DEVELOPMENT OF EFFORT AND FISHING FLEET CAPACITY IN THE ICELANDIC COD FISHERY

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ABSTRACT

Individual Transferable Quota systems (ITQ's) were implemented in the Icelandic groundfish fisheries in 1984, or twenty years ago. The system was not a 'pure' ITQ system from the beginning, notably with different regulations for different fleet segments and with several changes along the way. The current system has mostly been unchanged since 1991. This paper looks at the development of effort and fleet capacity between 1980 and 2000 with emphasizes on the trawler fleet. The paper gives a general overview of the development of effort by using several different definitions of effort and capacity. This overview shows a difference in development based on time period and vessel category, suggesting different behavior of fishermen under different versions of the management schemes. The paper then goes on to examine the trawler fleet more closely, with a special emphasizes on the period from 1995 – 2000. A translog cost function for the trawler fleet is estimated, based on observations from individual vessels and fishing companies. The cost function is used to determine the level of production efficiency in the Icelandic trawler fishery and the results from the estimation of the cost function are used to examine if resource rents are dissipated or realized in the Icelandic trawler fishery.

Keywords: Fisheries management; Production functions; Resource Rents; ITQ; Iceland

INTRODUCTION

It is twenty years since an individual quota system was established in the Icelandic groundfish fisheries. What started out as an individual quota (IQ) system, for a trial period of one year, is today an Individual transferable quota system (ITQ). The system has developed continuously over these twenty years and it is only in the last four years that relative stability has been obtained in the legal framework for the quota system.

As expected there have been many debates and controversies over the ITQ management system. The debate in the popular media has focused on the equity and distributional issues of the management system and to some extend the effectiveness of the system to rebuild fish stocks. The debate on improvements in efficiency and profitability of the Icelandic groundfish fisheries has not been as noticeable in the popular media, but rather been focused within the academic literature. Most of the research that has investigated changes in productivity and efficiency has examined the fishery as a whole using aggregate data to measure efficiency gains (Arnason and Valsson (1999)), Arnason (2003) and Arnason (2004)). This paper looks at the behavior of individual fishing companies in order to look in more details on how fishing companies operate under an ITQ fisheries management scheme.

The paper begins with an overview of the development of the Icelandic fisheries management system over the past decades. It then goes on to analyze the development of effort for several fleet segments from 1980 through 2000. Fourth section looks at the efficiency of the trawler fleet during the period from 1995 through 2000. Then the question on resource rents is examined, followed by a concluding section on efficiency gains and economic behavior of individual fishing companies under Individual transferable quota system.

MANAGEMENT OF THE ICELANDIC FISHERIES

Management prior to 1984

Based on the fisheries management laws from 1948 Iceland expanded its exclusive economic zone in incremental steps. Table 1 below shows the year and extent of each expansion. The final expansion came in 1975 when the exclusive economic zone (EEZ) was moved from 50 nm to 200 nm miles, causing tension between two NATO allies, Iceland and United Kingdom.

The law from 1948 also changed the approach to fisheries management. Based on research by government scientists and in cooperation with international organizations such as ICES, the government started to use area closures, restrictions on mesh sizes and restrictions on the use of trawl gear in coastal waters and sensitive nursing grounds.

From 1950s through the 1970s the fisheries management in Iceland was based on effort control and limitation of entry of foreign vessels. Domestic vessels had de facto open access to all major fisheries. The major steeping points in the development of the Icelandic fisheries management system are listed in table 1.

Table I: Major events in Icelandic fisheries management

Source: Adapted and extended from Arnason (1995) and Helgason (1995)

Year	Event
1948	Law that emphasize Icelandic jurisdiction over fish stocks in Icelandic water, and that the management of those stocks should be on scientific basis
1952-1972	Exclusive Economic Zone Expanded to 50 NM
1965-1975	Initial steps using effort control, total and producer quotas for controlling catch. Harvesting moratorium on herring.
1975	The “Black Report” issued by the Marine Research Institute. EEZ expanded to 200nm.
1976	De-facto recognition of Icelandic authority over 200nm EEZ by the British Government
1976	Protection of juvenile fish through temporary area closures. Total catch quotas for Cod.
1977	Individual Effort Restrictions in the demersal fisheries
1983	Individual Vessel quotas to be implemented in 1984 for one year. Quota shares based on catch history from 1981 through 1983.
1985	The Individual Vessel quota system extended for one year. Effort quotas introduced as an alternative.
1986	Individual Vessel Quotas extended for two years
1988	Another two year extension for the Individual Vessel Quota system. Transferability for quota shares made easier. Effort Quota system is still in place as a option. New fisheries law is passed where it is emphasized that the Icelandic fishing grounds are the common property of the Icelandic nation.
1990	New fisheries management law passed, this time without any time limits on allocation of share quotas. Quota shares are divisible and fully transferable. Effort quota system discontinued. New system takes place on January 1st 1991.
1993	Government committee recommends the ITQ system to be kept in place, indefinitely.
1998	The supreme court rules that only granting fishing licenses to vessels that were fishing between 1981 and 1983, or replacement vessels for such a vessel, is unconstitutional. The supreme court explicitly states that they are not ruling on distribution of quota shares.
1999	Addition to the fisheries management laws grants the authority to issue licenses to fish to all Icelandic citizens. Distribution of quota shares is not affected and fishing without a quota share is illegal.
2000	The supreme court rules that fishing without quota is illegal, putting an end to a dispute that started with the supreme court ruling from 1998. The verdict strengthens the legal basis of the quota system.
2002	A resource rent tax becomes a part of the fisheries management law, to be implemented by the fall of 2004.
2004	The last fleet segment (boats under 6 GRT) is changed from a days-at-sea system to a ITQ based management system.

After it was obvious that the effort controls did nothing to stop the overexploitation of the groundfish stock, fisheries managers, fishermen associations and boat owners started looking for other management methods. The conclusion was to establish an IQ system, beginning in 1984. The system was reinstated for 1985, where the allocation was more or less based on the initial allocation from 1984, even though some reallocation occurred between different vessel categories.

In 1985 the fisheries management using IQ and days-at-sea (DAS) systems was reinstated for two years (1986 and 1987). During 1985, 26 trawlers elected to be under the IQ system and 80 elected to operate under the DAS system. The system was reinstated in 1988 for two years (1988-1990) without any significant changes.

The period from 1984 through 1990 can be seen as an evolution period for the current Individual Transferable Quota system. All players within the system (fisheries managers, vessels owners, fisherman, etc.) learned by doing and in the process some gained and some lost. It was seen as a crucial point, in order to increase efficiency in the Icelandic fisheries, that uncertainty of the ownership of the harvesting rights (the ITQ share) should be minimized. Experience from the IQ system, as well as the ITQ system in the capelin and herring fisheries favored a private property right system to be implemented in all Icelandic fisheries. In 1990, Althing passed a law implementing an

ITQ system in all major fisheries within Icelandic waters, under one set of principal rules and regulations, to take effect from January 1st, 1991.

Several significant changes in the management of the Icelandic fisheries occurred under the new fisheries management legislation from 1990. This included that the statistical year for quota holdings was changed from the calendar year to begin on September 1st and end on August 31st the following year. The days-at-sea system was abolished for all vessels over 10 GRT, and vessels between 6 GRT and 10 GRT were offered to enter a separate ITQ system, or a temporary hook and line system (1991 - 1993), where vessels were only allowed to fish with hook and line on specific days of the year (Runólfsson 1999).

In 1996 a local fisher applied for a license to fish, along with a substantial amount of groundfish quotas. The individual was denied the license, and quota, on the ground that fishing vessels, not individuals, are issued licenses. The case went to the Supreme Court in Iceland in 1998. The Supreme Court ruled in favor of the individual. The court ruled that only issuing licenses to vessels that were in the system in 1983 was unconstitutional (Palsson 1999). The court explicitly stated that it was only ruling on the issue of a license, not the quota. Hence, after the verdict the Icelandic government had to issue a license to all individuals interested in obtaining a commercial-fishing license. However, the government still required quota in order to be allowed to land fish in port.

Another individual decided to challenge the quota requirement, and went fishing without quota. He was charged with illegal fishing. The municipal court did not find him guilty of illegal fishing, in part based on the Supreme Court verdict from 1998. This case went before the Supreme Court in February of 2000 and the Supreme Court gave its verdict in April that same year. This time the Supreme Court ruled[i] that it was legal to limit fishing by a system, such as the quota system. This strengthened the legal ground for the quota system.

Currently the fisheries management for the Icelandic groundfish fisheries can be summarized as follows. The first article of the fisheries management law states that all ocean resources are the common property of the Icelandic nation. The objective of the fisheries management law is to promote efficient and sustainable use of the resources, in order to enforce employment and livelihood in the country. It explicitly states that the rights to harvest those resources does not give the holder property rights over it, and that the government can recall the harvesting rights. The total allowable catch (TAC) is set for individual fisheries which then are divided among those who hold the right to catch the specific species. These harvesting rights, or quotas, are divisible and transferable, both on an annual basis and in perpetuity. There are limitations on how much individual companies can hold. Each vessel can not hold that much quota that it is obvious that the vessel can not harvest the quota within a fishing year[ii]. In addition the total quota holdings by an individual, legal entity and/or related individuals or through indirect ownership can never exceed a certain percentage of the TAC. This percentage is between 12% (cod) and 35% (redfish) depending on the species. In addition the total quota holdings by related individuals or companies can not exceed 12% of the overall TAC for all species, as measured in cod equivalent values[iii].

The minister of fisheries sets annual total allowable catch (TAC) for all species harvested within the Icelandic EEZ. The TAC must be set after the minister receives advice from the Marine Research Institute (MRI), but the wording of the law does not require the minister to comply with the MRI, a fact which several ministers of fisheries have utilized over several decades. The TAC for the cod stock is set differently. The TAC is calculated using a specific rule, so called "Quota-rule"[iv] which is calculated as 25% of the total fishable biomass, but there are limits on annual changes of +/- 30.000 metric tons. Hence the TAC for cod is based directly on the scientific evaluation of the MRI but with some leverage to minimize the impact of large change in annual catch quotas (Danielsson 1997). Total Allowable Catch for other demersal species is set directly by the minister for a period of one fishing year, which starts 1st of September and ends August 31st next calendar year.

In 2002 the Icelandic parliament amended the fisheries management legislation from 1990 to include a fishing fee to be paid by all quota owners. This fee was put into the legislation in order to try to address the equity issues that have risen around the Icelandic ITQ system (Eythorsson 2000), and is basically a collection of some of the resource rents. The fee is calculated based on average values of landings, average values of labor costs, fuel costs and other costs. The quota fee is set at 6% for 2004 and will increase to 6.6% in 2005, 7.3% in 2006, 8% in 2007, 8.7% in 2008 and 9.5% in 2009.

The Icelandic ITQ system has been two decades in making. There has been a lot of controversy and debate about the system and so far two Supreme Court verdicts have ruled directly on the fisheries management law. Different segments of the fleet have had different regulation over the time period. The trawlers where put under an ITQ system in 1988 but the last segment of the coastal fleet was not under ITQ fisheries management until May 2004. Due to the different regulations by fleet segments it is interesting to examine how effort has developed within each fleet segment.

DEVELOPMENT OF EFFORT IN THE ICELANDIC FISHERIES

Defining fishing effort

Fishing effort is defined in different ways between different research disciplines and even within the same discipline. For the fisheries biologist effort is a measure of fishing mortality due to fishing activities, the infamous $F_{0,1}$. Fishing mortality in the Icelandic cod fishery is shown in Figure 1.

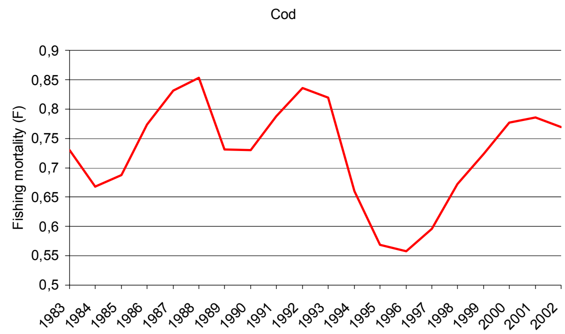


Figure 1: Fishing effort defined by fishing mortality. Source: Marine Research Institute

The Icelandic Marine Research Institute (MRI) has indicated that fishing mortality should not exceed 0.4, but as can be seen from the figure above the actual fishing mortality has often been considerably higher than the targeted fishing mortality.

Economist look at effort as the inputs (capital and labor) used to harvest the catch in any given fishery. Technical measures, such as vessel characteristics (length, width and engine power) are also used to measure fishing effort. Due to this wide variety in definitions of fishing effort one has to look at several measures when trying to examine the development of fishing effort over long periods. In this paper we have chosen to use seven definitions of effort which all focus on the economic aspect of effort. The seven definitions are; number of vessels; number of trips; man-days-at-sea (two versions); engine-power-days-at-sea, man-power-days-at-sea and capital value (Bergsson 2001).

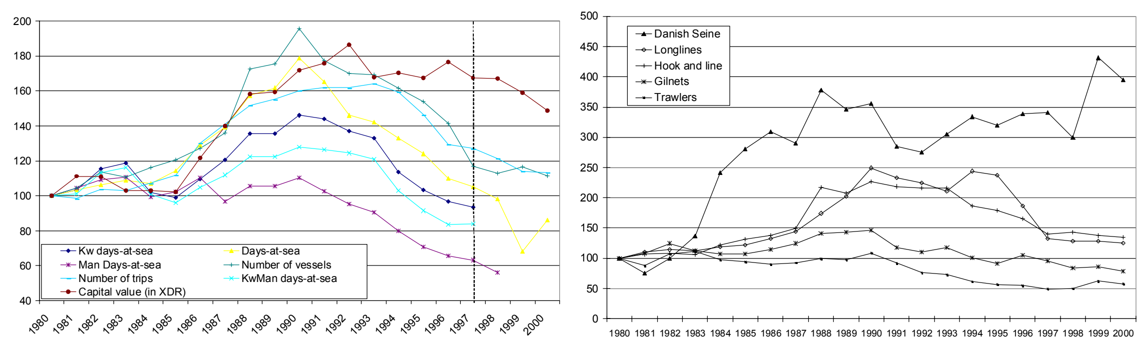


Figure 2: Development of fishing effort as measured by seven different effort definitions and devlopement of effort by vessel category (measured by number of vessels).

Figure 2 above shows the development of effort as an index change with 1980 as the base year[v]. There are two graphs in the figure. The graph on the left shows development for all vessels using different definitions of effort. The graph on the right shows development of effort for individual fleet segment, measured as number of vessels. The graph on the left shows that all indexes increase from 1980 through 1983. In 1984 and 1985, the first years of the IQ system, there is a decrease in effort as measured by man Days-at-Sea, number of trips, Days-at-sea and Kw Days-at-sea. In 1986 effort starts to increase and it continuous to do so until 1992. This effort increase coincides with the period of the management system when both effort control and quantity control were used to regulate groundfish fisheries, in all vessel categories. This might be seen as an indicator for increased effort due to the days-at-sea system and the build in race to fish for those operating under that system. It is also noticeable that soon after the new fisheries management law came into effect on January 1st 1991 there is a reduction in fishing effort as measured by each one of the seven different definitions. Hence, regulations obviously have direct and immediate impact on the economic behavior of fishermen.

The story becomes even more interesting when looking at individual vessel categories. Most notable is the increase in effort (as measured as number of vessels) using the Danish seine and the reduction of effort in the trawler category. Danish seines are used to harvest flatfish species, but it is a multi-species fishery with cod and other groundfish as bycatch. Most of the flatfish species were not under the quota system between 1984 and 1990. Table II shows the results of the effort analysis for all gear types and all seven definitions of effort.

Table II: Changes in effort by effort defintion and gear type

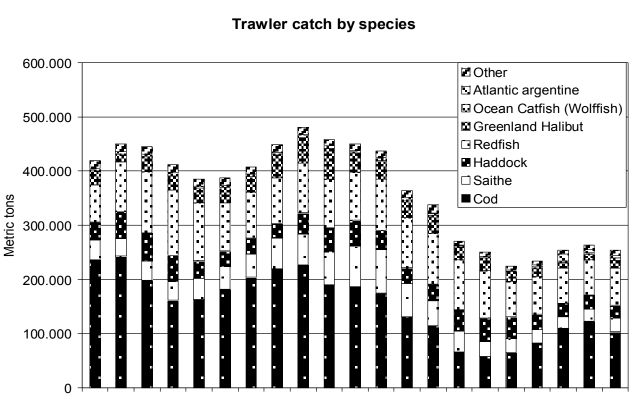
Effort definition	Hook and line	Gilnet	Longline	Danish Seine	Bottom trawl	Overall
No. of vessels	+	÷	+	+	÷	+
No. of trips	+	÷	÷	+	÷	+
Days-at-sea	÷	÷	+	+	÷	÷
Man-days-at-sea	÷	÷	÷	+	÷	÷
Kw-days-at-sea	+	÷	+	+	÷	÷
ManKw-days-at-sea	÷	÷	÷	+	÷	÷
Capital value	N/A	N/A	N/A	N/A	N/A	+
Catch	+	÷	+	+	÷	÷

Several interesting facts emerge from this table. First of all only gillnets and bottom trawls decrease their effort between 1980 and 2000 as measured by all seven effort definitions. Hook and line increase their effort by the measure of number of vessels, number of trips and kw Days-at-sea, but decrease their effort measured as days-at-sea, man days-at-sea and hence man/Kw days-at-sea. Overall effort decreases measured in days at sea but increases in number of vessels and number of trips, as well as in terms of capital value.

Vessels using gillnets changed to Danish seines and targeted non-quota species, but their overall share in the catch was relatively low. Longlines had also favorable treatment prior to 1991. Only half of the catch was measured towards the quota if caught by longline. Hence vessels using longlines increased until 1991 but started to reduce again after this was abounded by the new fisheries management law in 1991.

The trawler category is also interesting since trawlers have been under the most stable part of the system. In 1988 the effort system was abounded for trawlers and all trawlers were under a de facto transferable quota system. This was reinforced by the new legislation in the early 1990s. The trawlers also caught relatively high portion of the entire groundfish catch, or about 50% of the cod catch annually between 1980 and 2000. Other categories have actually increased their share, and even their actual landings. Danish seines harvested almost no cod in 1980 but were up to 10 thousand metric tons in 2000. Longliners increased their catch as well but gillnets received a smaller share, and smaller tonnage in 2000 than in 1980. Smaller boats using hook and line have increased their share of the catch considerably, or from 5% in 1980 to more than 10% in 2000. The smaller boats have been under a mixed system of output control (quota) and effort control (Days-at-sea) over the entire period.

If we examine the catch composition of the trawler fleet and compare it to the Danish seine fleet some interesting facts emerge. Figure 3 shows the composition of the catch for each gear type.



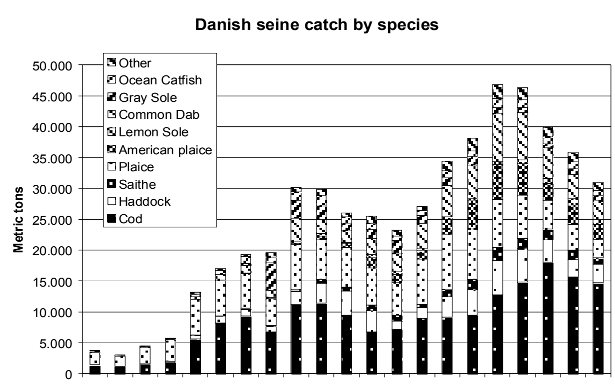


Figure 3: Catch composistion for trawlers and Danish Seine Source: Marine Resource Institute, personal communcation.

For the trawler fleet the species composition has been relatively unchanged though the catch has declined by more than 40% over the period. Cod still accounts for little less than 50% of the overall catch, with redfish being the second most important species for the trawlers. For the Danish seiners other species account for more than 50% of the overall catch, with several flatfish species accounting for the remaining catch.
Vessels using Danish Seines obviously target other species than the trawlers, and their catch is increasing over the period. The Danish Seines are utilizing the system to target non-quota species, with quota species as bycatch.

The results from the effort analysis show clearly how different management regulations have direct impact on the effort level used in the Icelandic groundfish fishery. It is interesting to see that the fleet segment (trawlers) which has been under the ITQ system the longest is also the one that shows decline in effort use of the time period. This is an indicator that fishing companies are adjusting their effort use to the available catch. The question is then how efficient they have become at harvesting their share of the quota. Next section looks at the efficiency of the Icelandic trawler fleet by estimating a translog cost function for the entire fleet and comparing the average performance of the fleet to the optimal effort level and optimal firm size.

MEASURES OF EFFICIENCY IN THE ICELANDIC TRAWLER FISHERY

Data

The data used in this research is from four different government agencies. The data is on catch, effort, vessel characteristics and cost of fishing operations.
Data on annual catch and number of days at fishing for vessels with reported cod catch by bottom trawling was obtained from the Marine Research Institute in Iceland. This resulted in 490 observations for the time period in question with 108 different vessels.
The number of vessels that landed cod annually declined steadily from 1995 through 2000. In 1995 there were 93 vessels; down to 69 vessels in 2000 or a 26% reduction in the number of vessels. At the same time the average catch almost doubles. There are two reasons for this. First of all the average size of the remaining vessels is increasing and from 1997 through 2000 catchability for demersal species increased, probably due to changes in environmental factors. This increase in catchability led to an overestimation of the cod stock, and thus higher quotas than was optimal. Fisheries scientist did not realize this until the year of 2000 and recommended a decline in catch levels and fishing effort in 2001 and 2002. Total catch increased from 119 thousand metric tons to 163 thousand metric tons. However, when the MRI data was compared with data from the Fisheries Directorate there were indications that the 1995 data from MRI showed less catch than estimated by the FD. Data for other years showed similar level of catch within the MRI and FD datasets. Data on vessels characteristics were obtained from the Icelandic Maritime Administration (IMA). Costs and earnings data were acquired from Statistics Iceland. Statistic Iceland collects data from annual reports and through survey work. However, the institute only collects data on companies, but not individual vessels. When companies operate both fishing vessels and on shore processing plants the company is asked for cost and earnings data for their fishing fleet separately from the processing operation. The cost and earnings data was then matched with the catch and vessel characteristic data to build the final data set used in the empirical analysis, as described in the next section.

Since many companies operate more than one vessel, and only about 80% of each fishing company is surveyed annually, the total number of observations decreases. After combining the data from the four different sources the final dataset has 157 observations. The descriptive data for the final dataset is shown in table V.

Table III: Descriptive statistics for company data (monetary units in millions of krona)

Year	1995	1996	1997	1998	1999	2000
Number of vessels	2.2	2.2	2.2	2.7	2.7	2.7
Days at fishing	365.1	341.5	349.0	408.0	479.7	521.8
Annual catch (MT)	3,098.6	3,446.7	4,304.0	5,389.1	6,075.9	6,609.5
Total Revenues	565,822.7	550,599.8	676,617.3	858,100.0	1,004,684.7	1,161,285.2
Total costs	518,057.4	527,375.4	650,802.1	805,303.6	909,047.7	1,042,434.2
Fuel	48,769.9	55,475.0	67,695.9	56,781.0	58,497.1	124,734.1
Maintainance	42,811.5	46,255.1	49,688.8	63,536.2	69,178.5	82,832.4
Crew share	198,136.7	204,091.8	254,835.6	329,134.4	374,222.0	452,398.2
Depreciation	68,566.2	74,547.9	86,424.5	125,677.0	141,495.2	163,405.1
Other costs	159,773.0	147,005.5	192,157.4	230,175.0	265,654.9	219,064.4
Per vessel						
Crew (average)	19.2	19.1	19.5	19.0	18.9	19.2
Registered length (meters)	49.9	49.3	50.3	50.0	50.6	50.5
GT	996.6	978.7	1,011.8	990.5	1,016.7	1,017.9
Engine Power (Kw)	1,817.8	1,775.7	1,834.7	1,800.1	1,821.5	1,851.5

The average company had 2,2 vessels, with maximum of 8 vessels for one company and minimum of one vessel per company. The use of these vessels is increasing since the average days at fishing increased from 365.1 per company to 521.8 per company in 2000 (an increase from 163 days per vessel to 197 days per vessel in 2000). The average annual catch increased from 3,100 metric tons in 1995 to 6,600 metric tons in 2000. This is an increase from 8.5 metric tons per day to 12.7 metric tons per day and per vessel. The increase in catch per company is probably due to two factors. First, the increase in catchability as described before and secondly because of consolidation of fishing rights and cooperation between companies.

The model

A dual approach is used to find the optimal use of capacity within the given time period. It is important to note that that this research focuses on a static estimation of the cost function, not dynamic one. Since we are not looking for the optimal path it is not necessary to take into account the stock dynamics and we can focus on the question of operational efficiency, given the current technology and catchability. A translog functional form is used to estimate the total cost curve for the trawler fleet. The translog functional form has been widely used which allows for more relevant comparison of the results of this research with others who have examined various fisheries (Carsten 2002). It is also relatively easy to calculate the returns to scale and scale elasticity. Those measures can be used to obtain the optimal fleet capacity at a technology and catchability of the fleet (Asche 2004). The model is estimated as a single output total cost function eventhough the trawler fleet harvests multiple groundfish species. This is possible due to the fact that the Icelandic Directorate of fisheries issues annually a cod-equivalent value for all species within the quota system.
The translog function used and share equations for each input used are:

$$\ln TC = \ln\alpha_o + \sum_{i=1}^{n}\alpha_i \ln w_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_{ij}\ln w_i \ln w_j + \alpha_Q \ln Q + \frac{1}{2}\alpha_{QQ}(\ln Q)^2 + \frac{1}{2}\alpha_{iQ}\ln w_i \ln Q + e \quad \text{(Eq. 1)}$$

$$S_i = \alpha_i + \sum_{i=1}^{n} \alpha_{ij} \ln w_j + \alpha_{iQ} \ln Q + u_i$$ (Eq. 2)

where TC is total cost, w_i stands for inputs (Capital, labor, fuel and other costs), Q is cod equivalent catch in metric tons, S_i are share for each input, α_i are coefficient to be estimated and e and u are error terms. There are four share equations so that n is equal to four. During the estimation of the system one equation (other costs) was omitted. To satisfy homogeneity and symmetry conditions the following restrictions are applied in the estimation of the system:

$$\sum_{i=1}^{n} \alpha_i = 1, \quad \sum_{i=1}^{n} \alpha_{ij} = 0, \quad \sum_{j=1}^{n} \alpha_{ij} = 0, \quad \sum_{i=1}^{n} \alpha_{iQ} = 0$$

Homogeneity:

$$\alpha_{ij} = \alpha_{ji}$$

Symmetry:

When the data is normalized at its mean the returns to scale (RTS) is calculated as:

$$RTS = \frac{1}{\alpha_Q}$$ (Eq. 3)

and the scale elasticity is calculated as:

$$e = \frac{1}{\alpha_Q + \alpha_{QQ} \ln Y}$$ (Eq. 4)

By setting the scale elasticity equal to one in equation 4 the equation can be solved for the optimal output

The econometric results are shown in the appendix but graphical representation of the estimated cost functions is shown in Figure 4.

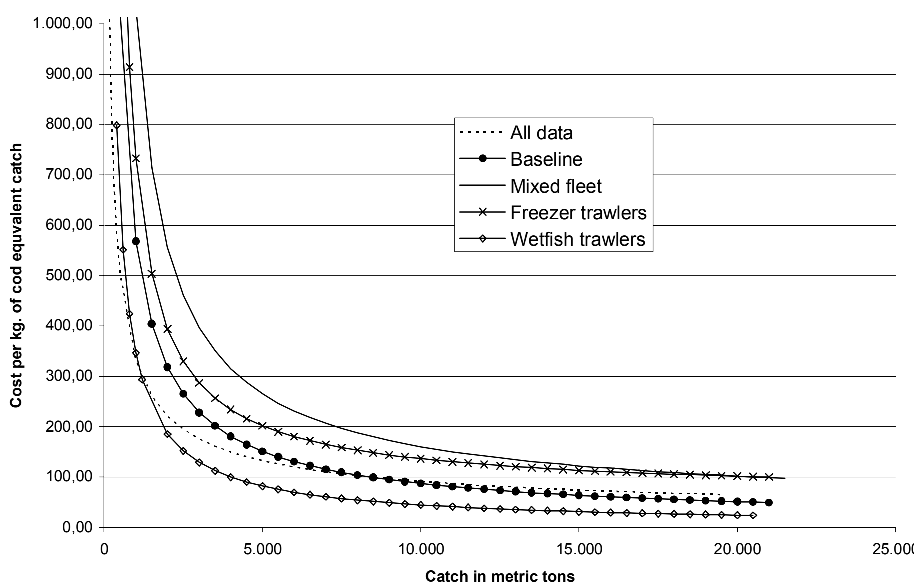


Figure 4: Estimated total cost functions for the Icelandic trawler fisheries

The initial dataset estimated used all 157 observations. The estimation had relatively good fit, or a R-square of 0.94. Returns to scale were calculated at 1.3 which is relatively low since an optimal cost minimization would result in returns to scale of 1. The optimal firm size would be about 26 times larger than the average firm size, or harvest about 120 thousand metric tons. Maximum annual harvest per large sized trawler (over 800 GT) is about 8000 metric tons. This number can of course change due to environmental factors, labour laws and labour contracts, etc. but managers within the largest companies agreed that 8000 metric tons would be close to the maximum average catch. Given that optimal firm size is 120.000 metric tons and that the average annual catch by the trawler fleet is about 225.000 metric tons of groundfish species there would only be room for two companies operating mixed fleet of freezer and wetfish vessels.

These numbers are rather extreme though they conform with theory that there should only be one company given exclusive rights to fishing. The fact that the data mixes together wetfish trawlers and freezer trawlers, as well as one boat operations with multi vessel companies, might have adverse effect on the estimation. In order to avoid that problem the data set was split into four different subsets. The first subset is called BASELINE and contained data that had cost per kilogram of landed fish lower than 300 Iskr. The second subset looked at companies with MIXED operations. The third subset looked at companies that operated only FREEZER trawlers and the fourth subset examined companies which operated only WETFISH trawlers. The results from the estimation and calculations of the optimal fleet size are shown in the table below.

Table IV: RTS and optimal firm size for each subset of data

	RTS	R^2	Average firm size (tons cod equivalent catch)	Number of companies	Number of vessels per company
All data	1.30	0.94	120,000	2	**15**
Baseline	5.11	0.94	133,000	<2	**17**
Mixed fleet	3.26	0.97	66,000	<4	**8**
Freezer trawlers	3.99	0.94	10.500	<22	**<2**
Wetfish trawlers	9.45	0.91	23.000	<10	**3**

There is a stark contrast in the estimation of the different datasets. This difference in average firm size is obviously related to each sub-sample. But the results conform in at least one way; there is still room for increasing efficiency within the Icelandic trawler fleet. Due to the nature of the translog function, and the fact that all optimal values are outside of each individual sample the accuracy of the forecasted optimal size might be low. However, the optimal firm size is obviously beyond the current limit on quota ownership. Hence, the Icelandic fisheries would become more efficient if the restrictions on quota shares were lifted. Given that the average catch of each vessel is 8000 metric tons then the trawler fleet could have been reduced from the 69 vessels used down to about 30 or 40 vessels, or up to 50% reduction.

RESOURCE RENTS IN THE ICELANDIC TRAWLER FISHERY

Resource rents are defined as the difference between total revenue and total cost, where costs are defined as the opportunity cost of capital, labor and other inputs used in the fishery. In a properly managed fishery the resource owners/harvesters can earn sustainable economic rent from their harvesting practices. Resource rents are therefore a measure of efficiency in the fishery, where higher resource rent mean higher level of efficiency.

It is difficult to measure resource rents, especially in a fishery where the fleet is heterogeneous and perhaps harvesting multiple species at the same time. Opportunity costs are also a concept that is difficult to obtain information on. What is the opportunity cost of a fisherman that has no other alternative of employment than fishing? Hence, fisherman fishing the same fish stock, from different ports might actually have different opportunity costs. Opportunity costs are difficult to measure except at very aggregate levels.

In this study we have estimated the actual costs of capital, labour, fuel and other inputs. Prices for capital and fuel were based on market prices, and assuming that the markets are efficient, should give us the opportunity cost for those inputs. The labor and other input cost are measured as user costs. Fishermen get a share of the catch value and hence reap part of the resource rent directly. The difference between the fisherman wages and the wages he could earn in other professions is his share in the resource rent. In Iceland fishermen bear a certain respect in society because they earn a high level of income, often triple or quadruple compared to what they could earn in other

professions. Heterogeneity in the fishing fleet also helps some captains to earn some intra-marginal rents through better harvesting techniques. All of this makes it difficult to estimate the true resource rents for the Icelandic groundfish fishery.
Using the estimated model from previous section and the average landing value from 1995 through 2000 one can calculate the potential and realized rents. Table V shows the results from those calculations.

Table V: Potential and Realized Resource Rents in the Icelandic groundfish fishereis

Potential Resource Rent	*Overall*	*%*	*Average Resource Rents*	*Actual*	*%*
Average revenue per kilo	166		Average Revenue	166	
Minimum cost at optimal firm size	82		Average cost	154	
Resource Rent	84	51%	Margin	12	7%
Resource rent of crew share	23	14%	Resource rent of crew share	23	14%
Total potential resource rent	**107**	**65%**	Total realized resource rents	**36**	**21%**

The results from the calculation show that the potential resource rent for the Icelandic groundfish fishery is between 50% and 65%, depending on if we use the actual labor cost or the opportunity cost of labor. Calculating the resource rent by using average values for costs and earnings and using the opportunity cost of labor as 65% of the crew share the realized resource rent is between 7% and 21% of total revenues.

The 7% margin on the average is higher than the economic performance as calculated by the National Economic Institute for the same time period. This is due to different treatment of capital costs in this research compared to the NEI study.

In theory a fisherman should be willing to pay all his resource rents for an additional unit of lease quota. If the quota market is efficient prices should reflect marginal prices and hence one could calculate the resource rents by simply dividing the lease price by the ex-vessel landings value. Using the annual lease prices for cod collected from brokers and from the Icelandic quota exchange (which now has been closed) and the annual landing prices for cod from 1997 through 2000 showed that at the margin quota buyers were willing to pay up to 75% of the landing value for an annual lease of quota. The result from that calculation is shown in the table below.

Lease price (Iskr, nominal prices)	Landing value at auction markets (Iskr. Nominal prices)	Margin
81,71	91,00	0,75
86,52	113,32	0,64
104,74	139,30	0,63
110,3	145,21	0,64

Other studies have found that resource rents in fisheries can be up to 60% to 70% of the landing value and hence these values seem to be reasonable. However, one must take into account that there has been a shortage of cod quota over the past two decades and there are high fines for landing fish without quota. Hence the lease quota price might include the cost of landing fish without quota, as well as the resource rent. That is the captain is willing to pay more than the resource rent to obtain one more kilogram of quota, in order to avoid suspension of his fishing license and to avoid fines. To support that theory one can look at the lease prices of haddock. Haddock used to be sold at the same price as cod at the domestic auction markets. Starting in 2001 the quotas for haddock were increased annually because of increased stocks, due to favorable natural conditions. In 2001 haddock and cod annual lease quotas were sold at about 110 to 120 Iskr per kg. By the end of 2003 the price of haddock quota had dropped to Iskr. 28. As a share of auction prices the annual lease price for haddock increased from 33% in 1998/1999 to 68% in 01/02 and then dropped again to 35% by the end of 2003 (Útvegshúsið 2004). This strongly reflects the increase in the TAC for haddock and the subsequent collapse in quota prices due to excessive supply of quota.

Based on the discussion above it is possible to state that resource rents in the Icelandic groundfish fisheries are somewhere between 30% and 60% of the landing value depending on the species and market conditions at any given time.

It seems therefore that some of the resource rent was being realized for the trawler fleet between 1995 and 2000. However, this was relatively low compared to the potential resource rents.

The ministry of fisheries recently issued the calculation of the new fishing fee to be 1.99 Iskr. per cod equivalent kilo, increasing to ca. 2.50 Iskr. per cod equivalent kilo in 2007. At the current auction prices this is less than 2% of the landing value.

DISSCUSSION AND CONCLUSIONS

This paper has focused on explaining economic behavior of Icelandic fishing companies operating wetfish and freezer trawlers. The results of the paper show that there is considerable difference in the development of effort depending on the regulatory framework for the fishery in question. It has also shown that operators of fishing companies respond to the incentives of the individual transferable quota system. Further analysis showed also that only small parts of the potential resource rents have actually been realized within the ITQ system. There is more room for efficiency gains by increasing the size of companies and utilizing returns to scale to minimize operating cost of each vessel, and that the year 2000 trawler fleet could have been reduced up to 50%

This study covers the period from 1995 through 2000. Since then some considerable changes have occurred in the Icelandic groundfish fisheries. Large fishing companies have been merged and sold into smaller pieces again and several trawlers have been decommissioned. In 2003 and 2004 thirty two fishing vessels (trawlers, gilnetters and longliners) were taken out of the Icelandic fisheries (either sold abroad or scrapped) but three new vessels were bought instead. The 32 vessel were registered close to 18.000 GT and the new vessels are registered as 6.000 GT. This is a net reduction of 12.000 metric tons in just two year (Fiskifréttir 2004). All of these changes indicate that the Icelandic trawler fleet is rapidly adjusting to the current regulatory regime by decreasing the number of vessels used to harvest the current share of TAC allocated to the trawler fleet.

This is maybe best seen in an example of the development of a particular fishing company. In 1990 three fishing companies owned 10 vessels measuring a total of 6,850 GRT. The three companies held quota of about 20.000 metric tons in cod equivalent values or 5.6% of the overall TAC measured in cod equivalent values. By 2004 these three companies had merged into one. The new company controlled about 20.000 metric tons of cod equivalent value (5% of the overall TAC) but it now used only five vessels to harvest this quota. These five vessels measured as 3,850 GRT. Three new vessels were bought instead of the eight vessels that the company either sold domestically or abroad or scrapped.

All evidence point in the same direction: The efficiency of the Icelandic trawler fishery is increasing though the process has now taken twenty years, and there is still room for further increase in efficiency.

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ENDNOTES

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[i] As an example of how important this issue is to the Icelanders the supreme court had 7 justices, as compared to 3, or 5 justices in other cases. The court did not reach consensus, and hence the majority ruling (4 out of 7) stated the verdict.

[ii] The exact wording in the legal text is wake, and no quantities or percentages are given to help define what is “obviously” to high quota holding per vessel.

[iii] This value measures relative value between different species of fish. It is based on relative prices from previous fishing year. In the fishing year 2004/2005 one kilogram of redfish is equivalent to 0,47 kilogram of cod. Hence, cod is more than twice as valuable as redfish. On the other hand one kilogram of lobster is equivalent to 6,52 kilograms of cod. Cod equivalent value is therefore a value unit used to make it easier to compare the value of different species.

[iv] See Danielsson, et. al. (1997) “Utilization of the Icelandic Cod Stock in a Multispecies Context.” *Marine resource Economics*, 12(4):pp. 329-344

[v] The data sources change in 1998 and some of the effort definitions could not be constructed for the period from 1998 through 2000.

Appendix

Table A
Estimation Results - All data

	Coefficient	Std. Error	t-Stat.	Prob.
A_0(1)	0.22	0.04	4.88	0.00
AD96(1)	-0.11	0.05	-2.23	0.03
AD97(1)	-0.19	0.06	-3.18	0.00
AD98(1)	-0.21	0.06	-3.31	0.00
AD99(1)	-0.10	0.07	-1.39	0.16
AD00(1)	-0.12	0.07	-1.71	0.09
A_C(1)	0.13	0.06	2.22	0.03
A_L(1)	0.41	0.05	8.04	0.00
A_F(1)	0.01	0.05	0.19	0.85
A_CC(1)	0.08	0.00	23.65	0.00
A_CL(1)	-0.01	0.00	-2.39	0.02
A_CF(1)	-0.05	0.00	-28.97	0.00
A_LL(1)	0.14	0.00	42.28	0.00
A_LF(1)	0.00	0.00	-3.07	0.00
A_FF(1)	0.07	0.00	49.30	0.00
A_OO(1)	0.23	0.05	4.36	0.00
A_Q(1)	0.77	0.03	29.78	0.00
A_QQ(1)	0.08	0.04	1.98	0.05
A_CQ(1)	0.00	0.00	-1.55	0.12
A_LQ(1)	0.00	0.00	2.21	0.03
A_FQ(1)	0.00	0.00	-1.39	0.17
A_OQ(1)	0.10	0.04	2.76	0.01
ASC_0(1)	0.09	0.06	1.51	0.13
ASL_0(1)	-0.07	0.05	-1.41	0.16
ASF_0(1)	0.08	0.05	1.58	0.12
	R-squared	0.93		
	Adjusted R-squared	0.92		
	S.E. of regression	0.24		
	Durbin-Watson stat	2.20		

Table B
Elasticities*

	Capital	*Labour*	*Fuel*	*Other*
Capital	**-0.61 (0.03)**	**0.9 (0.05)**	**0.72 (0.13)**	**0.68 (0.06)**
Labour	**0.90 (0.04)**	**-0.36 (0.04)**	**0.41 (0.08)**	0.09 (0.10)
Fuel	**0.72 (0.13)**	**0.41 (0.08)**	**-0.24 (0.01)**	**0.20 (0.07)**
Other	**0.67 (0.05)**	0.20 (0.07)	**0.20 (0.07)**	**-0.21 (0.04)**

** Bold numbers are statistically significant at the 95% level*