Biological information, profitability of fisheries and lease and asset prices for ITQs in Iceland

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Abstract. Fisheries economists have studied fisheries managed with ITQs and compared them to fisheries that are differently managed. Most of these studies have found ITQs to be economically superior. This paper studies the ITQ-fisheries in Iceland. It focuses on features that are difficult to explain using traditional fisheries economics. It is shown that lease prices for quotas are extremely high compared to the profitability of the fisheries. The persistence of this state of affairs reveals reluctance to exit from the fisheries. The paper discusses also predictions from traditional fisheries economics concerning correlation between prices of quotas and size of the stocks. It is shown that some of these predictions are not valid in the Icelandic case. This reveals some scepticism (or ignorance) among fishermen about the predictions of bioeconomic models, especially the biological part of these models. Whoever is right, this scepticism does matter for the efficiency of policies.
The ITQ-system makes it possible to measure and test the behaviour of fishing firms in economic terms. What this paper reveals about Icelandic fishing firms is probably present in other fisheries as well. There are even reasons to expect that they are less important in Iceland than they are elsewhere.

Keywords: ITQ-fisheries, Biological information, Profitability, Lease price of quotas, Price of quota shares.

1. Introduction

Fisheries economics has developed powerful tools to explain and predict behaviour of fishermen. In many cases the theory has been extremely successful. The analysis of open access fisheries and the tragedy of the commons, of the race to fish in fisheries open for limited periods of time and of capital stuffing in fisheries managed with licences have been proved correct too many times.[1] In other cases the success is not equally clear. Efforts to diminish capacity, e.g. by using decommissioning, have frequently been unsuccessful. There seems to be more inertia in firms exiting from the fisheries than traditional economic theory would lead one to expect. There are examples of decommissioning schemes where the main complaint was that the fishing firms that accepted decommissioning were so completely bankrupt that the equity of the firm was negative even after the decommissioning payments![2] Some of the inertia against exiting from the fishing industry can be explained by uncertainty and sunk costs in the spirit of the new investment theory.[3]

Another area where fisheries economics has not been sufficiently successful is in convincing the fishermen about its legitimacy. This is somewhat odd as fisheries economics predicts that successful fishermen will gain enormously from sensible fisheries management based on this theory. Frequently successful fishermen respond to such predictions by saying: "you cannot store the fish in the ocean as you can store your money in the bank." Even if the statement is formulated in economic terms it probably express more scepticism about the biological basis of fisheries economics than about the economic one.

Management of fisheries with Individual Transferable Quotas (ITQs) is one area where fisheries economics has had considerable success. In the theoretical literature this system of management has been shown to be optimal under fairly general conditions and empirical investigations have shown that this system seems to be superior to the alternatives in many cases.[4] This paper will not discuss the relative merits of ITQs but focus on certain features that seem to be at variance with the predictions of the traditional theory. It is probable that these features exist in most fisheries, but they become apparent and easily measurable and testable through their effects on the economic variables in the ITQ-system. The paper will use data on profitability and on quota prices in the Icelandic fisheries to show the inertia against leaving the fishery. It will also use these data to investigate if the quota prices reflect the biological information given by the Marine Research Institute (MRI) in Iceland and the fisheries economics that are the basis of the quota rule that has been used for managing the cod stock since 1995.

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[1] See Wilen (2000).
[2] See Holland e.al. (1998).
[3] See Danielsson (2002b). For the new investment theory see e.g. Dixit and Pindyck (1994).
[4] See Sutinen (1998).

All important fisheries in Icelandic waters have been managed with ITQs since 1984. Until 1990 the system was not uniform and trade in quota shares was only allowed if the vessel that the quotas were attached to was also traded. Since 1991 the system has been largely comprehensive. The main exception has been a special system for vessels below 6 GRT that use hand-line and long-line. There is also some experience with a quota rule for cod, which has been in use since 1995. This rule can be used for forecasting the size of the cod stock. The quota rule and the bioeconomic model of the Working group that proposed the quota rule[5] lead to some testable predictions about the relationship between the size of the cod stock and the quota prices. Rejection of these predictions can imply that the agents are not as rational as the biologist and economist of the Working group, but it can also imply that some of these predictions are simply incorrect.

It should be noted that large fishing firms are relatively important in the Icelandic fisheries. Stock companies that are registered on the Icelandic Stock Exchange control almost half of the quotas. One would expect that such firms use more of scientific (academic) knowledge in their decision-making and that considerations concerning sunk cost of labour skills and the value of independence that small-scale fishermen sometimes feel do not enter their decisions on whether to remain in the fishing industry.

The rest of the paper is organised as follows: Section 2 describes data on revenue and profits from the Icelandic fisheries before all costs of quotas and the lease value of the quotas for most of the important quota species. It is shown that the profits are far below the lease price of the quotas. Section 3 examines the predictions of fisheries economics about the relationship between the stock size and the ratio of the asset price and the lease price for quotas. It finds that this price ratio should decline as the size of the stock increases. Section 4 examines this relationship empirically and finds that this price ratio increases with the size of the stock. Section 5 discusses that theory predicts that prices of quota shares in terms of kronors per 1% should move smoothly when a new quota year starts. The prices in terms of kronors per kg of allocated quota in the quota year should, on the other hand, change to allow for the changes in the allocated quotas. In Iceland the prices of quota share for cod (and most other species) are quoted in terms of kronor per kg of allocated quota. Data seems to indicate that this fact influences the movement of prices so that it is the price of the quota share for cod in terms of kronor per kg of allocated quota that moves smoothly while the price in terms of kronor per 1% jumps in September, at the start of the new quota year, in accordance with the changes in the allocated quotas. Section 6 analysis if new information on the conditions of the cod stock published in May each year by the MRI affects the price of the quota share. It finds that there is very weak indication that this is the case. Section 7 concludes.

2. Lease price of quotas and profits

Table 1 shows revenue and net profit from Icelandic fisheries before all costs of quotas during the period 1992-2000. The table also shows the lease value of the fishing rights for the most important species estimated on the basis of total landings and the average lease price for the quotas. Some species had to be left out because of lack of data on the lease price of quotas. The most important of those that have been left out are capelin, Icelandic herring, the Atlantic-Scandinavian herring and scallops. The important capelin and the Icelandic summer-spawning herring could only be included for some years. To make the data comparable some fishing rights that are not in the form of ITQs have been valued using the lease price of the quotas.

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Revenue	48,345	50,923	51,698	53,592	57,523	56,643	59,483	60,729	60,858
Net profits	1,630	1,670	783	2,484	1,997	188	3,116	2,809	3,603
Lease value of quotas	14,837	12,072	14,462	20,645	21,951	23,429	24,516	30,287	30,615

Table 1: Revenue, net profits and the lease value of the quotas for cod, haddock, saith, redfish, greenland halibut, plaice and shrimp. Unit: Millions of Icelandic kronors. Source: National Economic Institute.

In all years the lease value of the quotas far exceeds the net profits of the fisheries. If the lease value of the quotas had been subtracted in the firms' accounts the fisheries would not have shown profit but huge losses in this period. In 1992 there would have been losses amounting to 27% of the revenue instead of a profit of 3% and in 2000 the losses would have been 44% of the revenue instead of a profit of 6%. What is especially noteworthy in table 1, and shows clearly the inertia against exiting from the fishing industry in Iceland, is that the lease value of the quotas far exceeds the net profits not only during some years, but that this is the case for all the years

[5] See Working group (1994). See also Danielsson e.al. (1997).

shown in the table. When data for 2001 and 2002 will be available this persistency in this relationship between the net profits and the lease value of the quotas will continue.

It is to be expected that the ratio of the lease prices for the quota and the first hand sales prices at the Auctions are different for different species. The theory would predict that the profitability is different and that this would be reflected in the quota prices. There are no estimates of the profitability of fishing for the individual species.[6] Figure 1 shows, therefore, the ratio of the lease price for the quota and the first hand sales price at the Auctions for three important groundfish species.

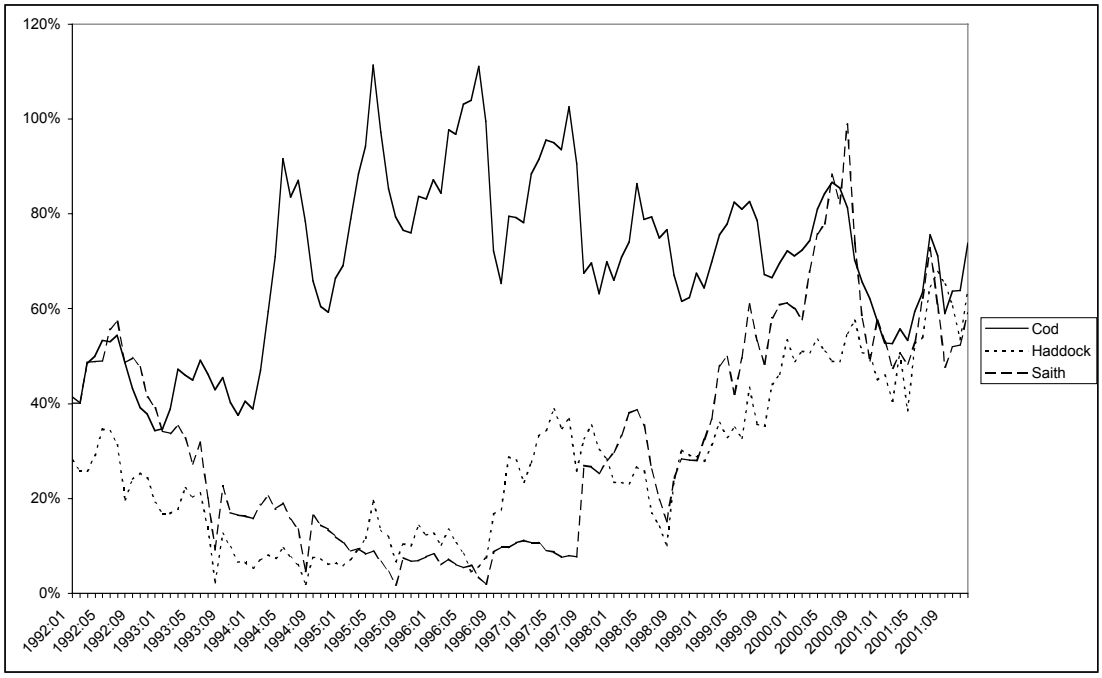

Figure 1: Ratio of lease price of quota and (Auction) market price of the fish Jan. 1992-Dec. 2001. Source: National Economic Institute.

It should be noted here that there are some restrictions on leasing quotas. A vessel looses its quota shares if it does not fish at least half of its quotas in one of two consecutive years. It is also forbidden to transfer more than 50% of the allocated quotas in one year to other vessels. The vessel-owners have shown considerable ingenuity in finding ways to get around these rules. There are no comparable restrictions on the trade in quota shares.

3. Theoretical relationships

Traditional fisheries economics makes certain predictions about quota prices in ITQ fisheries, both the lease price and the asset price. The lease price in period t (ρ_t) is equal to the marginal profit from fishing in that period. It is commonly assumed that the cost is linear in the harvest. If the agents are price-takers then

$$\rho_t = p_t(h_t) - c \cdot g(B_t, B_{t+1}) \qquad (1)$$

where p_t is a unit price of harvest, h_t is the total harvest (which is equal to the total quota), c is a constant, g is a monotonically decreasing function in all variables and B_t is the size of the fish stock by the beginning of period t. Equation (1) shows that the lease price of quotas will change with the size of the stock. These changes will depend on the quota rule, which gives the total quota/harvest as a function of the stock size, the elasticity of demand and the form of the function g.

[6] Danielsson (2000) and Danielsson (2002a) used quota prices to estimate the profits from fishing for individual species.

Traditional fisheries economics predicts that the asset price of fishing one unit of harvest (ρ_t^a) is equal to the expected discounted marginal profits, or, equivalently, equal to the expected discounted lease prices. Dropping the expectation operator the asset price of the quota that gives the holder the right to land one unit of harvest can be calculated as

$$\rho_t^a = \sum_{k=0}^{\infty} \beta^{k+1} \rho_{t+k} \ , \qquad (2)$$

where $\beta = 1/(1+i)$ is the discount factor and i is the rate of interest.

If the quota asset is defined as a share in the total quota, as is the case e.g. in Iceland, then the price of the quota share that gives the right to catch one unit of harvest in period t ($\rho_t^{sa,kg}$) is

$$\rho_t^{sa,kg} = \sum_{k=0}^{\infty} \beta^{k+1} \frac{h_{t+k}}{h_t} \rho_{t+k} \qquad (3)$$

As the the quota share is the right to a certain percentage of the total quota in each period it is more reasonable to express that price in terms of kronor per some fixed share of the total quota, e.g. 1%. This price ($\rho_t^{sa,1\%}$) is

$$\rho_t^{sa,1\%} = 0.01 \sum_{k=0}^{\infty} \beta^{k+1} h_{t+k} \rho_{t+k} \qquad (4)$$

It follows directly from equations (3) and (4) that

$$\rho_t^{sa,1\%} = 0.01 \cdot h_t \cdot \rho_t^{sa,kg} \qquad (5)$$

If the fish stock is in bioeconomic equilibrium and is expected to remain there then all quota prices are equal in all periods and $\rho^{sa,kg} = 100 \cdot \rho_t^{sa,1\%} / h^* = \rho^a = \rho / i$, where h^* is the equilibrium harvest. If the fish stock is out of equilibrium the relationship between the quota prices depends on the assumptions about the adjustment path. If the stock is below its equilibrium and the quota rule is monotonic, then $h_{t+k}/h_t > 1$ and it follows from (2) and (3) that $\rho^{sa} > \rho^a$, while if the stock is above its equilibrium then $h_{t+k}/h_t < 1$ and $\rho^{sa} < \rho^a$.

It is not the aim of this paper do discuss possible relationships between the quota prices but to explore this relationship for the Icelandic cod stock using the bioeconomic relationships that have been estimated for this stock and the quota rule that has been established for this stock. Since 1995 the management of the Icelandic cod stock has followed an explicit quota rule, which makes it possible for the fishermen to predict future quotas if they think they can predict the future biomass of the cod stock.[7] When the rule was adopted it was claimed that it was approximately optimal.[8] The quota rule prescribes that the Total Allowable Catch (TAC) in the next quota year (starting September 1st) should be 25% of the estimated size of the fishable biomass (cohorts of age 4 and

[7] Or, to be more precise, if they think they can predict the Marine Research Institute's future estimates of the size of the fishable biomass.

[8] Working group (1994). The Working group proposed 22% as the optimal ratio but the government decided on 25%. In simple bioeconomic models, like the model below, where prices and technology are constant and cost is linear in the volume of harvest, the optimal management is to stop all fishing when the stock is below its optimal size and wait until the stock has grown to its optimal size. And if the stock is above its optimal size, it should be fished down to its optimal size as quickly as possible. This is the so called bang-bang solution (See Clark, 1990, pp. 92-93). The quota rule above is obviously not optimal in the model in this section. It is, on the other hand, possible to point to factors that are not included in the model but justify a quota rule, which is similar to the quota rule above. By-catch of cod and various adjustment costs are two such factors. Both obviously justify smoother optimal quota rules than the bang-bang solution and both are very difficult to model and estimate.

older).[9] The estimated size should be the average of the estimated size at the beginning of the (calendar) year and the forecasted size at the end of the (calendar) year. If the quota year was the same as the calendar year then the quota rule could be formalised as:

$$h_t = \lambda\left(\alpha B_t + (1-\alpha)B_{t+1}\right), \tag{6}$$

where B_t is the fishable biomass at the beginning of period t and λ and α are parameters. In the quota rule for the Icelandic cod α =0.5 and λ =0.25.

Assuming that the growth of the fishable biomass follows the logistic growth function then

$$B_{t+1} = B_t + rB_t\left(1 - B_t/K\right) - h_t\,, \tag{7}$$

where r is the intrinsic growth rate and K is the carrying capacity. Substituting from (7) into (6) gives

$$h_t = \frac{\lambda B_t}{1+\lambda(1-\alpha)}\left[1 + (1-\alpha)r\left(1 - B_t/K\right)\right]. \tag{8}$$

The cost per unit of harvest in period t is given by $c\left(0.5(B_t + B_{t+1})\right)^{-\gamma}$ where c is the price per unit of effort and γ is a parameter. If p_t is the price per unit of harvest in period t then the profit per unit of harvest is equal to the lease price, i.e.

$$\rho_t = p_t - c\left(0.5(B_t + B_{t+1})\right)^{-\gamma} \tag{9}$$

It is now possible to make certain predictions about the relationship between the size of the stock and the price ratio ρ_t^{sa}/ρ_t . If the stock is below its optimum sustainable level the quota rule gives steady increases in the stock and the harvest. If the unit price of fish is independent of the harvest then the profit per unit of catch increases because larger stock leads to decreases in the unit cost of catching. It follows that if the unit price is independent of the harvest then the lease price for quotas will increase when the catch increases. The cost function is convex in the size of the stock. If the elasticity of demand is sufficiently large the concavity of the cost function will make the profit function concave in the size of the stock and therefore ρ_{t+k}/ρ_t will be a decreasing function of the stock size. As (8) gives that h_t is concave in the stock size h_{t+k}/h_t is decreasing in the stock size. It then follows that $\rho_t^{sa,kg}/\rho_t = \sum_{k=0}^{\infty}\beta^{k+1}\frac{h_{t+k}}{h_t}\frac{\rho_{t+k}}{\rho_t}$ is a decreasing function of the stock size if demand is sufficiently elastic.[10]

Figure 1 shows the relationship between the ratio of asset price and the lease price of quota for one unit of harvest. It is assumed that the price is 109.01 when the supply is 235,000 tons, c =7318.6 and γ =0.7. These values have been chosen so that the profit is equal to the estimated profit from fishing cod in Iceland in 2000 when the harvest was 235,000 tons and average of the estimated stock at the beginning of the year and at the end of the year (as estimated at the beginning of 2001) was 552,000 tons. The biology is modelled using a logistic growth function calibrated so that the model has similar characteristics as the age-structure model, which the MRI in Iceland uses for the cod stock. (See Danielsson, 2000). The parameters are r =0.5242 and K =2720.

[9] In 1995 there was also a minimum TAC of 155,000 tons. In the year 2000 it was decided not to have any minimum but it was also decided that the TAC should not change by more than 30,000 tons between two consecutive quota years. Both of these restrictions have been effective in some years. For the sake of simplicity the discussion in this paper will ignore them.

[10] What is "sufficiently elastic" here depends on several factors. As shown below "sufficiently elastic" can be quite moderately elastic.

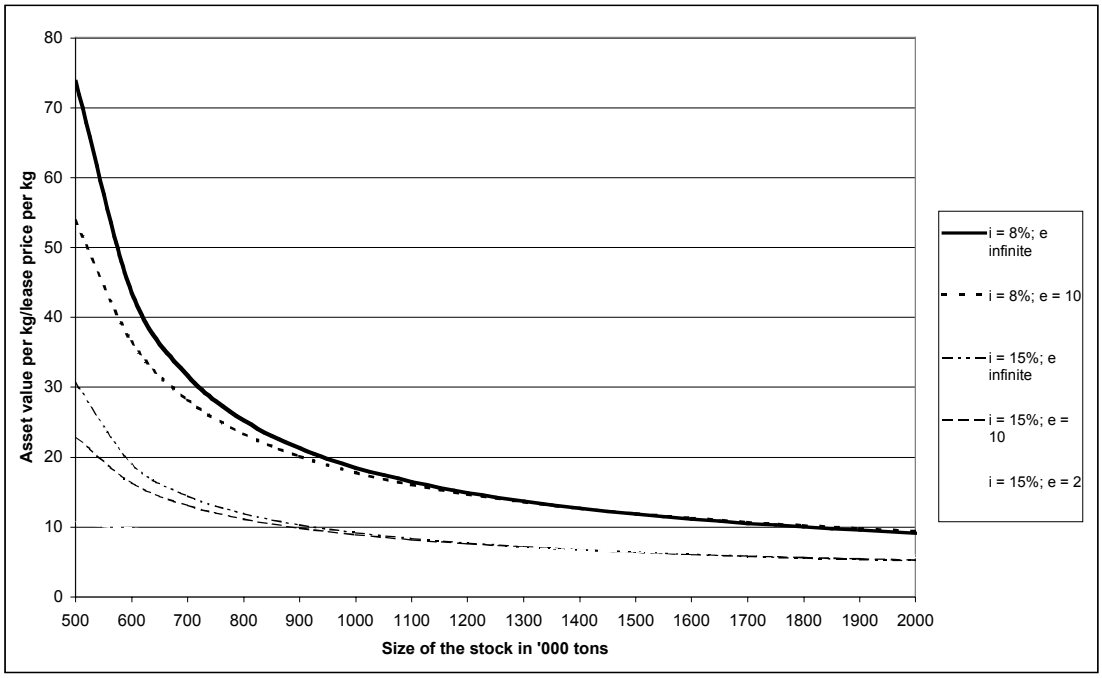

Figure 2: Ratio of Asset price and Lease Price per kg of quota at different stock sizes.

Figure 2 shows the ratio of asset price per kg and the lease price per kg for two rates of interest, 8% and 15%, and three values on the elasticity of demand, $+\infty$, 10 and 2. As is to be expected the line becomes flatter (and lower) as the interest rate increases and the elasticity of demand decreases. Even at 15% rate of interest and elasticity of 10 (the estimate for the elasticity used in Working group, 1994), the ratio in figure 2 is quite high at low stock levels. When the stock is 600,000 tons the ratio 16.3 but declines to 8.9 when the stock is 1,000,000 tons. Even when the elasticity of demand is 2 the ratio in figure 1 declines from 9.7 when the stock is 600,000 tons to 7.7 when the stock is 1,000,000 tons.

If the rate of interest is increased towards infinity the line showing the ratio of prices as a function of the size of the stock becomes horizontal even if the elasticity of demand is infinite. If elasticity of demand is low then the ratio can be increasing in the size of the stock. But for realistic value of the rate of interest and the elasticity of demand the ratio of the asset price per unit of harvest and the lease price per unit of harvest declines with the size of the stock. This decline will be greatest at low stock sizes. During the last 10 years the estimates of the size of the Icelandic cod stock have varied between 560,000 tons in 1995 and 1,031,000 tons in 1999, i.e. in the interval where the theory predicts that the ratio of the asset price and the lease price should decline rapidly.

4. Empirical relationships

In figure 2 the ratio of the asset price for 1 kg of allocated quota for Icelandic cod and the lease price for 1 kg is plotted against the size of the cod stock as it was estimates by the MRI at the time. The stock estimates are published in May each year and the price ratio is based on arithmetic averages of the prices during the 12 months period beginning in May of the year which the stock estimates refer to and ending in April of the following year.

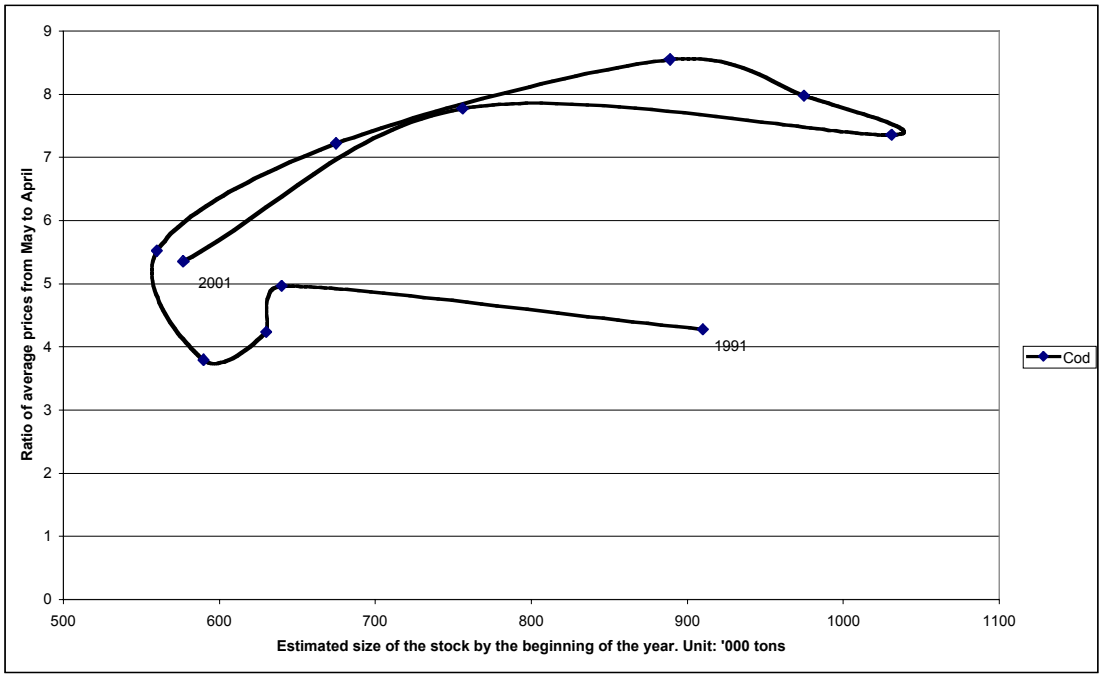

Figure 3: Ratio of the price of the cod quota asset giving 1 kg and the lease price for 1 kg 1991-2001. Sources: National Economic Institute and the Marine Research Institute.

The year 1991 is an outlier and should probably be excluded as the price data are less reliable in this year than they are for later years. 1991 is also the first year after the introduction of the new quota law which allowed vessel-owners to trade quota shares without trading the vessels that the quotas were attached to.

Contrary to the theoretical predictions, figure 3 shows that the ratio of the asset price and the lease price increases with the size of the stock. It also shows that the correlation between the ratio and the stock size is quite high. If 1991 is included the coefficient of correlation is 0.58, while if 1991 is excluded the coefficient of correlation is 0.77. Both are significant. The fact that figure 3 shows that the ratio moves downward with the size of the stock contradicts the hypothesis that the reason for the increases in the ratio before 1997 was greater confidence in the security and permanence of the quota rights.[11]

The MRI has repeatedly stressed that the cod stock feeds on shrimp. In the report by the Working group (1994), the report where the quota rule for cod was advocated, it is repeatedly stated that the adoption of the rule would lead to increases in the cod stock and to decreases in shrimp catches. With this in mind it is interesting to look at table 2, which gives data on the ratio of the asset price and the lease price of the quota for several species.

	Cod	*Hadd-ock*	*Saith*	*Redfish*	*Greenl. halibut*	*Plaice*	*Shrimp*	*Herring*
May '91-Apr. '92	4.28	5.20	3.84	3.91	4.15	4.00	14.40	
May '92-Apr. '93	4.96	6.53	4.88	4.32	4.09	4.88	10.01	
May '93-Apr. '94	4.23	10.10	9.35	4.86	4.20	7.69	7.02	5.12
May '94-Apr. '95	3.79	11.21	9.83	4.44	5.44	6.29	4.33	3.96
May '95-Apr. '96	5.52	10.90	14.12	4.10	6.34	6.98	4.05	4.93
May '96-Apr. '97	7.22	10.91	16.26	5.20	5.21	9.62	5.81	7.66
May '97-Apr. '98	8.55	9.36	9.55	7.83	4.30	8.34	8.12	7.20
May '98-Apr. '99	7.98	9.74	8.82	8.64		6.93	25.24	
May '99-Apr. '00	7.35	6.75	9.35	8.49	5.89	5.31	17.47	16.25
May '00-Apr. '01	7.78							
May '01-Apr. '02	5.35							

Table 2: Ratio of the asset price of quota giving 1 kg of quota and the lease price of 1 kg. Sources: National Economic Institute and the Quota Exchange of the Union of Icelandic Vessel-owners.

[11] See National Economic Institute (1999), pp. 198-199.

In the year starting in May 1994, the month when the report of the Working group was published, the ratio is higher for shrimp than for cod, contrary to what one would have expected. In the year starting in May 1995, the month when the government decided on the quota rule for cod, the ratio is higher for cod than for shrimp. This continues until the year starting in May 1998 when the catch of shrimp collapsed, the cost of fishing increased and the lease price for shrimp quota decreased. It was 68 kr/kg in the year starting in May 1996, it decreased to 52 kr/kg in the year starting in May 1997 and to 14 kr/kg in the year starting in May 1998. The asset price, on the other hand, remained fairly stable. It was 397 kr/kg in the year starting in May 1996, 424 kr/kg in the year starting in May 1997 and 342 kr/kg in the year starting in May 1998. This seems to indicate that the fishermen expected the shrimp fishery to recover in terms of quotas, in spite of the declared policy of the government. The asset price in terms of kronor per 1% decreased very much in the year starting in 1998. It should be noted that the estimate of the asset price in that year is based on very few quotations.

It is also worth noting that table 1 shows that the ratio of the asset price and the lease price is not higher in the case of cod than in the case of haddock, saith or redfish. The cod was though considered by the MRI to be in deep crises throughout the period and having large potential, while the others were considered to be much closer to their long run sustainable conditions, especially during the first half of the decade.

5. A case of denomination illusion

At the start of a new fishing year in September the share quota, which gives one unit of harvest, will change if the total quota changes. The new information about the conditions of the fish stocks and the advice of the MRI has then been available since May and in many cases the Minister of fisheries has made public his decision on the quotas in June. For these reasons it is not to be expected that the price of the quota share in terms of kronor per 1% ($\rho_t^{sa,1\%}$ in section 3) changes at the start of a new quota year. But if $\rho_t^{sa,1\%}$ does not change as a consequence of a change in the allocated quota in the ongoing quota year (h_t in section 3), then equation (5) in section 3 gives that the price of the quota share in terms of kronor per kg of allocated quota ($\rho_t^{sa,kg}$ in section 3) must change when h_t changes on September 1st. It is possible to test if this is the case by estimating regressions that explain the movements in $\rho_t^{sa,1\%}$ and test if the change in h_t is a significant explanatory variable. Equation (10) below was estimated for this purpose using monthly data for the period from October 1994 to April 2002, giving 91 data points

$$D\rho_t^{sa,1\%} = \underset{(0.0811)}{0.1996}\_D\rho_{t-1} \underset{(0.0260)}{-0.0910}\_LPQ_{t-1} \underset{(0.0988)}{+1.0938}\_Dh_t \underset{(0.00021)}{-0.00097}\_t \underset{(0.2507)}{-0.8369} \qquad (10)$$

where $LPQ_t = \log\left[\rho_t^{sa,kg} / \rho_t\right] - \log(h_t)$ and D is an operator such that $DX_t = \log(X_t) - \log(X_{t-1})$. The standard deviations are in the parenthesis. R-square was 0.63 and R-square adjusted was 0.61, standard error of the regression was 0.043, Durbin-Watson statistic was 1.964, Akaike info criterion -3.40 and Schwarz criterion -3.26. This equation explains considerable part of the total variation. The fact that the time trend (t) is very significant in the equation indicates that some significant economic variables might be missing. The important thing to note here is though that the coefficient of Dh_t is significantly different from 0, but not significantly different from 1, contrary to what theoretical reasoning seemed to indicate. Equation (5) gives that regression of $D\rho_t^{sa,kg}$ on the same explanatory variables as in equation (10) gives the same parameter estimates as in (10), except that the parameter for Dh_t is 0.0938. It is not significantly different from 0. This equation explains considerably smaller part of the total variation as R-square is 0.29.

6. Effects of new information about the stock

Fisheries economics assumes that the fishermen use available information about the biological conditions and the potential of the different fish stocks when they decide on their demand and supply for quotas. This is simply to assume that the fishermen behave rationally, given the bioeconomic model. To test this in the case of the Icelandic cod stock it seems reasonable to look for effects of changes in the stock estimates on the prices of quotas. The MRI publishes a report on the state of the stocks and gives their advice in late May each year. The

estimates of the size of the stocks are based on the trawl surveys in March and on their analysis of the catches. MRI tries as far as possible to prevent leaks about their work. In some cases the estimates in the report agree with what fishermen believe, but sometimes they do not. The reports in 2000 and 2001, where the MRI reported that it had grossly overestimated the cod stock in the period 1997-2000, was a surprise to many fishermen. It is, of course, not so that everybody agrees with MRI's reports but the main unions of the crew and the main union of vessel-owners have accepted MRI's advice during recent years. The main exceptions have been the unions of captains and mates and that of the small-scale fishermen. The president of the union of captains and mates, a successful captain of a trawler owned by the largest fishing firm until he became president of the union last winter, said in a interview in May 2000: "The quota system …. has not contributed in any way to a growth in the fish stocks. I think that in the last 3-4 years we should have caught more than we did. I think we have missed the opportunity to take advantage of a natural, periodic, increase in the cod stock. My feeling is that the fisheries biologists pretend to know more than they do. Instead of showing the courage to admit this they continue with their nonsense year after year …." (Ægir, 2000) This man has long experience as a captain of a fishing vessel but he is not directly involved in the decisions to sell or buy quotas for his vessel. But his livelihood depends on the state of the fish stocks. The MRI believes now that the main reason for the present crises in the cod stock is that increased catchability in the years 1997-1999 was believed to signify increases in the size of the stock, which led to over-estimations of the stock and to too high quotas according to the quota rule.

To test if the new information on the state of the cod stock published by the MRI in May each year influences the asset prices of the quotas the regression in the previous section was repeated using $BIOE_t$, the difference in the logarithm of the estimated size of the stock in May of a given year and the logarithm of the forecasted size of the stock done one year before, as an explanatory variable. This variable is zero except in May. Different lags were used but this equation seemed to fit the data best:

$$D\rho_t^{sa,1\%} = \underset{(0.0811)}{0.1812}\_D\rho_{t-1} \underset{(0.0258)}{-0.0943}\_LPQ_{t-1} + \underset{(0.0978)}{1.0954}\_Dh_t \underset{(0.0844)}{+0.1376}\_BIOE_{t-1} \underset{(0.00021)}{- 0.00092}\_t \underset{(0.2492)}{-0.8719} \qquad (11)$$

The sign of the estimated coefficient of $BIOE_{t-1}$ is as was to be expected and it is almost significant at the 5% level (one sided test). But this estimate is very unstable. If estimation period is not October 1994-April 2002, but October 1994-April 2001, i.e. the large revision of the estimates that was done in May 2001 is excluded, then the estimated coefficient of $BIOE_{t-1}$ is no longer significant (t-ratio 0.91). The explanatory power is though marginally greater as the R-square adjusted is 0.64 in this case instead of 0.62.

7. Conclusions

There are a number of factors that can partly explain some of the results above. Many fishing firms are integrated and it is the aggregate profit from fishing and processing, which affects their supply and demand for quotas. There is political uncertainty concerning the future of the ITQ-system and concerning future changes in the resource tax, which is levied on all quotas. There are disagreements about the ITQ-system among the fishermen and some of them find it morally disagreeable to profit from trade in quotas. The property rights that the ITQs provide and the markets for these property rights have not been established in the same way as property rights and markets have been established for assets used in other industries. One conclusion could therefore be that the differences between the theoretical predictions and empirical facts of the Icelandic ITQ-system are merely an expression of a quite long learning period required to establish the system and for the agents to learn to behave rationally within it. But if such a long learning period is the managers should try to find methods to shorten this learning period and perhaps avoid some of the excesses that have happened in some ITQ-systems. In that way the fisheries, and the community at large, would be able to benefit more from the advantages of the ITQ-system.

Another possibility is, of course, that bioeconomic models are missing some important factors that influence the behaviour (and rationality) of the managers of the fishing firms. If this is the case then fisheries economists can expect exciting times full with unexpected discoveries.

References

Clark, C.W., *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*, John Wiley & Sons, New York, 1991.

Danielsson, A., Stefansson, G., Baldursson, F.M., Kristjansson, Th., Utilization of the Icelandic Cod Stock in a Multispecies Context, *Marine Resource Economics*, Vol. 12, 1997, pp. 329-344.

Danielsson, A., *Integrated Environmental and Economic Accounting for Commercial Exploitation of Wild Fish Stocks*, a paper presented at the X-th Biennial Conference of IIFET (International Institute of Fisheries Economics and Trade), Corvallis, Oregon, USA, July 2000.

Danielsson, A., *Quota Prices and the Cost of Rationalisation in ITQ-fisheries*. Paper presented at the XIIIth Conference of EAFE (European Associaton of Fisheries Economists), Salerno, Italy, April 2001.

Danielsson, A., *Fisheries Accounts: Icelandic Case Study*. To appear in FAO handbook on integrated environmental and economic accounting for fisheries, January 2002(a).

Danielsson, A., *Quota prices when there are sunk costs and uncertainty and their role for capacity utilisation and optimal discarding*, a paper presented at the 2nd Wold Congress of Environmental and Resource Economists, Monterey, California, USA, June 2002(b).

Davidse, W.P., Harmsma, H., van Wijk, M.O., McEwan, L.V., Vestergaard, N, Frost, H., *Property Rights in Fishing, Effects on the industry and effectiveness for fishery management policy*, Onderzoekvwerslag 159, November 1997.

Dixit, A.K. and Pindyck, R.S., *Investment under uncertainty*, Princeton University Press, 1994.

Holland, D., Gu_mundsson, E. and Gates, J., Do fishing vessel buyback programs work: A survey of the evidence, *Marine Ploicy*, Vol. 23, no.1, 1999, pp. 47-69.

National Economic Institute, _róun sjávarútvegs, kvótakerfi_, au_lindagjald og almenn hagstjórn, sk_rsla _jó_hagsstofnunar til Au_lindanefndar í *Au_lindanefnd – Áfangask_rsla me_ fylgiskjölum*, forsætisrá_uneyti_ (Development of the fisheries, the quota system, resource tax and economic policy, a report by the National Economic Institute for the Committee on Resources), March 1999.

Sutinen, J., Individual Transferable Quotas as incentive measure for the conservation and the sustainable use of marine biodiversity, OECD, 1998.

Wilen, J.E., Renewable resource economists and policy: What difference have we made, *Journal of Environmental Economics and Management*, vol. 39, no. 3, May 2000, pp. 306-327.

Working group, Hagkvæm n_ting fiskistofna, *Sk_rsla vinnuhóps um n_tingu fiskistofna* (Efficient exploitation of fish stock, A report by the Working group on the efficient exploitation of fish stocks), 1994.

Ægir, The magazine of the Fisheries Association of Iceland, May 2000.