however, if you expect the price of ITQs and/or capacity to increase over time. Then you will also make a profit because your book value increases. Note that there is no banker present to restrict your investments and loans. Thus, you must make sure yourself that you do not make bad investments. Finally note that return on capital varies randomly from year to year due to variations in fish prices, unit operating costs and in harvests."

"Break even ITQ price-long run is the maximum you could have paid for an ITQ last year and still have covered all costs of fishing (variable and fixed operating costs, depreciation and interest payments on the book value of capacity). The indicator builds on the assumption that your capacity equals your harvest. Since in some years the harvest will be lower than your capacity and in some years you will not utilise the entire quota, the indicator over-estimates the break even ITQ price. Like return on capital the indicator is subject to random variation."

"Break even ITQ price-short run is the maximum you could have paid for an ITQ last year if you only wanted to cover your variable operating costs. Like return on capital the indicator is subject to random variation."

Initial values are shown in Figure 1. Initial capacity is 800 tons/year and initial expected quota is 500 tons/year for all players.

Note the following about the experiment. With free competition between the firms, the equilibrium is a situation where the capacity is such that the rate of return equals the market interest rate. Since the marginal harvesting costs are constant in this experiment, there will be no quasi rent, i.e. no profits because average costs are lower than marginal costs. This fact will not distort the comparison between the two systems. However, when compared to real fisheries with considerable quasi rents, profits in the experiment will be biased downwards.

### 2.2. The ASQ treatment

The main difference between the ITQ and the ASQ treatments is the quota regime. In addition, data for last year are adapted to the quota regime, and the initial bank deposits are considerably larger in the ASQ than in the ITQ treatment. This reflects the assumption that when ASQ is introduced, current holders of established customs or ITQs are remunerated.

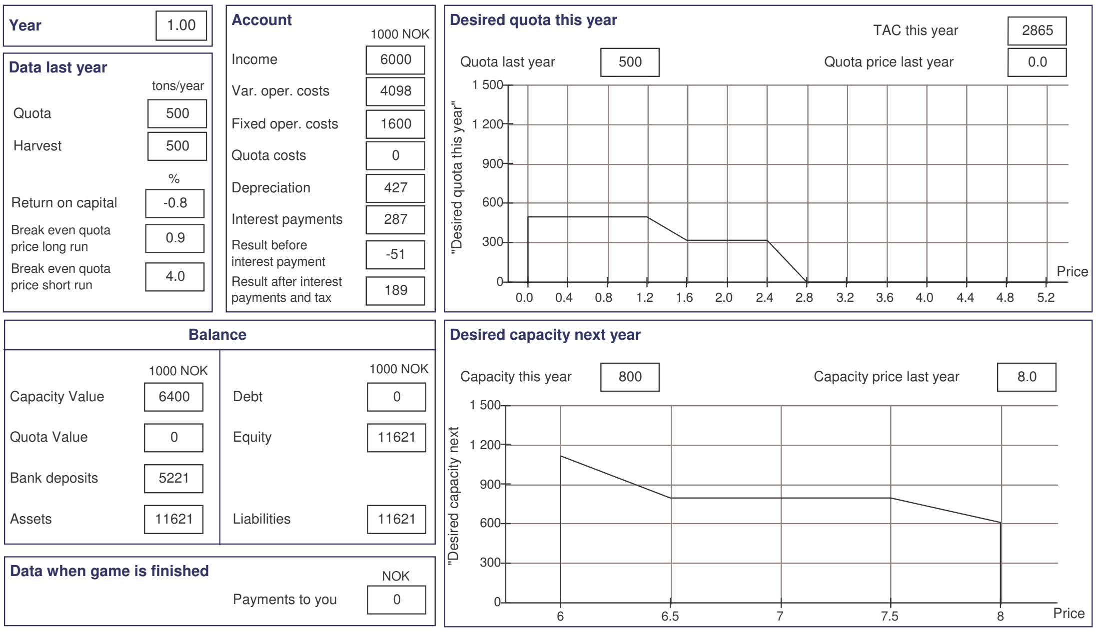


Figure 2: PC-screen for the ASQ treatment

Figure 2 shows the PC-screen. In this case the players use the upper graph to enter the desired seasonal (yearly) quota as a function of possible quota prices. As in the ITQ treatment, the players get to know the TAC and the available capacity before they make the quota decision. The players are also reminded of the last quota price. Based on all bid-curves, the computer finds the equilibrating quota price that allocates the entire TAC in accordance with the individual bids. Only monotonically decreasing curves are accepted, and the quota price is limited to the range from zero to 5.2 NOK/kg.

In the ASQ treatment the fish price is a more central variable than in the ITQ treatment. Therefore it is added to the section for data last year. The fish price minus the variable operating costs denote an upper limit for the quota price, referred to as the "break even quota price - short run" in the same section. The "break even quota price - long run" indicates the maximum payment for an ASQ when capital and fixed operating costs are added to the variable operating costs. The players get to know that these estimates are influenced by random variables, as in the ITQ treatment.

## 2.3. Hypotheses

We concentrate on the following hypotheses.

*2.3.1. Efficiency*

To judge efficiency we need a benchmark. The deterministic variant of the game (all random variables equal to their expected values) illustrates some basic properties of our experiment. In equilibrium, the sum of individual quotas would equal the TAC (3500 tons/year). Each player's capacity would equal that player's quota. The price of capacity would equal the market price of new capacity, and the quota price (ITQ or ASQ) would be such that each player in the market earns exactly the market rate of interest. That is, each player would be indifferent about staying in the fishing market or leaving it. Since all costs and prices are fixed (no returns to scale), there would be infinitely many equilibria ranging from one monopolist to four players (those with low unit operating costs) with equal market shares.

As indicated above, the optimal solution requires that all high cost producers sell their capacity to low cost producers the very first year. This is so because the unit operating costs follow players and not capacity. Thus the cost difference can be thought of as related to company efficiency, choice of fishing grounds, type of gear, location of home base etc.

When we introduce randomness, total capacity should no longer equal the TAC. Total capacity will reflect a trade off between having excess capacity in years with low TACs and having too little capacity in years with high TACs. The players get to know the uniform distributions of TACs and fish prices. Over time they have to learn about the distribution of their own unit operating costs from data in their accounts. The unit operating costs of others can only be guessed at from observed market prices of quotas and capacities. As a first approximation to the perfect benchmark, however, we assume that the players do have full information about the distributions of unit operating costs. Then we discuss the effects of limited information about unit operating costs.

In the idealised case the low cost producers start out with a considerable overcapacity after having bought out the high cost producers. Their choice is between selling excess capacity at a low price (6 NOK/kg/year) at once, or to keep excess capacity to avoid investments at 8 NOK/kg/year to replace scrapped capacity in the near future. By numerical optimisation[2] and an infinite time horizon[3], we find that the expected equity

2 Optimisation is performed by the program SOPS, see http://www.ifi.uib.no/sd/software.html.

3 We assume infinite horizon since equity in the final year includes the value of fishing capacity and ITQ holdings in the ITQ treatment. Observed subject behaviour suggest that the players interpreted the game similarly. The results show no clear signs of changed behaviour towards the end of the thirty year period.

is maximised by an immediate reduction in total capacity from 5600 tons/year to 4005 tones/year. Then capacity should drop to 3138 tons/year over a five year period and stay constant thereafter.[4] Hence in the steady-state situation, randomness implies that total capacity should be lower than expected TAC.

Since, even in this idealised case of optimisation, players need time to fine tune their estimates of expected variable operating costs, total capacity should converge to the benchmark path after a few years. Since aggregate market behaviour reflects averages of random variables, deviations should not be large and convergence quite fast. We formulate the following null hypothesis for actors that all behave rationally:

*H1. Total capacity will converge to the optimal path for low cost producers in few years time*

An alternative to H1 states that capacity will adjust slowly and will stay higher than the optimal path. The major reason for this is the complexity of the optimisation problem and the likely use of simple heuristics to guide decisions. The most important guide to capacity decisions is probably capacity utilisation. The initial total capacity is 5600 tons/year and the players know that the TAC varies between 1750 and 5250 tons. Depreciation will bring total capacity below the maximum TAC in one year. For how long the players are likely to let capacity drop with depreciation is hard to predict. However, from comments heard in debates about overcapacity, there seems to be a bias in the direction of thinking that there is no overcapacity as long as the total capacity is utilised at times. One indicator that may help reduce such a bias is the reported return on capital. However, this is a measure that varies considerably from year to year due to variations in the TAC, unit costs, fish prices, and quota prices.[5] Just and Weninger (1997) show how uncertainty slows down adjustments of capacity and ITQ holdings. Grafton (1996), Linder et al. (1992), and Anderson (2000) find slow adjustments towards equilibrium for the case where fish stocks are included in the analysis, different from our experiment. There could also be a status quo bias involved. Since it is difficult to figure out what the optimal size of capacity is, fishers may use the historical situation as an anchor. See evidence of this effect in another experiment with complex dynamics, Brekke and Moxnes (2003). Finally, in case of Herbert Simon’s satisfising, grandfathered ITQs will normally give returns on capital invested in fishing

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4 The capacity policy is not very sensitive to the following changes. Cutting capacity to the equilibrium level in just one year reduces equity by 1%. Letting capacity drop only with normal depreciation from the initial level of 5600 tons/year reduces equity by 5%. A time horizon of 30 years instead of 100 years (infinite) leads to a 0.2 % increase in the optimal long-term capacity.

5 In data from real firms the underlying variation is typically masked by cost items such as maintenance that are varied in pace with expected profits for the year.

capacity that exceed the market rate of interest. In the ASQ treatment, players are remunerated for their grandfather rights at the outset of the experiment. Hence, in both treatments the players have a financial cushion that may reduce the need to seek equity maximising strategies through capacity reductions.

The alternative to H1 is also motivated by observations in fisheries where the ITQ system has been implemented. Eythórsson (2000) refers to the Icelandic buy back programme initiated in 1994 as an indication “that the government’s expectations of the ITQ system as a measure for capacity reduction had not been fulfilled.”

Then we turn to a comparison of efficiency between the ITQ and ASQ treatments. We state the null hypotheses

*H2. The ITQ and the ASQ systems have the same effect on total capacity development*

We have no strong prior reasons to state an alternative to H2.

In the above optimisation we have assumed that high cost producers would be phased out in the first year. This is overly optimistic since cost differences between firms are not known a priori. However, in an idealised world, learning could be quite quick. We state a somewhat imprecise null hypothesis

*H3. The market share of high cost producers will tend towards zero over less than one decade.*

H3 is consistent with the Hayek hypothesis, which holds that prices contain enough information to direct the resources in the economy to their most efficient use. Previous tests of the Hayek hypothesis have typically shown a quick convergence towards equilibrium. However these experiments have assumed reliable and frequent feedback, Smith (1962). The alternative hypothesis is that an average cost difference of 14.3 percent for the variable operating costs (8.3 percent of the fish price) will not lead to much reduction in the market share for high cost producers over the time horizon of the experiment (30 years).

Note that if H3 is rejected, the benchmark for total capacity will be reduced. If we recalculate the benchmark capacity making the extreme assumption that all players are high cost producers, the first year capacity will be 3440 tons/year and the equilibrium capacity 2609 tons/year. Hence, if high cost producers remain in the market, the test of H1 will become a conservative one in case of over-capacity.

Then to the comparison of the effect on high cost producers in the two systems.

*H4. The ITQ and the ASQ systems have the same effect on the market share for high cost producers*

For H4 uncertainty in future ITQ prices, Just and Weninger (1997), and speculation in rising ITQ prices, are reasons for high cost fishers to hold on to their ITQ holdings. If so, they also have an incentive to maintain sufficient capacity to harvest what they have paid for. This effect could be fully offset in real markets where one can lease out the yearly quotas, and can be only partly offset if governments require ITQ holders to own a minimum of capacity. This leads us to state the alternative to H4 that the ITQ system will lead to a slower removal of high cost capacity than the ASQ system.

### *2.3.2. Prices and risks*

The market price of fishing capacity should drop to 6 NOK/ton/year in the first year and be in the range from 6 to 8 NOK/ton/year in the following five years. Since there is an upper limit to the price of fishing capacity in the experiment, and since there will be a rather steady need for replacements after five years, we expect capacity prices to remain fairly stable at the upper level after five years. We state no alternative hypothesis.

*H5. Average capacity prices equal the corresponding benchmark price*

We expect to see no differences between the ITQ and the ASQ systems.

*H6. Capacity prices do not differ between the ITQ and the ASQ treatments*

The benchmark for the ITQ price is found from the net present value[6], given the optimal benchmark capacity development. Initially the price is 24.2 NOK/ton. It decreases to 22.8 NOK/ton as capacity is reduced to its long-term level after five years. Prices should remain stable since any departure from the benchmark should lead to counteracting market operations.

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6 The ITQ price equals the difference between the present value of equity (discounted by the interest rate after tax) and the initial equity (capacity valued at the export price of 6 NOK/ton/year due to overcapacity), divided by the total amount of ITQs, 3500 tons/year.

*H7. Average ITQ prices equal the corresponding benchmark price and are stable*

The alternative hypothesis for the ITQ price is a price path that starts low and then exceeds the benchmark for long periods. At least four factors may play a role. First, uncertainty about the fundamental value of ITQs, implies learning. As the game starts, ITQs have no explicit price, such that zero may serve as an anchor that leads to a downward bias when it is blended with the suggested break even ITQ price. Over time the historical anchor will move upwards, as if expectations are adaptive, and this will lead to a price increase during the early years and to smooth prices at later points in time. Second, uncertainty and expected price variations suggest that it is possible to buy at low and sell at high prices, implying high demand in early years. Third, the ITQ market may be seen as "the only game in town" since selling out and earning interest on bank deposits is an option with no action and no uncertainty, see Lei et al. (2001). This could be seen as an artefact of the experiment, however, many real fishers are also likely to be hesitant to leave the business that they know and enjoy. Fourth, there is the possibility of speculation and price bubbles. This behaviour has been found in experiments with declining underlying asset values, notably Smith et al. (1988), and in an ITQ experiment with a limited lifetime of ITQs of four years, Anderson and Sutinen (2005). In our case, the ITQs have an infinite lifetime such that speculation should seem less risky than in the experiments with limited lifetimes. Hence, the probability of price bubbles should be at least as high as in previous experiments. Possible price increases during the early years, due to the two first reasons, may give rise to expectations about further increases in ITQ prices. That could start off a bubble. Considerable natural variation in combination with speculation could lead to considerable price variations over time and possibly repeated bubbles and crashes.

In the benchmark for the ASQ treatment the social optimum is ensured through competition. Whenever the TAC is lower than the fishing capacity, the price of an ASQ is 5 NOK/kg, equal to the expected fish price of 12 NOK/kg minus the expected unit variable operating cost of 7 NOK/kg for the low cost firms. Whenever the TAC exceeds capacity, the benchmark ASQ price equals zero. Given these ASQ prices, capacity is adjusted such that the marginal return to capital tends towards the market interest rate. Thus, the ASQ system should also lead to the socially optimal total capacity of 3138 tons/year. Repeated Monte Carlo simulations over a 5000 year period with a simple investment strategy come close to this result and give an average ASQ price of 1.96 NOK/kg. Hence in these benchmark simulations, the ASQs have a price of 5 NOK/kg 39% of the time. If the capacity is higher than the socially optimal capacity, as it is initially, the ASQ price will equal 5 NOK/kg more frequently and the average ASQ price will be higher.

*H8. ASQ prices are 0 NOK/kg whenever the TAC exceeds the total capacity; otherwise they are 5 NOK/kg.*

An alternative hypothesis is that ASQ prices will be declining gradually with increasing TACs relative to total capacity and that the ASQ prices will be somewhat lower than the benchmark. A declining tendency results if the subjects maintain different expectations about the break even ASQ price (fish price minus randomly varying operating costs). If the TAC is very low, only the subjects that believe the break even price is above 5 NOK/kg and bid accordingly will get quotas. If the TAC is just below the total capacity, almost everybody is likely to get their demanded quotas, at a price just above the lowest bid. TACs exceeding total capacity should still lead to zero quota price.

A lower price than the benchmark could result if subjects think that every year should contribute somewhat to fixed operating costs and to capital costs. If players experience that other players behave accordingly, a norm may develop for how much one needs to bid to obtain quotas.[7] If low cost producers do not take over the entire market, the high cost producers will also contribute to a lower ASQ price since their expected maximum bid is 4 NOK/kg.

An important aspect of fishery policy instruments is their effect on risk and survival of fishing firms. We formulate no specific hypotheses for the two instruments. Regarding a comparison between ITQs and ASQs we state the null hypothesis

*H9. The risk for fishers is the same with the ITQ and the ASQ systems.*

An alternative hypothesis holds that the ITQ system poses the greatest risk. This is because variations in the ITQ price influence the value of the entire ITQ holdings of a firm, Gylfason and Weitzman (2003), while variations in ASQ prices only influence yearly cash flows. We measure risk by the number of cases where equity becomes negative and by the average standard deviation of return on equity.

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[7] Typically, experimental markets produce prices between the Nash equilibrium and competitive prices. This has also been the case in experiments where quotas have been used to correct for externalities, Plott, C.R. (1983). "Externalities and Corrective Policies in Experimental Markets." *The Economic Journal* **93**(march):106-127. However, previous experiments have not been as complex as ours with respect to fishing capacity and natural variation. Our pricing institution is also somewhat different from those used previously.

*2.3.3. Concentration*

As argued in connection with H3, concentration should increase as high cost producers disappear from the market. From the point of view of efficiency, this is a desired effect of both regimes. Here we consider another aspect, the possibility that concentration increases for other reasons than efficiency, for instance due to differences in risk aversion and ambition. This can be measured by the tendency towards concentration within the low cost group and within the high cost group. In each of these two groups, the players have the same cost parameters such that cost differences cannot explain possible increases in concentration.

We will observe concentration in the two cost groups in each of the treatments; however we state no explicit hypotheses about the levels of concentration. A major reason for this is that we find it difficult to formulate a benchmark. Since there are no new entrants and all players start with the same initial market share, concentration is bound to increase whenever one of the players changes her bids for ITQs or ASQs from the initial distribution. We also note that the experiment only provides a partial test of concentration. It does not capture potentially important differences among actors regarding business strategies, locations, bank connections etc. As already mentioned, experiments may bias outcomes towards even distributions, Lei et al. (2001) or towards initial allocations Brekke and Moxnes (2003). Hence, what we observe in the experiment should only be seen as a first indication.

For the comparison of the two policy instruments we state the null hypothesis

*H10. Concentrations will be the same in the ITQ and the ASQ systems within the groups of low and high cost producers.*

*2.3.4. Fairness*

We consider fairness in terms of distributions between the firms and the government and among the fishing firms. Economic texts usually assume that with the ITQ system, the fairness issue is settled initially. Fishers are given ITQs based on established customs (grandfathering) or they buy the ITQs from the government for instance in auctions.

In reality several factors may bring up the fairness issue over time. First, the initial allocation may be seen as unfair. Second, people may erroneously perceive high yearly profits as a windfall, ignoring the capital costs of holding ITQs (this point is most easily seen for those that have bought and not received ITQs for free). Third, the ITQ values may increase over time due to increasing fish prices, greater TACs, lower harvesting costs, and lower discount rates, creating real windfall profits to the ITQ owners over time.

We do not investigate perceptions of fairness among the players. Rather, we measure how the profits are shared between firms and government for the two policy instruments. Recall that initially firms in the ASQ treatment receive remuneration for their grandfathered rights. If this money is saved in bank accounts, it should earn comparable returns to the grandfathered ITQs. Hence we state the null hypothesis

*H11. With initial remuneration of grandfathered rights in the ASQ system, both systems should yield the same distribution in present value terms between firms and government.*

Perceived unfairness of the systems may provoke attempts to introduce taxation of the resource rent in the ITQ case. However, if at that time some ITQ owners have low equities, a new resource tax may be seen as causing bankruptcies. This is one reason why it is also important to consider distributions between fishers. We observe the distribution of firm equities. We state the null hypothesis

*H12. Distributions of firm equities will be similar in the ITQ and the ASQ systems.*

### 2.4. Other aspects of the design

Participants were randomly assigned to markets and placed in cubicles. Thus, they could not know who the other participants in their own market were. Written instructions were available and read aloud by the experiment leader. Participants asked quite a few questions about how to operate the game and about definitions of the performance indicators. A blackboard, graphs and equations were used to clarify. Most sessions with two treatments took around two hours to complete. All sessions used the same sequence ITQ first and ASQ last, a sequence that should be reversed if more sessions are added. Average payoffs were close to NOK 200 (comparable to typical student wages).

There were all together five markets. Participants in two of the markets were master students in system dynamics at the University of Bergen. Three groups were economics students at the University of Bergen (at various stages of their university study). After the first two groups had played, we changed the instructions somewhat to remind the players that keeping the money in the bank is sometimes better than investing in the fishery business (under the heading Return on Capital in the final instructions). We also changed the definition of Return on Capital to include the value of the ITQ holdings in the measure of total capital (in addition to the capacity value). The changes probably had little effect since the overall results of the economics students fell between those of the two system dynamics student groups.

The experiment was programmed in Powersim Constructor, which allowed for simple programming and fast exchange of information between the networked computers.

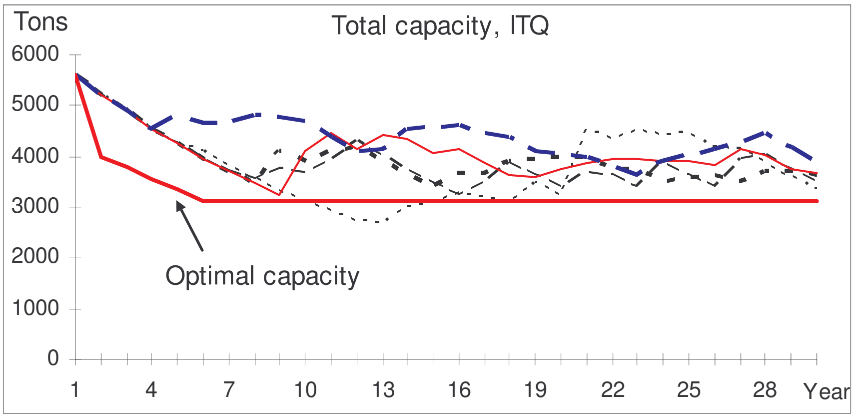
In the results section we will also mention results from three pilot experiments. Two with students from the Norwegian School of Economics and Business Administration in Bergen, and one primarily with researchers in economics. The latter group did not have a monetary incentive to perform. In these three pilot experiments there were no upper limits for individual shares of the total amount of ITQs, there were increasing marginal operating costs, the experiments did not last for 30 simulated years (due to the slow working of the initial Excel version of the experiment), plus several more cosmetic differences.

## 4. RESULTS AND DISCUSSION

We present the results in the same sequence as the hypotheses.

### 4.1. Efficiency

Figure 3 shows that all markets, for both the ITQ and the ASQ systems, start out with normal depreciation and zero new investments, with the exception of one market in the ASQ treatment where some capacity is sold out of the market. Consequently, there is a clear tendency for capacities to fall with normal depreciation. Recall that this is a strategy reduces the net present value by 5 percent compared to the benchmark strategy where a considerable amount of capacity is sold out of the market the first year. In the longer run all groups end up with capacities that are larger than the benchmark. The averages (medians) over groups are significantly higher than the benchmark (at the 5-percent level) in most of the 29 years: 22 (22) in ITQ and 20 (24) in ASQ. If all years are seen as independent observations, the overcapacity for the entire period would be highly significant. Hence we reject H1, total capacity does not converge towards the optimal capacity in any of the treatments. The alternative hypothesis about overinvestment seems more likely.



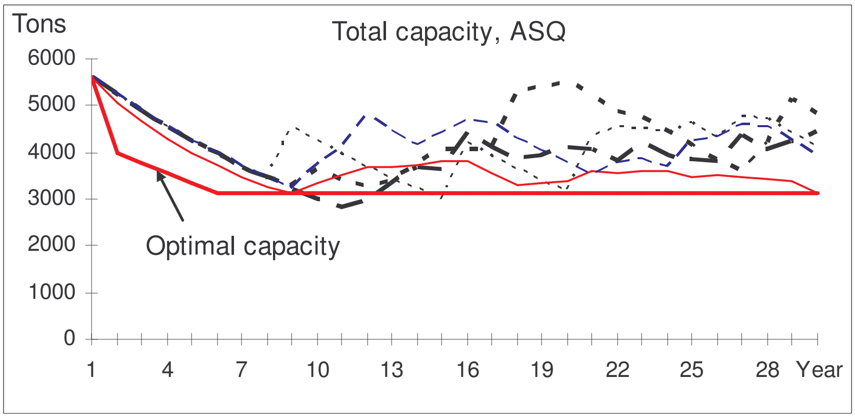




Figure 3: Benchmark and total capacity for each of the five markets in both treatments.

There is no significant difference between the two treatments with respect to capacity. Thus we cannot reject H2.

Then we turn to the fraction of high cost fishers. Unit operating costs are 14 percent higher in high cost firms than in low cost firms; unit operating costs are respectively 67 and 58 percent of the fish price. In spite of this difference the market share of high cost firms does not decline much over time with any of the two systems, different from the benchmark, see Figure 4. Average market shares of high cost producers are significantly greater than the benchmark. The average market shares over the last 25 years of the experiment are respectively 38 and 37 percent for ITQ and ASQ. Only 5 and 4 observations of average market shares are significantly below the initial market share (43 percent) for respectively ITQ and ASQ. Regressions show no significant declining trends. Hence, we reject H3; market shares of high cost producers do not tend towards zero.

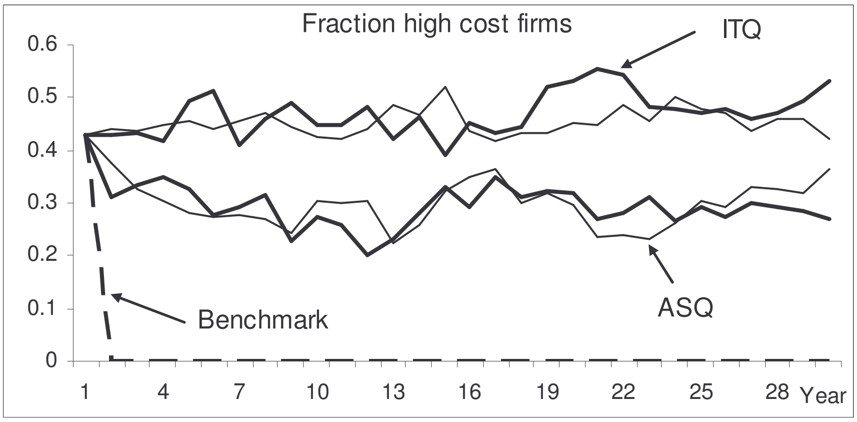



Figure 4: 2.5 and 97.5 percentiles for the average fraction high cost firms in the ITQ and ASQ treatments.

Figure 4 shows almost perfect overlaps of the two confidence intervals. Hence we cannot reject H4; the two systems seem to have the same effect on market shares of high cost firms. The average fraction is 0.38 in both treatments.

An analysis of equity relative to benchmark equity is still lacking and will be inserted here, as well as an attempt to quantify where the losses come from.

### 4.2. Prices and risk

Figure 5 shows 2.5 and 97.5 percentiles for average capacity prices for the two treatments. In the early years the market clearing prices are in the interval from NOK 6 to 8 per kg/year, indicating that all the trade is between the participants with no ordering of new capacity or sales out of the fishery, with one exception of net sales in the ASQ treatment. In the long run the prices are equal to NOK 8 per kg/year most of the time, signalling ordering of new capacity. Most markets have an episode or two where capacity is not replaced and with prices slightly below NOK 8 per kg/year. With the exception of the first year, when fishing capacity should be sold out of the market, capacity prices are not significantly different from the benchmark. Hence, we do not reject H5 except for in the first year for the ITQ system.

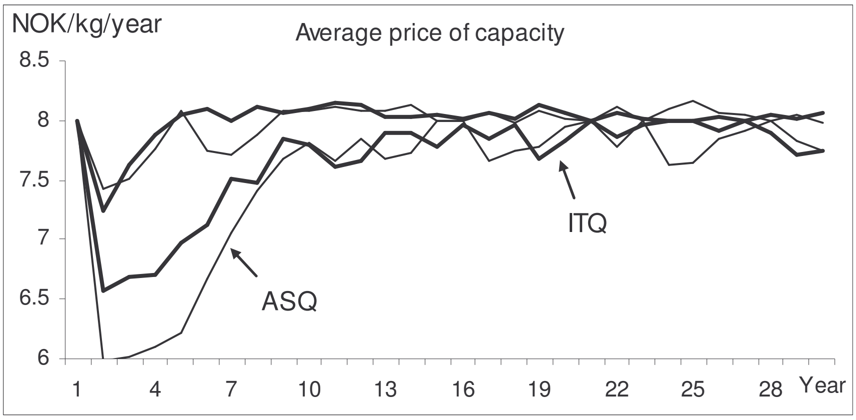



Figure 4: 2.5 and 97.5 percentiles for average capacity prices for the ITQ and ASQ treatments.

Figure 4 shows that there are no significant differences between the ITQ and the ASQ treatments; this is easily seen from the overlapping intervals. Thus, we cannot reject H6.

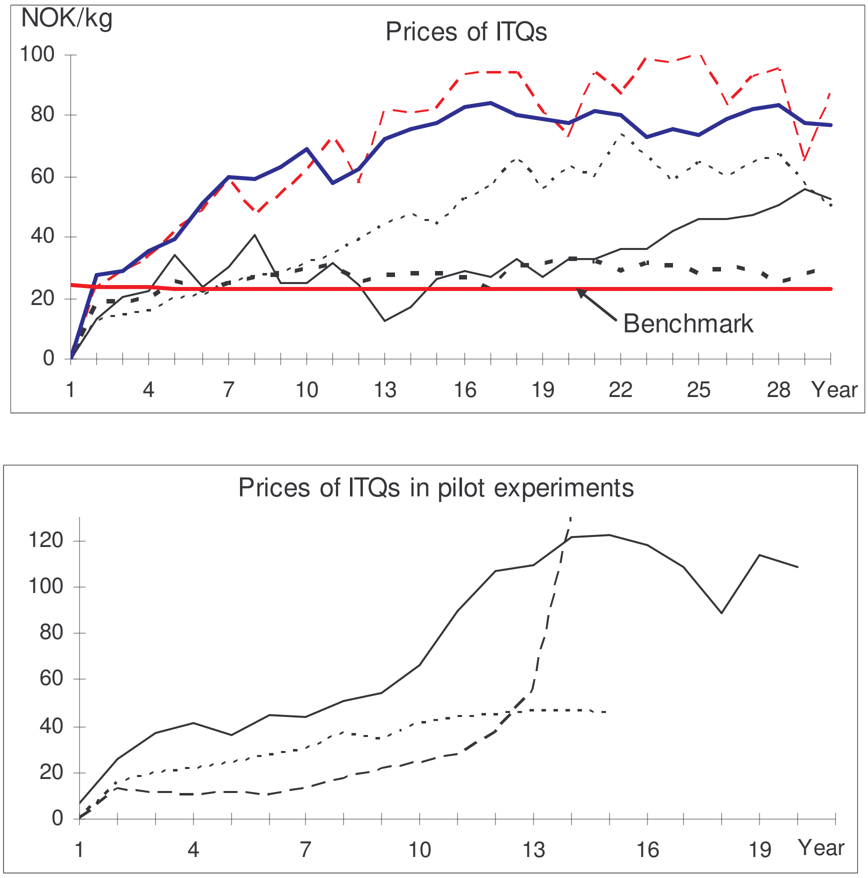



Figure 5: Prices of ITQs in the five markets (upper) and in three pilot experiments (lower).

Figure 5 shows the development of ITQ prices in the five groups. The average price over all five markets is slightly below the benchmark the two first years.[8] Thereafter it is higher than the benchmark. For instance over the last 20 years the average price is NOK 57 per kg, 150 percent above the benchmark. The average (median) price is significantly higher than the benchmark at the 5-percent level in year 8 and in all years after year 18 (all years after year 6 with two exceptions). If the prices are seen as independent over years, the deviation from the benchmark is highly significant. Thus, we reject H7 and notice support to the alternative hypothesis saying that prices will start low and increase over time.[9] In addition we observed price fluctuations that last for only a few years. Similar tendencies are seen in the three pilot experiments.

It is interesting to note that the traded volumes of ITQs are similar to the volumes observed in real ITQ-fisheries. The first 8 years 11.0 percent of the total ITQ holdings were traded, in the next 8 years 9.5 percent, and in the last 9 years 7.8 percent. Hatcher et al. (2002) report that traded volumes in most fisheries have been in the range 10-20 percent per year. Hence, the behaviour we see in our experiment is not explained by exceptionally low or high trading activity.

Next we consider the ASQ price. Figure 6 shows that prices in all five markets fall in the predicted range from 0 to 5 NOK/kg. Prices vary from year to year. However, they are not as volatile as suggested in H8, not being either 0 or 5 NOK/kg. Hence we reject H8. Rather prices tend to fall in the interior region most of the time.

The lower part of Figure 6 shows how the ASQ prices vary with the ration of the TAC to the total capacity for Market 1. The scatter plot tends to support our alternative hypothesis that prices will increase gradually when the TAC decreases relative to the total capacity. A simple linear regression comes out with highly significant coefficients. Similar results are obtained for the other four markets.

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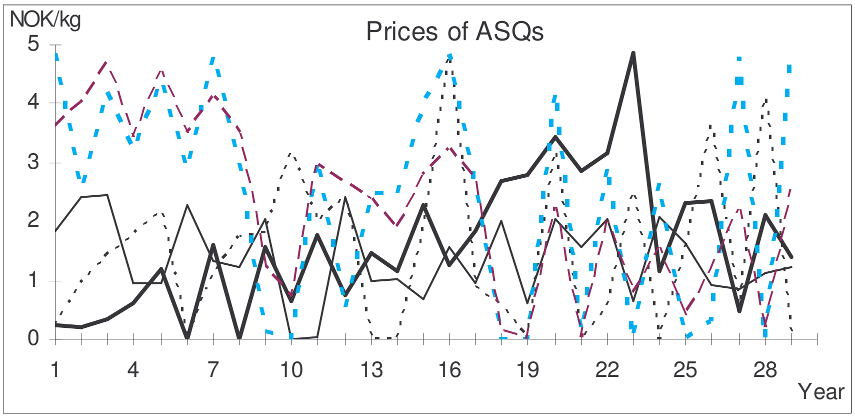
8 The first year the p-value is 0.18 (0.18) for the average (median).

9 One player figured out a weakness of the pilot experiments. By buying all quotas, he was able to bid up the price of his own ITQ holdings and thus get a huge equity at the end of the game, with no risk of a fall in ITQ prices.



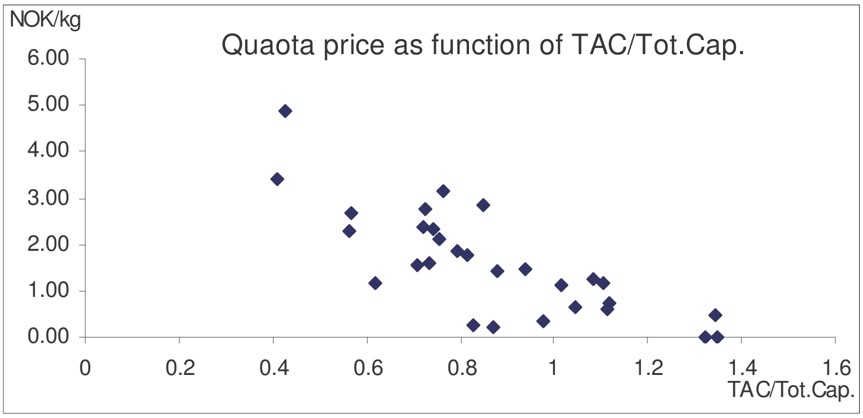




Figure 6: Prices of ASQs in the five markets (upper). Scatterplot for Market 1 (lower).

To compare the risk of negative equity, we first count the number of instances where a firm gets negative equity one or more times. In the ITQ (ASQ) treatment 2 (4) out of 20 players with low costs experience negative equities, and 4 (7) out of 15 players with high costs get negative equities. To test for differences between the two treatments we use a two-related-samples sign test. We find no significant difference (p=0.27) and cannot reject H7 based on this test.

Then we consider the variation in equity from year to year. First we calculate increases in equity from year to year for each individual. Figure 7 shows the increases for both ITQ and ASQ together with a normal return to equity (equity times interest rate after tax, 4.32 % p.a.). Next we find the standard deviation from year 3 to year 30 for each individual. For ITQ the average standard deviation over individuals (standard deviation of average) is 3565 (367) while for ASQ it is 958 (60). The difference is highly significant and this is a reason to reject H7.

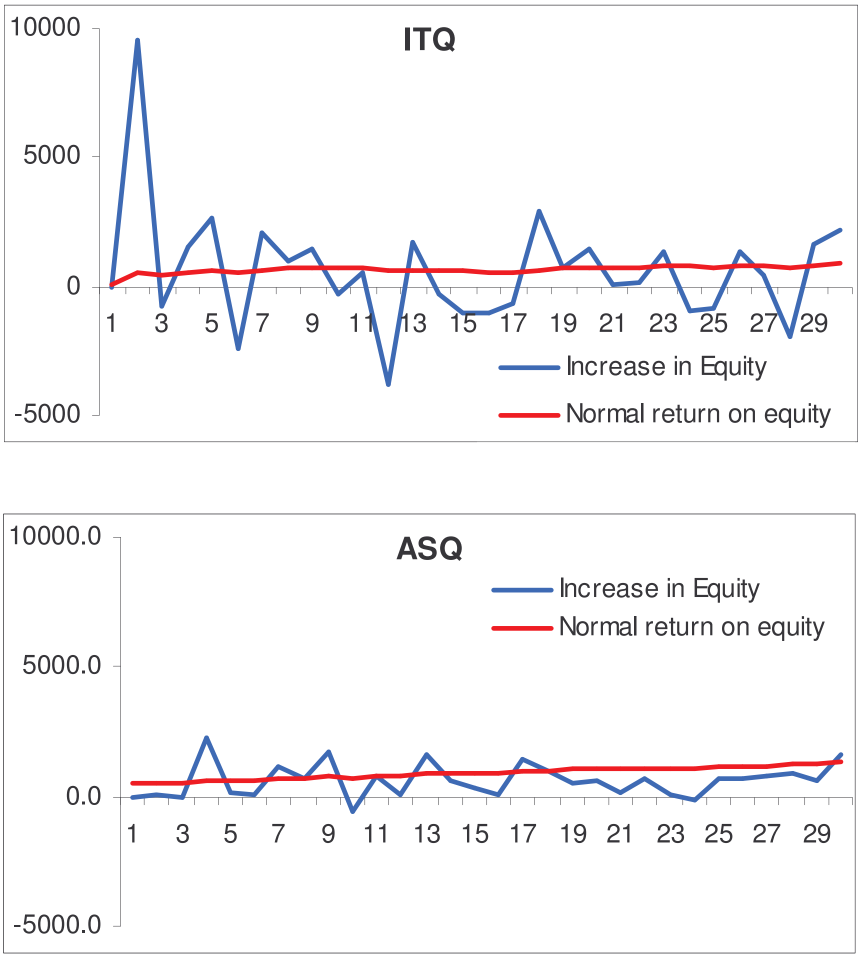



Figure7: Increase in equity and normal return on equity, ITQ and ASQ treatments, group 1 player 3.

### 4.3. Concentration

Figure 8 shows the Herfindahl indeces[10] for capacity for low cost producers in all markets in the two treatments. As argued before the index cannot decrease when there are no new entries in the market. Initially the index is 0.25 with 4 equal firms. A concentration towards 3 equal firms gives an index of 0.33 and towards 2 equal firms an index of 0.5. The latter is about as high it ever gets in any of the markets.

10 The sum of squared market shares.

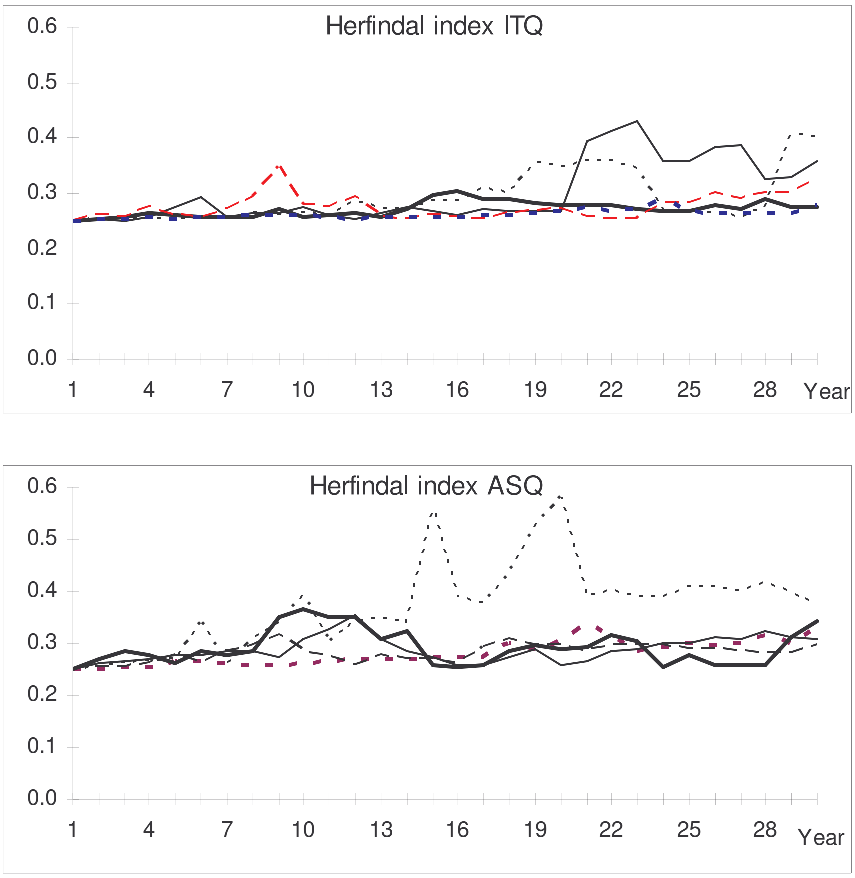



Figure 8: Herfindahl indeces for capacities for low cost producers in different markets, ITQ (upper) and ASQ (lower)

The average Herfindahl index for the years 10 to 30 for low (high) cost producers is 0.29 (0.43) in the ITQ treatment and 0.31 (0.38) in the ASQ treatment. All differences are highly significant. We cannot reject H10 however note that the differences are small.

### 4.4. Fairness

This part is still lacking. We will consider distributions of equity among fishers and between private and public sector. What is clear is that there is considerable variation in equity between fishers, even among those with identical costs. Total equities are much lower than benchmark equities.

## 5. CONCLUSIONS

We have conducted a laboratory market experiment to investigate the appropriateness of two systems for fishery regulation, individual transferable quotas (ITQ) and auctioned seasonal quotas (ASQ). Different from most laboratory market experiments, fleet capacity is dynamic and updates from year to year. This is a very important aspect of the experiment since the main motivation for implementing the ITQ system is overcapacity. ITQ holdings are also kept track of from year to year. The market institution ensures a perfect equilibrium given the players' bid and offer curves.

We have found that neither the ITQ nor the ASQ system ensure full efficiency. Fishing capacity is systematically too high and high cost firms do not disappear from the market, in spite of the participants' monetary incentives to behave optimally. The major reason for inefficiency is mismanagement. The participants suffer from lack of precise information, they have to deal with stochasticity, they must handle a dynamic investment problem, and they are in a gaming situation that requires strategic thinking. None of the two market institutions serve to provide perfect information for the decision makers to solve these problems. Price information, as suggested in the Hayek hypothesis, is not sufficient to solve the management problems. It is likely that more time, expert advice, experience etc. would lead to higher efficiency. On the other hand, it is know from numerous other management experiments that some of these problems tend to persist. Importantly, our experiment does not suggest that the ITQ and ASQ systems lead to worse outcomes than other market systems. Rather, the experiment suggests that dynamics and stochasticity can lead to inefficiency of any market of that type.

With the ITQ system we find a tendency for ITQ prices to start low and then increase for a long period. The beginning is probably dominated by a bias towards free quotas, then speculation in future price escalations seem to dominate. Different from the price bubbles observed for assets with limited lifetimes, we observe ITQ prices that tend to stay above the fundamental value. Such a tendency serves to make the barrier to entry higher and it makes it more risky for entrants. Ideally newcomers should not enter a market where they cannot obtain a higher return than the bank interest. On the other hand, if the (overvalued) market price for ITQs is taken as the best indicator of the fundamental value, newcomers could be lured into entering.

With the ASQ system, fishers have to compete and pay for seasonal quotas. At the outset this is just like other markets where one has to compete and pay for raw materials. The experiment shows that ASQ prices vary with the ratio of the total allowable catch (TAC) to the total fishing capacity. Since different players have different perceptions about their current costs, and have different strategies, the ASQ price will vary gradually with the mentioned ratio.

Probably surprising to most people, it seems that the ITQ system leads to greater risks for fishers than the ASQ system. While there is no significant difference between the number of fishers going bankrupt, variations in equity from year to year is significantly larger with ITQ than with ASQ. The main reason for this is that the ITQ price influences the value of the entire ITQ holding, while the ASQ price only influences the costs of one season's catch.

The experiment does not reveal strong tendencies towards concentration. The removal of high cost capacity is very limited. Among fishers with identical costs, there is also a certain tendency towards concentration. This is somewhat stronger among high cost than among low cost fishers. While the effects are not strong in the experiment, it demonstrates that concentration could take place for other reasons than higher efficiency. Higher ambition could for instance be a cause. Hence it also suggests that ITQ and capacity trade is not necessarily a proof of differences in efficiency.

The experiment provides some insights about fairness. For both ITQ and ISQ we observe the obvious; some fishers will always struggle with low profitability. This is also the case with permanent and free ITQs when one is aware that ITQ owners should earn rent on the asset value of their ITQ holdings. Since this point seems easy to miss, above normal returns to investments in capacity may be seen as unfair. We also observe great variation of equities between players. Again more resources for the players would probably have reduced this spread. On the other hand, the complexity of the task allows for a wide spectre of strategies, some successful and some not. Hence, the spread we observe could be one of the causes of so-called X-inefficiency, Leibenstein (1966).

While the two systems are quite similar in many respects, as one should expect from theoretical considerations, there are also some differences that should lead to increased interest in the ASQ system. The ASQ system has lower barriers to entry, it seems less risky to fishers, it taxes the resource rent and may thus be seen as more fair. The ASQ system is likely to provide more reliable price information for the process of setting TACs, since ITQ values may be influenced and biased by speculation. This seems important, particularly when setting TACs in multi-species fisheries. The ITQ system, if implemented, may create a barrier for a subsequent implementation of the ASQ system. This is so if ITQ prices are inflated such that late entrants face bankruptcies if they loose their permanent rights. The same mechanism also makes it difficult to implement resource taxation in the ITQ system. In any case it seems fair and correct to remunerate fishers with custom rights when implementing the ASQ system, however at reasonable prices.

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