Profits in Cod Fisheries

An empirical analysis of the Norwegian case

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Preface

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Abstract

This study focuses on the economic effects of introducing quotas to an open access fishery. When quotas are introduced, effort should decrease. This leads to higher prices and lower costs. Thus, overall profits should increase. An empirical analysis of profits in the Norwegian cod fisheries is conducted. Quotas were introduced in this fishery in 1990, and the dataset used covers 1985-2005. The empirical results suggest that there have been a considerable increase in profits for the fishers. Few variables on effort and opportunities explain profits. Binary variables for years with and without quotas, however, explain a lot of the change in profits. The effects of other changes to policy and market conditions are also controlled for. These indicate that the quotas increased profits in two rounds. First right after the introduction, and then again some years later, as fishers started to trade quotas. A simulation of the stock and landings is also conducted, which result in a simulation of profits. This suggest that profits have been larger post 1990 than they would have been had the open access been left as it was.

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1 Introduction

During the 1980s Norwegian fishers experienced several years of declining stocks of the North East Arctic Cod.[1] Inspired by Iceland's introduction of quota regimes to limit the harvest of cod in 1984 (Arnason 1993) and in New Zealand in 1986 (Mace and Sissenwine, 1992), the Norwegian authorities in 1990 introduced a quota regime on the Norwegian cod fisheries. Although the intention may have been to save the stock of cod from annihilation, this regime shift had substantial economic consequences.

An open access fishery is prone to become a Tragedy of the Commons. If a fisher leaves fish in the sea, this fish can grow and spawn. The fisher will incur a cost of one. His future gain is y/x, where y is the discounted future increase in the stock. x is number of fishers, since all will gain from his sacrifice. If the future is discounted at a fair rate and/or the number of fishers is large, his net present gain will be lower than his cost. Thus, he will never leave fish in the sea. This will drive effort up, profits down and the stock will stay on a small level.

From a theoretical point of view, this closing of a previously open access fishery should therefore lead to a limited harvest, a healthier stock and higher profits. The question this paper will try to answer is

Did the closing of the fishery for cod lead to higher profits for the fishers? And if this is the case, how much higher profits?

Why is this interesting? First, it is interesting to see if the policy which intended to save the stock caused fisheries to be more economically self-sustainable. In the same period as the fisheries were closed, subsidies to the industry were cut. One intention of this investigation is to reveal whether the fishers made more money when receiving subsidies, or when fishing under a closed regime.

Second, Norwegian politicians did not introduce a system where quotas were tradable. However, it is argued in the literature that the system has developed into one where quotas are traded, but with a lot of friction. The hypothesis that this happened will be tested.

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[1] NOR: Skrei

Third, is the system optimal today? Are there reasons why the laws governing the fishery should be amended, if one only looks at profits? Should the system be taxed heavier?

Assessing the main question requires controlling for natural changes to the stock, changes in prices and for other government policies. A dataset obtained from the Directorate of Fisheries is used to give the answers. The dataset is based on the Directorates yearly profitability survey, and contains individual data on income, costs, landings etc. A panel data analysis of profits is performed. This will answer which factors explain profitability. Binary variables are included in the analysis in order to see if different policies matter for profitability. These cover the years the policy is in place. The estimated effect of these dummies tells us whether the policy had a ceteris paribus effect on profitability.

A simulation of the profits is also done. Data on the stock of cod is obtained from the International Council for the Exploration of the Sea (ICES). This is used to estimate how the stock would have developed without the introduction of a quota system. This simulation is used to adjust the landings of the individual fisher, and to simulate the price of cod in different years. Building on all this, counterfactual profits are simulated. If the simulation is lower, this is an indication that the profit margins would have been lower in the post 1990 era if the quotas had not been introduced.

The rest of the thesis is organized as follows: Section 2 gives a theoretical background for the quota regime, and the version seen in Norway. Section 3 describes how the stock is simulated as it would have been without quotas. Section 4 describes the data on profitability from the Directorate of Fisheries. Section 5 describes a simulation of counterfactual prices. Section 6 describes the simulation of profits. Section 7 describes the regression analysis. Section 8 discuss the results and concludes. Bibliography, Other Sources and Appendices are provided in the back.

2 Quotas

The purpose of this section is both to explain quota regimes in its theoretical form and its implementation in Norway. It will also be argued that some time-dependent binary variables should be included in the analysis, in order to control for changing policies and market conditions.

In short, section 2 describes a textbook explanation of the differences between an open access and a closed regime. The change has some theoretical predictions for the fishery. First of all, profits under open access are zero by assumption. Since positive profits will draw more entrants into the fishery, this will draw overall prices down and costs up, to the point where all economic rents are dissipated. Changing to a closed regime will increase the profits, as new entrants are denied fishing.

Second, the size of the stock should increase. This is based on the notion that in a fishery where everyone is free to enter, no one will have the stock in mind, only their own profits. For a given level of stock, the fishers will therefore land more fish if they are free to do so, than if they are faced with a maximization problem.

The Norwegian implementation of quotas had a special character. The stated reason for the change in policy was not to increase the profits for the fishers; it was to save the stock. Other changes in policy also occurred in the period in question, and these need to be controlled for.

A special implication discussed in this section is that if quotas are introduced without a lawful opportunity to trade in them, a market will occur anyway. Later this hypothesis will be tested. A discussion of whether the trade should be made lawful is found in section 8.4.

2.1 Open and Closed Fisheries

This section lays the theoretic framework for the rest of the thesis. A textbook explanation of the difference between an open and a closed fishery is described. Section 2.1 is based in its entirety on Perman et.al. (2011, chapter 17). The model described is of the simplest static form, but it is to the point. For a description of a dynamic world, the source should be consulted.

2.1.1 Growth and Harvest

A fishery is a stock of fish that is harvested for economic purposes. The stock of fish is normally denoted *S* and measured in tons. Its Growth Function is a function of the stock itself. It is denoted *G = G(S)*, and is assumed to have some kind of bell shape. For the purpose of this work, logistic growth is assumed.

$$G(S) = g\left(1 - \frac{S}{S_{max}}\right)S \qquad (2.1)$$

In equation (2.1), g is a parameter saying something about intrinsic growth. This is the growth in the stock if the stock itself is very small. S_{max} is the maximum carrying capacity of the environment the stock lives in, the maximum tons of fish the sea could possibly support. The growth G(S) thus increases to a certain level of the stock, and starts falling. As the stock grows beyond this point and approach S_{max}, growth approaches zero. Thus growth is concave in its whole domain.

The stock is harvested by fishers. This Harvest is denoted as *H*. and can be written as

$$H = eES \qquad (2.2)$$

In equation (2.2), E stands for effort and S for stock. Harvest grows in both; if more effort is laid down or if the stock is higher, more fish is caught ceteris paribus. e is a catch ability coefficient. It represents efficiency, or technology. Higher e gives higher landings for given levels of effort and stock.

The growth minus the harvest is the net growth in the stock:

$$\frac{\partial S}{\partial t} = G - H \qquad (2.3)$$

Equation (2.3) shows the differentiated value of the stock over time. This equals Growth – Harvest.

2.1.2 Benefits and Costs of fishing

The fishers gain revenue for their landings. This can be represented by the equation

$$B = PH \qquad (2.4)$$

In equation (2.4), P is price and H is Harvest, as before. Fishers also have costs of fishing. In this setup, these are represented by the costs of effort, with the unit-cost w:

$$C = wE \qquad (2.5)$$

The net benefit of fishing is called NB and is defined as:

$$NB = B - C = PH - wE \qquad (2.6)$$

2.1.3 Equilibrium

The model is closed by stating a biological and an economic equilibrium. The first is based on the idea that the stock should stay on a fixed level. This means that the net growth in equation (2.3) should equal zero, and thus Growth and harvest should equal:

$$G = H \qquad (2.7)$$

An open access fishery is recognized by the property that anyone can join it. If there are profits to be made, in the sense of higher earnings than in comparable jobs ashore, fishers will join. They will do so to the point where the profits are eroded away. This happens through two effects. Because more fish is offered on the market, prices will fall. And because more fishers are present in the fishery, the necessary effort of catching the last fish will increase to a level where the costs of catching it equal the revenues. This is based on the notion that some fish are easy to catch, and some are harder. The easy ones cost less in terms of effort, and are caught first.

For the purpose of this theoretical framework, all fishers are assumed to be equally efficient. Thus the economic equilibrium is recognizable by the notion that profits should be zero. This means that equation (2.6) should equal zero and

$$PH = wE \qquad (2.8)$$

2.1.4 Open Access Equilibrium

By replacing G and H in equation (2.7) with their respective definitions in equations (2.1) and (2.2), and rearranging, equation (2.9) is obtained:

$$S = S_{max}\left(1 - \frac{e}{g}E\right) \quad (2.9)$$

Equation (2.9) gives the stock as a function of its maximum limit, Effort by the fishers and the parameters for efficiency in fishing and intrinsic growth in the stock.

Substitute (2.9) into the Harvest Function in (2.2) and obtain the Harvest as a function of the same parameters:

$$H = eES_{max}\left(1 - \frac{e}{g}E\right) \quad (2.10)$$

Equations (2.8) and (2.10) together represent two equations in two unknowns, Harvest and Effort. By solving this system, it is possible to find their equilibrium values. By inserting these values into (2.9), the equilibrium value of the stock is obtained (OA is an abbreviation for open access):

$$E^{OA} = \frac{g}{e}\left(1 - \frac{w}{PeS_{max}}\right) \quad (2.11)$$

$$S^{OA} = \frac{gw}{Pe} \qquad (2.12)$$

$$H^{OA} = \frac{gw}{Pe}\left(1 - \frac{w}{PeS_{max}}\right) \quad (2.13)$$

2.1.5 The Closed Fishery

In a perfect world, one person owns the whole fishery, and has to take all the results of his actions into account. This means that he maximizes todays and all future profits with respect to certain conditions, and adjusts his landings thereafter. An alternative to the view that one person own the whole fishery is that many fishers own it together, and adjust their landings in order to maximize the aggregate profits of the fishery. [2] This is called a closed or private property fishery.

The change from the open access case is that the fisher(s) will maximize profits:

$$Max\ NB = PH - wE \quad (2.14)$$

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[2] See Demsetz (1967) for a discussion of property rights.

By substituting the Harvest Function into this, and maximizing w.r.t Effort, the first order condition is obtained. By substituting the stock from equation (2.9) into the FOC and differentiating, equation (2.15) is obtained:

$$PeS_{max} - 2PES_{max}\left(\frac{e^2}{g}\right) = w \quad (2.15)$$

Equation (2.15) show that under the condition of maximized profits the marginal benefit and costs of Effort is equal. Thus this is the limiting constraint on the fishers; they fish till their effort no longer pays of. This can be solved for Effort to give

$$E^* = \frac{1}{2}\frac{g}{e}\left(1 - \frac{w}{PeS_{max}}\right) \quad (2.16)$$

This can be substituted into (2.9) to give

$$S^* = \frac{1}{2}\frac{PeS_{max} + w}{Pe} \qquad (2.17)$$

And using H = eES:

$$H^* = \frac{1}{4}g\left(S_{max} - \frac{w^2}{P^2e^2S_{max}}\right) \quad (2.18)$$

2.1.6 Open Access versus Closed fishery

Comparing the equilibrium results in (2.11) - (2.13) and (2.16) - (2.18), it is evident that the open access fishery yields lower levels of the stock than the private property fishery. By assumption, profits under open access is zero, and larger than zero in a closed fishery.

In this simplified model, the equilibrium Effort is only half as large in a closed fishery as it is in an open access fishery. But even in a more complicated model the Effort will always be lower in the closed case. By inserting the two equilibrium Efforts into the Harvest Function H = eES, and plotting against the growth, it is evident from Figure 1 that the growth in Harvest as the stock grows is larger under open access than in a closed fishery:

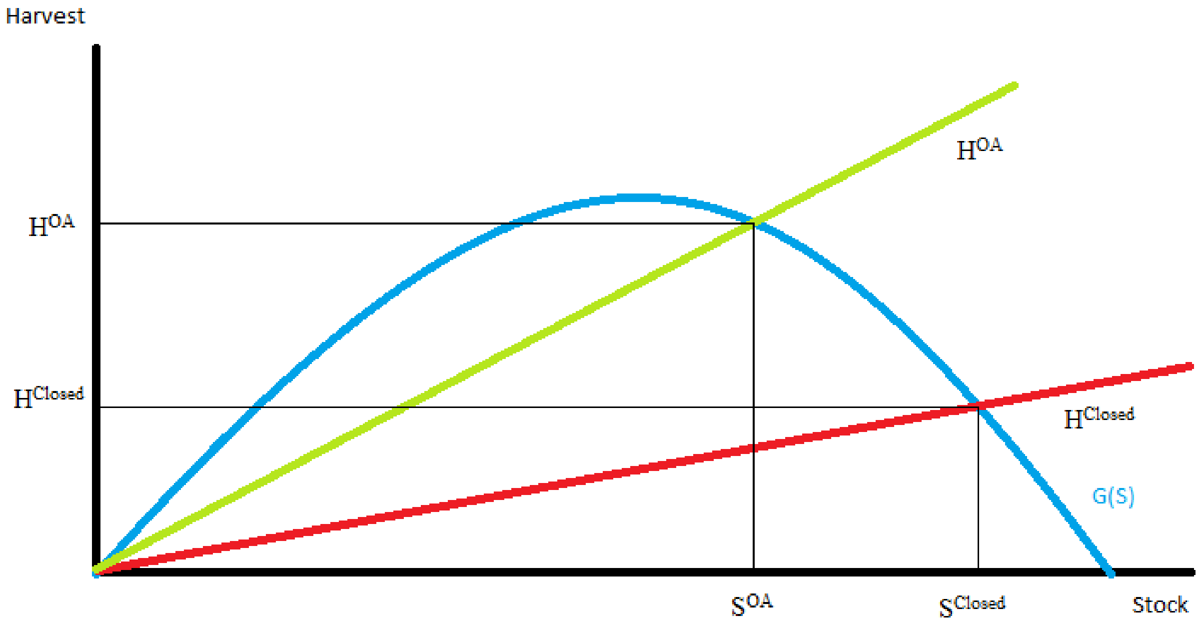

Figure 1: Harvest versus effort in open and closed fisheries

From Figure 1 it is seen that the equilibrium solution for the stock is larger in a closed than in an open fishery. It is also seen that the higher Effort yields a steeper Harvest Function for the open access than for the closed fishery. And in this figure, equilibrium harvest is higher under open access than in the closed case. But this is not necessarily so. If the two Harvest functions are steeper, the two equilibrium Harvests come closer, and at a point the closed case Harvest will climb above the open access case. This is due to the quadratic form of the Growth function G(S).

2.2 Closing the Fishery

2.2.1 Why?

From the theory described in section 2.1, it is clear that an open access fishery is a market with externalities. However, for most of mans history, fisheries have been open. There are several reasons why this is the case.[3] First, in order to really threaten the existence of a stock, the level of technology has to come to a certain level. Even if more people were engaged in fishing in earlier times, they could not fish the ocean empty.

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[3] Homans and Wilen (1997) discuss the differences between theoretical open access and real-world applications.

Second, an effective state is needed to place regulations. And this state has to take the costs of making unpopular decisions. In the northern parts of Norway the sentiment seems to have been that unconstrained fishing is a human right.

If an effective state is in place, it has at least three alternatives in its approach to a general fisheries policy. If the people revolt at the thought of regulations, and the technological level is on a level where the stock is unthreatened, the state probably will chose to leave the fishery open.

The state could also choose the objective to maximize efficiency, or profits. Some kind of closing is an option. This will increase the profits to the fishers, and taxes to the state. If the state further charges a resource tax, as the Norwegian state does on oil production, it can increase its income further. As a bonus, the equilibrium level of the stock will go to a larger level. In a stochastic world, were the stock is affected by sickness, predation from other species etc., this is an insurance against annihilation.

On the other hand, the state can have as its objective to avoid this annihilation. This is applicable if the stock has come down to a very low level. This is the reason why the Norwegian fisheries for cod were closed in 1990. Then a nice by-effect of the closing will be the increased tax-revenue from the fisheries.

2.2.2 How?

In order to create profits in the fishery, some kind of management is needed. Theoretically, a tax that internalizes the externality would be optimal, correcting the market failure. The tax would have to bring the private cost of catching the marginal unit of fish up to the social cost. However, this is not a feasible solution; it is not possible to transfer the theoretical beauty to the real world (Perman et.al., 2011, p 596-598).

A feasible solution is to set a Total Allowable Catch (TAC). (Perman et.al., 2011, p 599).[4] It has to be based on biological estimates of the size of the stock. Its goal can be to keep the stock safe from annihilation, to maximize Harvest in the long run, or to maximize economic profits. In most real fisheries where it is used it is a scientific advice on what is the optimal

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[4] See Asche et.al., (2009), for a good discussion of TAC, ITQ, and its effects.

catch of a stock in order to obtain sustainable harvest in the longer term. The TAC is then adjusted every year.

The important aspect is that total Harvest is limited, and thus profits for the fishers has to be maximized with a new constraint:

$$\bar{H} = eES \qquad (2.19)$$

If the TAC is set so high that it is not filled, it is not a binding constraint on the fishery. If it is binding, the zero-profit assumption is no longer binding. However, in this model, more entrants will join the fishery if there are profits. This will drive total costs up to the point where fishers again make zero profits.

By dividing the TACs into quotas, an artificial property right is established for the fishers. Although they do not calculate their long term profit when deciding how much effort to use, they do limit it in a way that creates less aggregate harvest. In turn, this creates a healthier stock. The lower landings lead to short term profits, through two effects. First, since each boat land smaller volumes, the cost of catching the fish is lower. Second, because the aggregate landings are lower, with constant demand the price of fish increases. Thus, on the margin, there is a profit of catching fish (Perman et.al., 2011, p 598-600). This is called the Individual effect, or Individuality. Individuality gives the fisher control over his own effort. He can plan his own season and effort, what matters is that he delivers his quota.

The quotas are called Individual Transferable Quotas (ITQ). The transferability of quotas is also important, because there are efficient and inefficient fishers. Let us say the market price of the quota is 20, and that the net present value of continuing in the fishery with that quota is 10 for the inefficient and 30 for the efficient. The inefficient fishers will gain 10 from selling their quota, and the efficient will gain 10 from buying it. Thus, after an auction, or some period of trading, the effort should be concentrated on the most efficient fishers, and the TAC will be harvested with the least possible effort (Perman et.al., 2011, p 599-600). This will increase profits. It is also reasonable that the profits of the efficient fishers will further increase as they can invest in larger boats and gear, enjoying economics of scale and becoming even more efficient.[5]

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[5] For a discussion of the distributional effects of ITQ in Iceland, see Eythórsson (2000).

2.3 The Norwegian Case

This thesis shall focus on the North East Arctic (NEA) cod and the coastal fleet of vessels below 28 meters, fishing with traditional gear.[6] One reason is that the size of the analysis should be limited. Another reason is that this fleet is quite stationary, they fish on their local fishing grounds or travel along the coast to seek opportunities, like in Lofoten. The seagoing fleet is more versatile, going up to Svalbard, to Iceland or Greenland to seek opportunities. This makes an analysis of the coastal fleet better suited to say something about the profitability in Norwegian fisheries. A third reason is that the dataset used only cover the years 1985-2005. As explained in this section, the coastal fleet experienced a regime shift in 1990. Obviously there were indirect effects on the landings off the seagoing fleet, but these can not be measured in the data.

2.3.1 Background for Regime Shift

Norway has vast fishery resources within its economic zones. It shares these resources largely with Russia and Iceland, as well as the EU (Bjørndal and Årland, 2002, p 307-308). These resources can therefore hardly be said to be affected only by Norwegian management.

Norway has a long history[7] of dividing the fleet into sea going vessels, often trawlers, and coastal vessels using traditional gear. It has been the policy to keep the larger, more efficient vessels out of the largest fisheries on the Norwegian coast. Trawlers have been outlawed from within 4 miles from the coast since 1908 (Hersoug, 2005, p 34). Purse seiners have not been allowed in the Lofoten fishery since 1958 (Hannesson et.al, 2010, p 762).

Within the coastal fishery, the seasonal fishery for NEA Cod in Lofoten is the most economically important, and has been so for maybe the last 1000 years (Hannesson et.al, 2011, p 748). Regulation has been gradually imposed over the last century, but prior to 1980,

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[6] Traditional or conventional gear includes long lines, gill nets and hand lines, as well as other, less used gear. See St. meld. 21 (2006-2007) for a useful list of explanations (In Norwegian).

[7] Improving technology has caused tensions between small boat fishers and modern vessels for many years. In March 1890 a few large steam driven seiners closed in a large share of the stock in the Trollfjord in Lofoten. This caused a fight between the crews of the seiners and smaller crafts, later known as the “Trollfjord Battle”. This incident directly affected the Lofoten Act of 1897 which prohibited seine in Lofoten. When the larger, more capital intense vessels turned to trawling, the same sentiment caused their prohibition from coastal fishery in 1908. (Hersoug et.al., 2000a , p 357)

no serious limitation on fisher's effort was made. In 1982 a time limitation was introduced in the Lofoten cod fishery; i.e., the authorities would set a TAC and stop the fishery when it was caught. The fishers would have to make their effort prior to the closing date, causing more intensive competition among the fishers, and probably lower quality. Maximum quotas[8] were introduced in 1983, but were set so high that few boats were affected by it (Hersoug, 2005, p 111). This regime might thus be described as a quasi-open access; even if there were regulations, the fishers had little incentive to limit their catch. In retrospect, it seems like a tragedy of the commons would "have to" arrive in the cod fisheries.

The stock of cod fell dramatically during the 1980s, and in the 1989 season the conventional TAC[9] was very small.[10] Because the weather was favourable, and the fish swam up to the shallow waters this year, the TAC was taken and the fish was closed already on April 18th, perhaps 6 weeks earlier than usual (Hersoug, 2005, p 113).

2.3.2 Implementation of Quotas

With this background, quotas were introduced as a crises measure in the fall of 1989. They were not supposed to be permanent; the Ministry of Fisheries argued that they were needed to help the stock grow, and that they would be removed after some time (Hersoug, 2005, p 113). However, this limitation on the fishery still exists.

The quotas introduced in 1990 were not transferable;[11] they were attached to the boat, and therefore called Individual Vessel Quotas (IVQ). The quotas were granted on the basis of

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[8] Maximum quotas are quotas on individual fishers. Group quotas are quotas on a group of fishers. The Maximum quotas does not always sum up to the Group quota. If the sum of Maximum quotas is larger than the Group quota it is called Overregulation. This is often done to ensure that the Group quota is caught, because some fishers do not catch their Maximum quota. (Bjørndal and Årland, 2002, p 310)

[9] By conventional TAC here I mean the proportion of the Total Allowable Catch given to conventional gear, the coastal fleet. The total TAC is set by the ICES in order to get sustainable yields over time. Yearly negotiations between Norway and Russia divide this quota between the two countries. The rule that divide the Norwegian part of the TAC into a share to the trawlers and share to conventional gear is called the Trawl-ladder. For small TACs, the proportion is high, 80% if it is below 100000 tons, but it is falling in TAC. The Trawl-ladder has changed several times, for a thorough discussion, consult Hersoug (2005, p 141)

[10] See page 34, section 3.5.1 for a graph on the development in the stock.

[11] For a discussion of the political climate leading to the IVQ-regime instead of a full-scale ITQ, see Hersoug (2005, chapter 6). The whole book is about the fight over policy in Norway. To sum up short, policy rarely is

catches[12] [13] in the 1987-1989 season (Hersoug, 2005, p 113-114). Those who had fished actively in these years were allocated in Group 1. Others, considered to have fishing as a part-time business, were allocated in Group 2. Higher quotas were granted to Group 1. An economically more sound approach would be to auction the quotas to the highest bidder (Nøstbakken, 2009, p 3). This way the most efficient fishers, with most to gain from fishing, would outbid the less efficient and thus fish the quota at the lowest cost. This auctioning could have been done even if the quotas were to be IVQs.

Hersoug (2005, p 113) argues that aspect of efficiency was not that important when quotas were introduced. For the politicians it was more important to secure a temporary regime that was fair, which was ensured by rewarding the fishers that had been effective earlier.

Hersoug (2005, p 134-135) argues that there is a “closing-logic” operating in Norwegian fisheries. Quotas are a result of TACs, since there is no point in estimating the TAC if it is not to be used for something good. The quotas take the form of IVQ, because there is no political will to introduce a full-scale ITQ. Furthermore, Hersoug et.al (2000b) and Aarset and Standal (2008) argue that a path dependent process lead to de facto ITQs. As soon as IVQs are established, fishers will start trading in the proxy asset, the boats. In other words, they will calculate the value of the quota belonging[14] to the boat into its value, and start trading. Changing the regime back is not an option, as no politician wants to be responsible for taking away fishermen’s property – the quotas – and redistributing them to fishers who have not paid for them.

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backed by economic arguments. A main idea of Hersoug is that as soon as you create (quasi) property rights to the fish, you create a market for quotas, intended or not.

[12] The way I read Eikeland (1991) he state that the quotas were granted on the basis of length of the boat. This is a factual contradiction to Hersoug (2005, p 114). I have to believe Hersoug, as the work by Eikeland is a Masters-thesis (Hovedfagsoppgave), and Hersoug is a much cited and renowned author. One should anyway not trust a Masters-thesis.

[13] Granting quotas on this basis of course has a dynamic element. Say that the authorities announce that at a date in future, they will give generous quotas to those who fish a lot now. Obviously, all fishers will adjust their effort to get more quotas in the future, if not to use, then to sell. See Hersoug (2005, p 129) for a discussion. Because the quotas were introduced with no time to adjust effort, this dynamic element is not important in this case.

[14] No quotas actually belong to boats. They are given licences to fish, and these licenses are renewed each year. Non-renewal happens extremely seldom. See Hersoug et.al (2000b, p 327) for a discussion.

2.3.3 Development of policies in the 1990s

In the course of the 1990s, the regime gradually changed. In 1989, 7500 boats were considered to be part of the active coastal fleet. After regulation the number of Group 1 boats was 3500. As the fishery picked up in the 1990s, the difference between owning a boat with and without a quota was immense. Soon the value of quotas was calculated into the price of the vessel when they were traded, and the system thus approached an ITQ system (Hersoug, 2005, p 160). Hersoug et.al. (2000b, p 327) argue that this had started to happen when their paper was written.

In 1991, it was decided that the trade of vessels must be done within counties (Hersoug, 2005, p 116). This implies that both the buyer and the seller must now have been a registered fisherman in the same county for the last 12 months before the sale.[15] (St. meld. 20, 2002-2003:27). This was consistent with the role fisheries have in Norwegian rural policy; the boats should be kept within the county. What was known to happen was that the buyer transferred the quota to his first boat, and sold the boat back to a fisher in Group 2, often to the original owner (Hersoug, 2005, p 116 &160). Theoretically, this limitation should lead to regional differences in boat prices, and implicitly in quota values.

In the early 1990s quotas were overregulated each year; the sum of maximum quotas was higher than the group-quota. The purpose of this was to make sure that the whole group-quota would be taken, as some fishers would not finish their quota. At a given, predetermined redistribution date, the authorities would redistribute quota from those who had fished a small part of their quota, to those who had fished a lot. The aggregate catch was still limited to the group-quota, in order to stop overfishing (Hersoug, 2005, p 118-119).

When the quotas was originally distributed in 1990, only the smallest vessels got 100% of their historical catch as quota, while the larger ones got a percentage decreasing in vessel-size; boats of 27 metres only got 50%. In the mid 1990s the TAC increased, and the small boats could seldom catch 100% of their quota. The large coastal fleet could fish their (small) quota prior to the redistribution date, and then get a new quota after redistribution, as the unused quota from the smaller vessels were redistributed. This caused large investments in the large coastal vessels (Hersoug, 2005, p 114-119).

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[15] For North-Troms and Finnmark the sellers does not have to be registered there; thus buyers in these counties can buy from the whole country. (St. meld. 20,2002-2003:27)

Towards the end of the decade, the overregulation came down from 100% to about 20%.[16] This gave much smaller growth in the large coastal-fleet, as the larger vessels no longer got hold of new quotas after the redistribution date. The growth effectively ended in 2002 with the introduction of the Finnmarks-model, in which the coastal boats were divided into four length-groups; <10, 10-15, 15-21 and 21-28 metres.[17] Redistribution of quota now happened only within each size-group, and large coastal vessels could no longer rely on getting extra quotas from small vessels (Hersoug, 2005, p 120-121 & 159).

2.3.4 Structural Policy

A twin program of fleet reduction was in operation in the last part of the period in question. From July 2003 the Condemnation Scheme gave coastal fishers the option to give up their activity and get a monetary compensation from the state. The quota was redistributed on the rest of the size-group the boat was a part of. Thus, boats not quitting received quotas from those who did quit (St. meld nr. 21, 2006–2007, p 15.)

From January 2004, the Structural Quota System (SQS) gave the fishers the opportunity to give up the activity on one boat and carry 80% of the quota over to another boat. The last 20% was redistributed on the rest of the fleet, which implies that fishers not taking part in the transaction were also provided with larger quotas under this scheme. This arrangement was available only to vessels between 15-28 meters. One vessel could acquire a maximum of three quotas, and the transfers were limited to the length-group the boat was in. For quotas of cod, haddock and saithe, the transfers were also limited to counties (Hersoug, 2005, p 162-163).

2.3.5 Quota Exchange System

From July 2003 a Quota Exchange System (QES) was introduced, in order to meet a demand for a more flexible trade of quotas. Under the scheme, whole or parts of quotas could be exchanged for quotas in other fisheries, or leased out. This laid the ground for more specialised fisheries, making fishers able to cut cost by equipping their boat only with gear to

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[16] x% over-regulation mean that the sum of all maximum-quotas is x% larger than the group-quota.

[17] Thus, since 1995 there have been six groups in the coastal fleet: the four length-groups in Group 1, Group 2 and boats larger than 28 metres.

catch i.e. demersal fish. The quota could be exchanged only three out of every five years, and the deal had to be signed before the start of the fishery.

Although creating flexibility, this system probably limited the effect of the SQS. Boats that otherwise would sell their quota, now could lease out part of it and gradually reduce their activity (Hersoug, 2005, p 161). Hersoug (2005, p 169) argue that the SQS and the QES actually have worked against each other, by showing that fishers prefer to lease quotas as long as possible. Together, SQS and QES constituted a softening of the IVQ regime. Trade and leasing of quotas made the system look more and more like ITQ.

2.3.6 Other changes to the fisheries in the 1990s

In 1964 the state and the Norwegian Fishermen's Association (NFA) entered into what was called the Main Agreement on Fisheries. The agreement regulated the relationship between the state and the fishers. The state used NFA as representatives of the fishers, and the yearly negotiations on subsidies took place in this forum (Christensen and Hallenstvedt, 2005, p 155-160). The subsidies to harvesting were generous, but fell dramatically after 1990. From 1991 to 1993 they decreased from more than 1 billion to less than 400 million NOK in aggregate. In 2002 they totaled at about 175 million (Flaaten and Hermansen, 2004, p 15). In 2005, the Main Agreement was terminated by the Norwegian Parliament. The subsidies were no longer seen as necessary to keep the fisheries active (Press release Ministry of Fisheries 47/2004).

Although there is no reason to dismiss the effects of the subsidies on the fleet, they will not be treated thoroughly here. First of all, as Flaaten and Hermansen (2004) argue, they are hard to pin down and the data are not easily accessible. Second, subsidies are not reported as a separate post in the data, but are a part of revenues. Thus, profits become abnormally high. As an isolated effect, the decrease in subsidies should lead to a fall in profits in the 1990s. Subsidies and quotas thus have opposing effects on individual profits. Since the subsidies disappeared in the same period as quotas were introduced, increasing or even stable profits would be a strong indicator that quotas lead to better margins for the fishers. Thus, in order to answer the problem of this thesis the need to explain subsidies' effect on the fleet is not strong.

From 1990 80% of the conventional TAC was given to Group 1, and then distributed to the fishers according to size of their quota. 20% went to Group 2. From 1995 the coastal fleet larger than 28 meters has been treated as one group (Hersoug, 2005, p 114 & 117). These vessels have received 12.8% of the TAC, leaving 77.7% to Group 1, and 9.5% to Group 2 (St. meld. 20, 2002-2003, p 35).

Thus, the Group 2 part-time fishermen conceded to large reduction in their quotas, both to larger vessels and to equally large vessels with full time fishers. In order to remain in the favourable Group 1, from 1994 fishers had to deliver at least 40% of their quota each year. This was done to be able to redistribute quota to new entrants, securing some recruitment of new fishermen (Hersoug, 2005, p 117).

It is always hard to track what fishers are really doing, even if they are registered in a central archive. But it seems like the coastal fishery became capital-stuffed in the 1990s. This means that the boats carry sub-optimally high levels of capital. In this business, more gear means smaller crew, as the machinery takes the place of the workforce. Thus, the request for hired fishermen goes down. Because of the limitation on catch, but not on timing of the catch, so called “Skipper Fishery” has emerged. This means that two or more skippers can crew each others boats in turn, and thus fill their quota with no or low cost to wages (Hersoug, 2005, p 132-133). This might partially explain why the proportion of young fishers has gone down radically since 1990. Even if new fishers can buy a boat without quota, fish as much as they are allowed under the Group 2 quota, and thus get a Group 1 quota, they cannot get experience from crewing on Group 1 boats.

Fishing cod cause by-catches of saithe and haddock, which complicate the regulation of these fisheries. From 2002 vessels in Group 1 of less than 15m participated in a project were they got a common quota for these three species. Catch of the other two was calculated into equivalents to cod, and cod limited to 70% of the overall quota. The conversion rates were quite favourable, so that the less profitable saithe and haddock were harvested as well. This system makes it possible for the authorities to manage the three species by changing the conversion rates. Vessels of the size 15-28 meter still get individual IVQs for all three species (Hersoug, 2005, p 124-126).

All in all, section 2.3 can be summed up with saying that the political regime moved from (almost) open-access to (almost) closed fishery in the 1980s. Further, it is possible to argue as Hersoug et.al (2000b, p 326-328) that the IVQ system was softened in the 1990s, when the market for vessels started to take the value of quotas into account. If this seems too vague, one could argue that a softening of the IVQ regime occurred with the SQS and QES.

It is also clear that Norwegian quota policy is quite complicated compared to Iceland’s or New Zealand’s ITQ system. This is because the Norwegian model seeks to cover a number of goals. When you transfer quota between your boats, 20% of it goes to perfect strangers who has done nothing to earn it. This is to reach out a hand to those in opposition of the SQS. Quotas can only be traded within counties, in order to keep with traditional Norwegian rural-area policy. And the Finnmarks-model was established to keep the diversified fleet, small and large, side by side (Hersoug 2005:166). The Ministry of Fisheries has many measures at hand, and seems to seek many goals with these.

2.4 Implications for the analysis

From the theory in section 2.1 some predictions come out about what should have happened to Norwegian fisheries after 1990. The stock should grow, and profits should increase.

From section 2.3 it is clear that several binary variables need to be tested in the analysis. The obvious one is one that take on the value zero in 1985-1989, and one in the period 1990-2005. This dummy will be a proxy for the introduction of quotas. When analyzing the causes of variation in profits, this will be included as an explanatory variable. The dummy is called D1.

Hersoug et.al (2000b, p 326-328) argue that the regime at this point had turned into a quasi-ITQ system, because value of vessels in trade largely reflected the value of rights to fishing. This paper is written in 1999. It is therefore not unreasonable to state the hypothesis that the regime changed from IVQ to ITQ in the years before. This process would by nature be gradual, but in order to investigate whether or not it took place, it is necessary to set a specific date. The year chosen is 1998. This is very speculative, and has to be this author’s responsibility. But by generating two separate dummies, one with value one in 1990-1997 and one with value one in 1998-2005, it is possible to test the explanatory power of this hypothesis. The first dummy would then test the effect on profits from Individuality, and the other would test the effect of Tradability. The dummies are called D2 and D3 respectively.

Another reason for choosing 1998 is that this year the Directorate of Fisheries started a new way of sampling their data (see section 4 for details). The dataset became stronger, which reduced measurement errors. Thus, by exploiting the length of the dataset before 1998, and the lower measurement error in the remaining years, an increase in profits should indicate that the proposed transition from IVQ to ITQ-regime increased profits.

As mentioned, it is quite speculative to assume the regime changed sometime in the 1990s. However, there is good reason to test whether or not the SQS and QES changed the IVQ system (see section 2.3.4 and 2.3.5). These were both introduced at the very end of the period the dataset cover, from the 2004 season. Also, SQS only covered boats in the sizes between 15 and 28 meters. Therefore it is natural to include two dummies. D4 takes on the value one in 2004-2005 if the boat is 15-28m. This is meant as a proxy for SQS. D5 takes on the value one in 2004-2005, irrespective of the length of the boat. This is meant as a proxy for QES.

As discussed in section 2.3.3, there was a growth in number of robust coastal vessels in the 1990s. This was caused by overregulation. When the Finnmarks-model was introduced in 2002, the robust vessels no longer got quotas from smaller vessels that failed to fill their quota. A question of interest is whether or not these vessels maintained their profitability after this period. A binary variable will therefore be included to investigate this. It will take on the value zero in 1985-1989 and 2002-2005, and one in 1990-2002. This dummy is called D6.

It is not possible to know beforehand how large the vessels had to be in order to experience an increase in profits and landings. This part of the analysis will therefore be done several times, first with boats ranging 25-28m, then 22-28m, then 19-28m and at last with boats 15-28m. Since the largest boats got largest quotas out of overregulation, the analysis is most likely to show that boats in the range 25-28m gained the most in terms of profit and landings. Notice that the length classes applied here does not coincide with those in the Finnmarks-model. Groups of approximately equal intervals are included to get a sort of linearity in the increase.

One should see these dummies for what they are; hypothesis to be tested. A critique of the pair D2 and D3 is that to pin down a year the change happened is impossible. Because the dataset available ends in 2005, an effect of D4 and D5 on profits can not be very significant. Testing the effect of D6 for the largest boats should capture the effect of large boats being able to receive “bonus quotas”. But as this analysis is done with more and more boats, there is a risk that the dummy captures the Individuality effect.

3 Counterfactual stock of Cod

3.1 Why?

When analyzing profits, and whether or not the new quota regime caused them to grow, one needs to make some comparisons between the observed and the counterfactual cases. It is therefore necessary to simulate how the stock of cod could have developed without a quota regime after 1990. The purpose of this exercise is to find a ratio between counterfactual and observed landings. Using this ratio, it is possible to adjust individual landings accordingly.

Furthermore, it is possible to regress prices on actual aggregate landings. The prices in this function are adjusted for inflation in the period. By changing the input from actual aggregate landings to simulated, this result in counterfactual prices. This is done in section 5.

This prediction is for NEA Cod, which is one of several species of demersal fish targeted by Norwegian fishers. Thus, only part of the fish regulated by the quotas is simulated counterfactually. This is a justifiable simplification, as this species mean most to fishers in terms of economy – see Figure 2 and Figure 3. Also it was the collapse of this species that caused the change of policy. Further, it would be far too complicated to predict the development of other species in light of the change of policy for NEA Cod. Sure, the change of regime for NEA Cod affected other species, in terms of access to food and predation. But it is not obvious in what direction and in what magnitude.

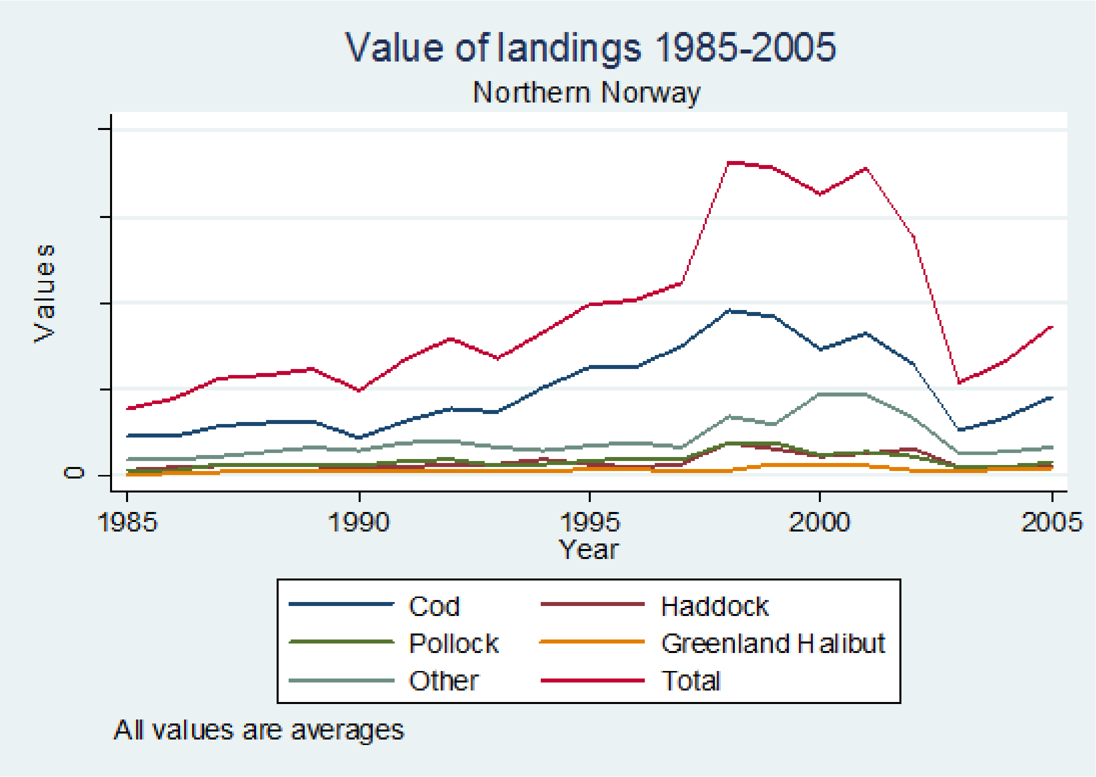

Figure 2: Value of landings for different species

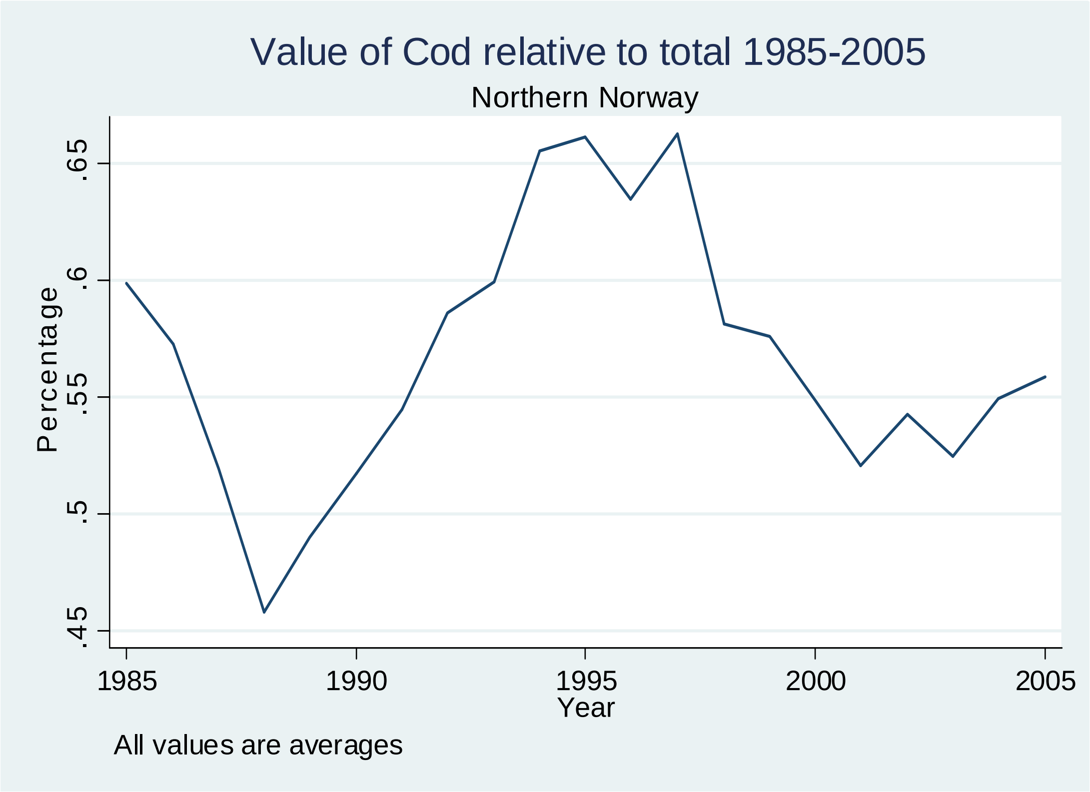

Figure 3: Relative value of landed Cod. Percentage.

Without doubt, this approach has some uncertainty attached to it. Nevertheless, it is an exciting and necessary way to analyze how things could have been.

The simulation is done for the stock of cod in the years 1990-2005, as the data on the economics of the fleet is restricted to 1985-2005 and the shift in regime was effective from 1990. Sections 3.2, 3.3 and 3.4 are not crucial for understanding the rest of the thesis, but it is advised to take a look at the results in section 3.5 and the adjustment of individual fishers' landings in section 3.6.

3.2 Definitions

Following Beverton and Holt (1957, ch. 3) and Clark (1976, p 269-276), the following definitions are used in simulating the stock of cod. When describing a stock of fish, the aggregate number that tells us how large it is is Total biomass – TBM. It is defined as

$$Total\ Biomass = TBM_t = \sum_{a=3}^{13+} N_{a,t} * AW_{a,t} \quad (3.1)$$

$N_{a,t}$ is the number of fish of a certain age a at time t. $AW_{a,t}$ is the average weight of fish of a certain age a at time t. TBM_t is measured in tons. The fish are counted from the age of three, and that cohort is called $Recruitment_t$ each year:

$$N_{3,t} = Recruitment_t$$

$AW_{a,t}$ is Average Weight of the fish of that age, or cohort.

Only a percentage of each cohort are mature, for the younger fish almost none, for the older almost all. In order to describe how large the stock is that produces new fish $Percentage\ Mature_{a,t}$ is included in the above equation, in order to get

$$Spawning\ Stock\ Biomass_t = SSB_t = \sum_{a=3}^{13+} N_{a,t} * AW_{a,t} * Percentage\ Mature_{a,t} \quad (3.2)$$

$Spawning\ Stock\ Biomass_t$ is measured in tons.[18]

$Landings_t$ is the total catch of fish, measured in tons.

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[18] NOR: Kjønnsmoden

$Landings_t$ cause $Fishing\ Mortality_{a,t} = FM_{a.t}$; i.e. the deaths of a certain cohort related to catches. $Natural\ Mortality_t = NM_t$ is a sum of two causes of death. The first is sickness, predation etc., which is commonly assumed to be 0.2. The other is cannibalism. Cannibalism within the stock is larger if other species, other sources of food, are small in a given year. Cannibalism is measured each year, and cause the variability in NM_t.[19]

3.3 Data

Data on the NEA Cod are obtained from the International Council for the Exploration of the Seas (ICES).

For each year 1946-2009, the dataset give calculations on Total Biomass, Spawning Stock Biomass, Recruits and Landings. Furthermore, it gives NM_t , Average Weight of each cohort, and Percentage Mature in each cohort.

A biologist might say that the data are calculated from small samples, and that it is impossible to obtain the level of accuracy the ICES claim. The purpose of this exercise is to find a ratio between simulated and observed landings. If both are under- or overestimated, the estimated ratio between them will still be close to the real parameter. Thus, for the use in this paper this is irrelevant, as the ratio is used to correct individual boats catches.

In the dataset, landings are an aggregate of landings in Russia, Norway, Iceland, the EU and any other nations landing cod. Only a proportion of the landings are done by Norwegian fishers. Thus, it is not fair to say that a difference between real and simulated landings come from a change in Norwegian policies only. Nevertheless, this simplification has to be done in order to proceed with the simulation.

3.4 Simulation of the stock

3.4.1 Recruitment

Recruitment is estimated as a relationship with the biomass of the spawning fish. One standard way to describe this is the Beverton-Holt relationship (Beverton and Holt, 1957, p

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[19] See Bogstad et.al. (2007, p 662), for a discussion of dynamics of access to food and cannibalism for cod.

49). Recruitment is defined as the number of three year olds, and SSB_{t-3} is defined as the Spawning Stock Biomass three years earlier. The Beverton-Holt relationship is then

$$Recruitment_t = a * SSB_{t-3}/(1 + b * SSB_{t-3}) \qquad (3.3)$$

The relationship is steep at start, and then flattens. This is justified by cod's enormous amounts of eggs. A small stock of fish can produce a large amount of recruits. But as the number of egg laying individuals grows, environmental conditions such as food and space cause the marginal Recruitment to approach zero. Recruitment thus asymptotically approaches a/b. a and b are estimated on the whole dataset, 1949-2009, in order to get the best possible estimates.

Using the dataset described in section 3.3 and plotting observed Recruitment against SSB three years earlier:

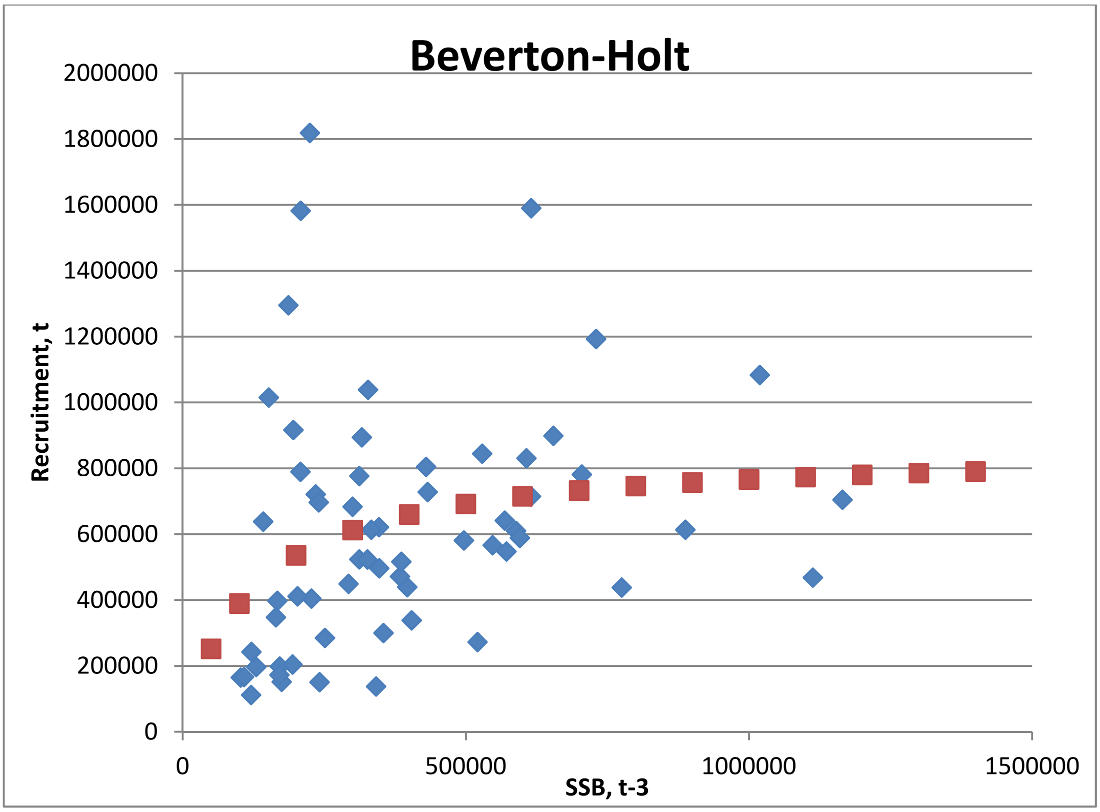

Figure 4: Beverton-Holt. Number and Tons.

Figure 4 plots the observed $Recruitment_t$ against SSB_{t-3}. Using the observations in blue, the non-linear relationship in equation (3.3) is estimated. $Recruitment_t$ is then predicted, and shown as the red line. As one can see from the observations, there is greater variability in

Recruitment for smaller stocks of cod. This is an indication that when the stock is small, environmental conditions have more to say for Recruitment.

3.4.2 Landings

Landings are estimated as a relationship between $Landings_t$ and $Total\ Biomass_t$. Testing several relationships, it turned out that landings were highly correlated with the stock of cod the year before (see Appendix 3.1). Defining TBM_{t-1} as the $Total\ Biomass_t$ lagged one year, the estimated relationship is

$$Landings_t = \beta_0 + \beta_1 * TBM_{t-1} \quad (3.4)$$

Using observations in the years 1960-1989 from the dataset described in section 3.3 and plotting observed Landings against TBM the year before are shown in Figure 5:

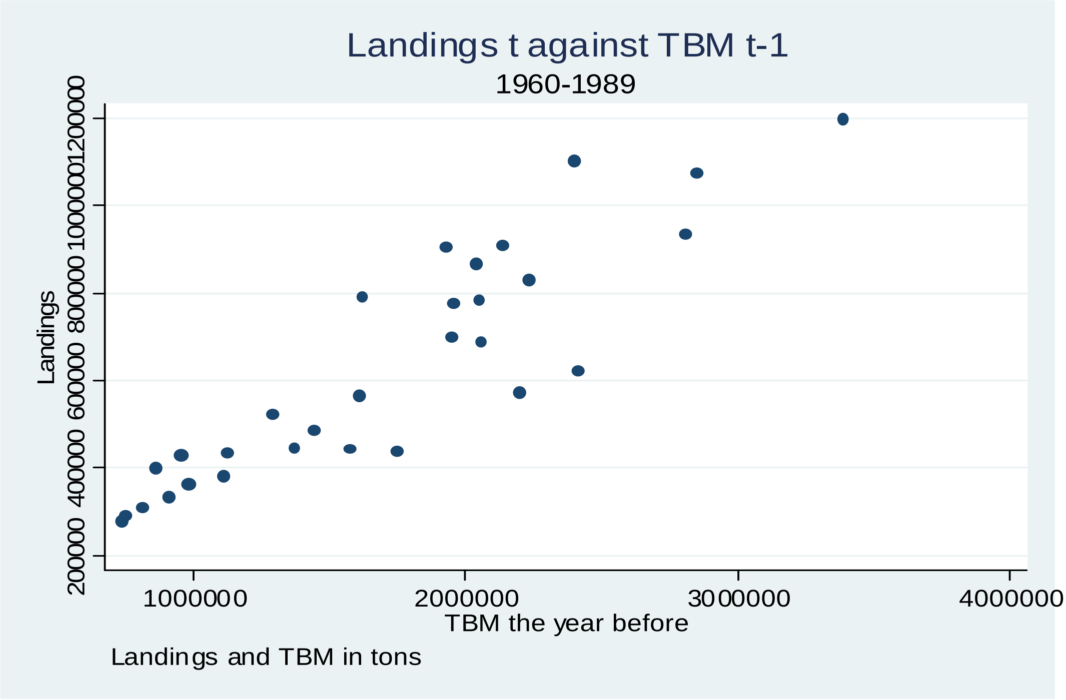

Figure 5: Landings against TBM the year before. Tons.

As one can see from Figure 5, this relationship is quite consistent, and has good properties. Figure 6 show the resulting predicted landings:

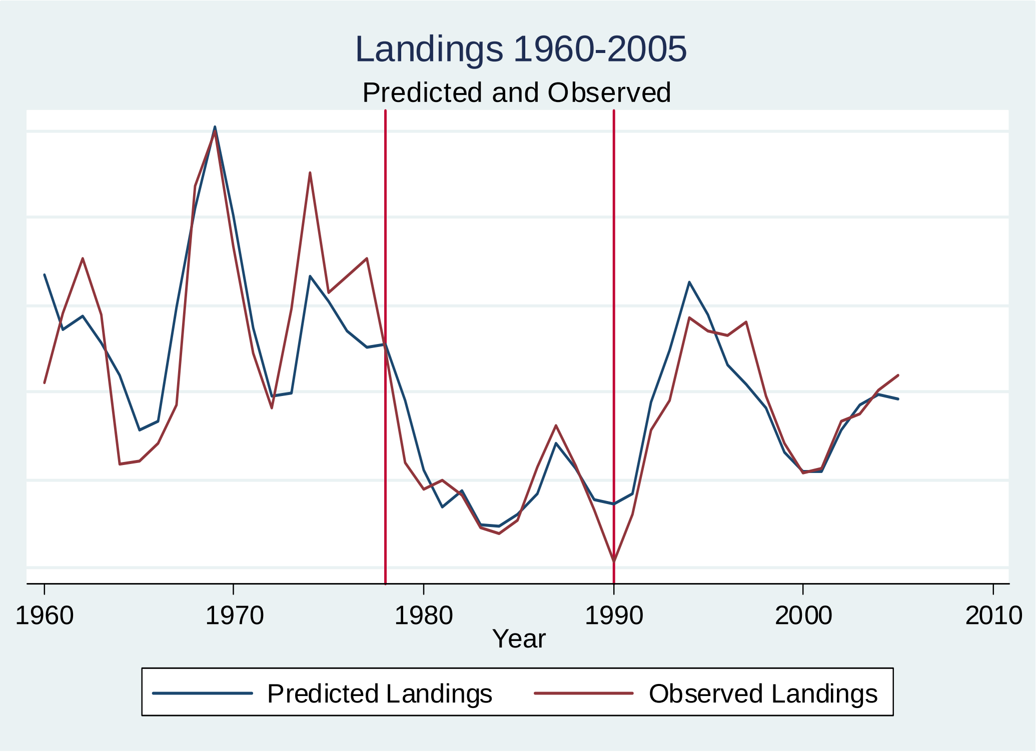

Figure 6: Landings, Predicted and Observed 1960-2005. Red vertical lines mark 1978 and 1990. Tons.

As follows from Figure 6, over time the prediction for landings is quite good, and better for the period 1978-1990 than before. This justifies the assumption that the landings observed in the 1980s would have continued from 1990, had there not been a change in policy (see Appendix 3.1 for properties of the residuals.)

Equation (3.4) is a key equation in the simulation. By estimating the parameters for the years 1960-1989 and using them in the simulation of the actual stock, it is possible to see how the stock could have developed if the quota regime had not been put in place. Technological change is assumed to be very small in this period.[20] Remember from section 2.1.1 that technology is represented in the Harvest Function by the parameter e. This is in other words kept unchanged in the analysis.

Regressing the equation for the pre 1990 era, the parameters tell us how high the landings were in the years of relatively unconstrained fisheries. In the simulation, this relationship is carried forward. The parameters tell us how high landings could have been in post 1990,

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[20] Hanneson et.al. (2010) describes the technological development in the post WW2 era as less marked than it had been before. However, this is a simplification. Technological change happened, but with lower marginal utility in the fisheries.

assuming the same technology and structure of the fleet as in the years before. As discussed earlier, the structure of the fleet changed, and naturally technology got better, but for this purpose it is simplified away.

The simulation thus starts with the estimation of landings in 1990:

$$Simulated\ Landings_{1990} = \widehat{Landings}_{1990} = \beta_0 + \beta_1 * TBM_{1989} \quad (3.5)$$

3.4.3 Adjusting Fishing Mortality

The Simulated Landings are used to adjust the Fishing Mortality, which affect the TBM_t and SSB_t.

$Fishing\ Mortality_{a,t} = FM_{a,t}$ is provided in the data, as a parameter of growth. If $Natural\ Mortality_t = 0$, the % that dies in a cohort each year is given by (Clark, 1976, p 271-272):

$$Observed\ \%\ dying_{a,t} \approx (1 - e^{FM_{a,t}}) \quad (3.6)$$

In the following, this is treated with strict equality.

By introducing

$$x_t = Simulated\ Landings_t / Observed\ Landings_t \quad (3.7)$$

it is possible to adjust the % $dying$ up or down, so that a higher value of counterfactual landings than observed cause higher counterfactual Fishing Mortality. Define $\widehat{FM}_{a,t} = Adjusted\ Fishing\ Mortality_{a,t}$. $\widehat{FM}_{a,t}$ follow implicitly from:

$$Adjusted\ \%\ dying_{a,t} = \left(1 - e^{\widehat{FM}_{a,t}}\right) = x_t * (1 - e^{FM_{a,t}}) = (Simulated\ Landings_t / Observed\ Landings_t) * Observed\ \%\ dying_{a,t} \quad (3.8)$$

Solve for $\widehat{FM}_{a,t}$, and get:

$$\widehat{FM}_{a,t} = -ln\left[1 - x_t * \left(1 - exp\left[-FM_{a,t}\right]\right)\right] \quad (3.9)$$

This is the adjusted Fishing Mortality for each cohort, for each year. As seen in equation (3.5), Landings in 1990 were simulated. Thus, equation (3.7) gives $x_t \neq 1$ from 1990. By setting t=1990, equation (3.9) gives:

$$\widehat{FM}_{a,1990} = -ln\left[1 - x_{1990} * \left(1 - exp\left[-FM_{a,1990}\right]\right)\right] \quad (3.9')$$

Thus, if Simulated Landings are higher than observed Landings in 1990, Fishing Mortality is higher for each cohort.

It is implicitly assumed here that higher landings cause higher mortality for each cohort, and in the same proportion on each cohort. This is a simplification, but it is justifiable. No fisher would increase his mesh size or alter other gear to catch larger fish, as this would mean less landed fish. For a discussion of this, see Diekert (2011).

3.4.4 Adjusted Number of Fish

One can calculate how many fish survive from year to year through the formula (Clark, 1976, p 272)

$$Number\ of\ fish \text{ of age a at time t} = N_{a,t} =$$
$$N_{a-1,t-1} * exp(-NM_{t-1} - FM_{a-1,t-1}) \qquad (3.10)$$

For example, for 1990, this means that the number of four year olds is:

$$Number\ of\ fish \text{ of age 4 in } 1990 = N_{4,1990}$$
$$= N_{3,1989} * exp(-NM_{3,1989} - FM_{3,1989}) \qquad (3.10')$$

By using equations (3.5), (3.7) and (3.9) in (3.10), it is possible to simulate the number of fish in each cohort every year, given only fishing mortality, natural mortality and number of fish in the cohort when it was three years old. An example is:

$$N_{5,t} = N_{4,t-1} * exp\left(-NM_{t-1} - FM_{4,t-1}\right)$$
$$= N_{3,t-2} * exp\left(-NM_{t-2} - FM_{3,t-2}\right) * exp\left(-NM_{t-1} - FM_{4,t-1}\right) \qquad (3.11)$$

From equation (3.9) it is clear that once Simulated Landings are used instead of Observed, Fishing Mortality have to be adjusted. This affects equation (3.10), $FM_{a-1,t-1}$ have to be replaced with $\widehat{FM}_{a-1\,,t-1}$ in order to get a simulated number of fish. Replace (3.10) in equation (3.10) and get the $Adjusted\ Number\ of\ fish\ in\ each\ cohort = \widehat{N}_{a\,,t}$:

$$\widehat{N_{a,t}} = N_{a-1,t-1} * exp(-NM_{t-1} - \widehat{FM}_{a-1\,,t-1}) \qquad (3.12)$$

Again, for four year olds in 1990:

$$\widehat{N_{4,1990}} = N_{3,1989} * exp\left(-NM_{3,1989} - \widehat{FM}_{3\,,1989}\right) \qquad = \\ N_{3,1989} * exp\left(-NM_{3,1989} - FM_{3\,,1989}\right) = N_{4\,,1990} \qquad (3.12')$$

A crucial assumption in the simulation is that within a given year all Recruitment happens before landings. Thus, as seen from the second line in this example, one gets the same number of four year olds as in the observed case. Fishing Mortality is not adjusted in 1989, but only from 1990. For all years after 1990 Fishing Mortality is adjusted. For later use, the number of four-year olds in 1991 is:

$$\widehat{N_{4,1991}} = N_{3,1990} * exp(-NM_{3,1990} - \widehat{FM}_{3\,,1990}) \qquad (3.12'')$$

3.4.5 Adjusted SSB and Recruitment

As stated in equation (3.2), SSB_t is given by

$$SSB_t = \sum_{a=3}^{13+} N_{a,t} * AW_{a,t} * Percentage\ Mature_{a,t} = \\ N_{3,t} * AW_{3,t} * Percentage\ Mature_{3,t} + N_{4,t} * AW_{4,t} * Percentage\ Mature_{4,t} + \ldots + \\ N_{13+\,,t} * AW_{13+\,,t} * Percentage\ Mature_{13+\ ,t} \qquad (3.2)$$

The relationship between different cohorts in equation (3.11) is exploited to calculate the simulated SSB_t using the number of recruits in each year before. As seen from equation (3.12), the numbers of fish in the simulation have to be adjusted, so that equation (3.2) turn into:

$$\widehat{SSB_t} = \sum_{a=3}^{13+} \widehat{N_{a,t}} * AW_{a,t} * Percentage\ Mature_{a,t} \qquad (3.13)$$

Thus, it is clear that a change from observed to simulated landings affect SSB through a change in fishing mortality. Average Weight and Percentage Mature are not assumed to change, as these are mainly affected by year-specific biological variations.

As known from equation (3.12’) and (3.12’’), $N_{a,t}$ is not affected by the change from simulated to observed landings until 1991. Thus, equation (3.13) will return the observed values of SSB_{1990}. SSB_{1991} is affected, since $\widehat{N_{a,1991}}$ is affected by simulated landings in 1990.

But the number of recruits is also affected by the change in landings. From the Beverton-Holt relationship in equation (3.3):

$$N_{3,t} = Recruitment_t \ = \frac{a*SSB_{t-3}}{1+b*SSB_{t-3}} \qquad (3.14)$$

Since SSB is not affected by the change from simulated to observed landings until 1991, (3.14) will return the observed Recruitment in the years 1990-1993. For example,

$$N_{3,1993} \ = \frac{a * SSB_{1990}}{1 + b * SSB_{1990}} \qquad (3.14')$$

For 1994, and all subsequent years, however, SSB is affected by the change in landings and will return $Contra\,factual\ level\ of\ Recruitment = \overline{N_{3,t}}$:

$$\overline{N_{3,t}} \ = \frac{a * \widehat{SSB_{t-3}}}{1 + b * \widehat{SSB_{t-3}}} \qquad (3.14'')$$

Example for 1994:

$$\overline{N_{3,1994}} \ = \frac{a * \widehat{SSB_{1991}}}{1 + b * \widehat{SSB_{1991}}} \qquad (3.14''')$$

Thus, the counterfactual number of recruits found in (3.14’’) replaces the observed number of recruits in equation (3.8) in the years 1994-2005. For the years 1990-1993, observed values are used.

To sum up: two effects affect the simulation of SSB in the years 1990-2005. The first is the change in fishing mortality for all cohorts. The second is the effect from a change in Recruitment.

It might not be clear at this point why so much effort is laid down in simulating SSB and Recruitment, but as one can see, it is necessary to simulate SSB in order to simulate Recruitment, which is needed to calculate Total biomass. Since SSB and Recruitment affect each other from year to year, it is needed to simulate them simultaneously for the whole period in question.

3.4.6 Yearly variations in environmental conditions

For a given year, there is a real value of the Spawning Stock Biomass, and a real value of Recruitment. Their relation is described in the Beverton-Holt relationship, which use parameters a and b to take the environment for Recruitment into account. This relationship is in reality year-specific, and includes the temperature in the water, access to food, conditions in the areas of spawning etc.

Again, the purpose of this exercise is to find a ratio between counterfactual and observed landings. In order to find the counterfactual landings, counterfactual total biomass is needed, where the only change from factuality is that the quota regime is not implemented in 1990. All other conditions should remain as in the factual process. There were years with good and bad environmental conditions in the period 1990-2005, and this would have been the same with no quota regime. Thus, when simulating the Recruitment in a given year, a year-specific Beverton-Holt curve should be used. This way it is possible to replace the observed value of SSB_{t-3} in the Beverton-Holt relationship with the simulated value $\widehat{SSB_{t-3}}$, and get back a simulated value for Recruitment. By simulating the counterfactual Recruitment with adjusted coefficients a and b, the Total biomass is simulated conditional on the estimated conditions for Recruitment observed from 1990.

Ideally, there would be a value of a and b for each year, so that changing the SSB would return the number of recruits that would have grown up under the given conditions. However, to change both parameters, two equations with the a and b would be needed for each year. This would only be a possibility if two values of SSB_{t-3} and $Recruitment_t$ where observed each year.

Since this is not the case, b is kept constant, and the yearly variations are summed up in a_t. This is not perfect, but it is a mathematical approximation that does not give too high errors. a_t is calculated for each year, using observed values on $Recruitment_t$ and SSB_{t-3}, by solving the Beverton-Holt relationship for a:

$$a_t = Recruitment_t * \left(\frac{1 + b * SSB_{t-3}}{SSB_{t-3}}\right) \quad (3.15)$$

Thus, it is possible to use the calculated values of SSB_{t-3}, $\widehat{SSB_{t-3}}$ in the Beverton-Holt in order to estimate Recruitment:

$$\overline{N_{3,t}} = \frac{a_t * \widehat{SSB_{t-3}}}{1 + b * \widehat{SSB_{t-3}}} \qquad (3.16)$$

SSB_{t-3} is not available until 1949, since the dataset starts in 1946. a and b are estimated on the largest possible dataset, 1949-2009, in order to get the best possible estimates. a_t is then calculated according to equation (3.15) for the years 1990-2005. Higher values indicate better environmental conditions.

3.4.7 Simulated Total biomass and Landings

Employing the same way of thinking as on SSB_t in section 3.4.5, it is possible to simulate the values of Total biomass. Number of fish is affected by the change in landings, and Recruitment is simulated from 1994. Thus, Total biomass is calculated using the equation

$$\widehat{TBM_t} = \sum_{a=3}^{13+} \widehat{N_{a,t}} * AW_{a,t} \qquad (3.17)$$

Average Weight is not assumed to change, as this is mainly affected by year-specific biological variations. As with SSB, observed values of Recruitment is used for 1990-1993, and simulated for 1994-2005.

As known from equation (3.4), Landings is a function of Total biomass the year before. Simulated values for landings are based on the simulated values for Total biomass. From equation (3.5):

$$\widehat{Landings_t} = \beta_0 + \beta_1 * TBM_{t-1} \ (3.18)$$

Since TBM_t is simulated from 1990; equation (3.18) is only used to simulate landings in 1990. From 1991, simulated values of TBM_t is used:

$$\widehat{Landings_t} = \beta_0 + \beta_1 * \widehat{TBM_{t-1}} \quad (3.19)$$

3.4.8 Increasing error terms

In this setup, the error term grows each year. A small error in the estimation of landings in 1990 will make the estimation for 1991 more insecure, and so on. However, this will be the fact no matter what simulation is used, and the results produced will the best guess of the counterfactual landings.

3.5 Results

Simulating as described, the following results are obtained. Blue line is always simulated values, red is observed.

3.5.1 Total Biomass

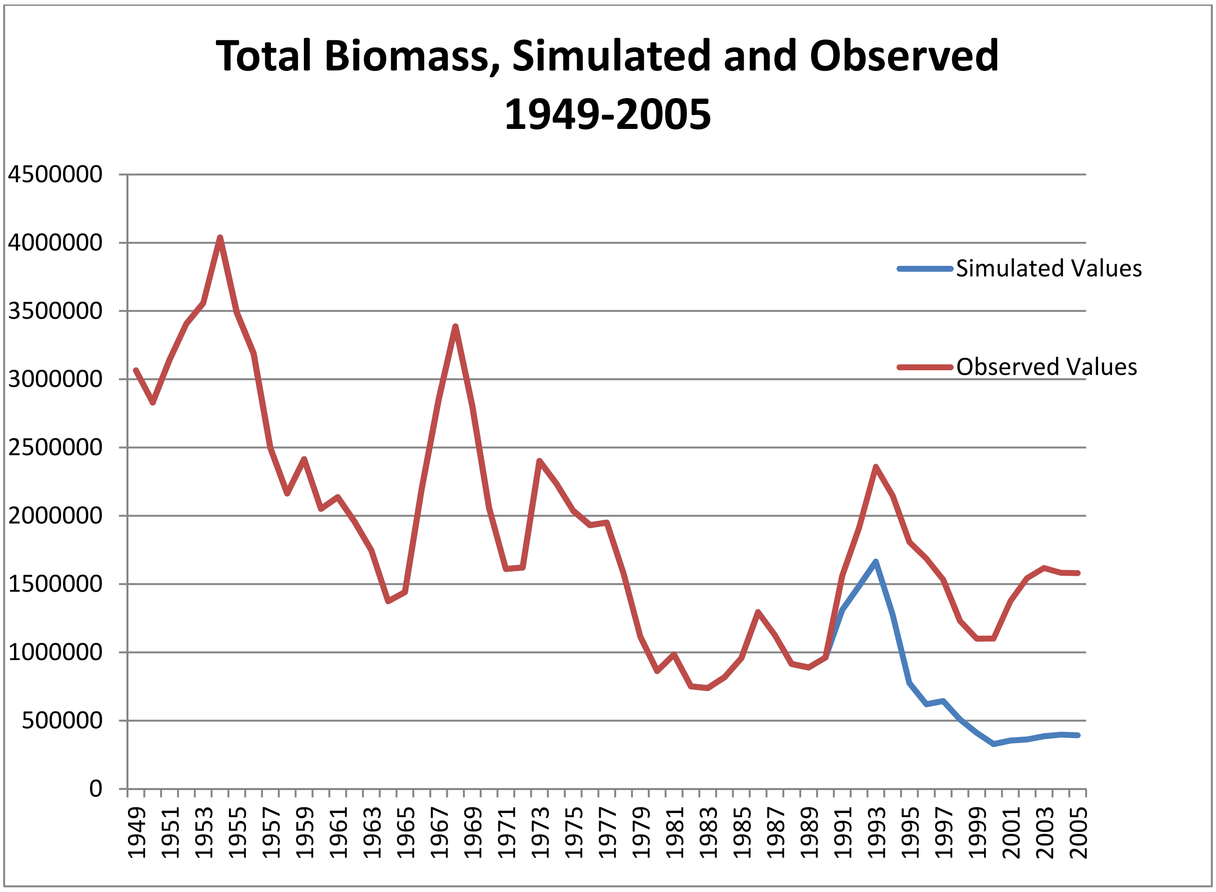

Figure 7: Total Biomass 1949-2005. Tons.

Figure 7 show that the Total biomass grew in the early 1990s, fell each year to 2000, and then grew again. Figure 7 show that the simulated stock of cod reach a historically low level in the years after 2000.

The simulation returns a lower path of Total biomass than what was observed, i.e. the counterfactual total biomass would have been lower than the factual if no quota regime had been implemented. This is consistent with theory if quotas where the limiting constraint on fishing. It is also seen from the graph that both observed and simulated values dropped in the period 1993-2000. While the observed stock later picked up, the simulated stabilized on a quite low level. But, one should be careful to draw conclusions; the margin of error grows each year.

3.5.2 Landings

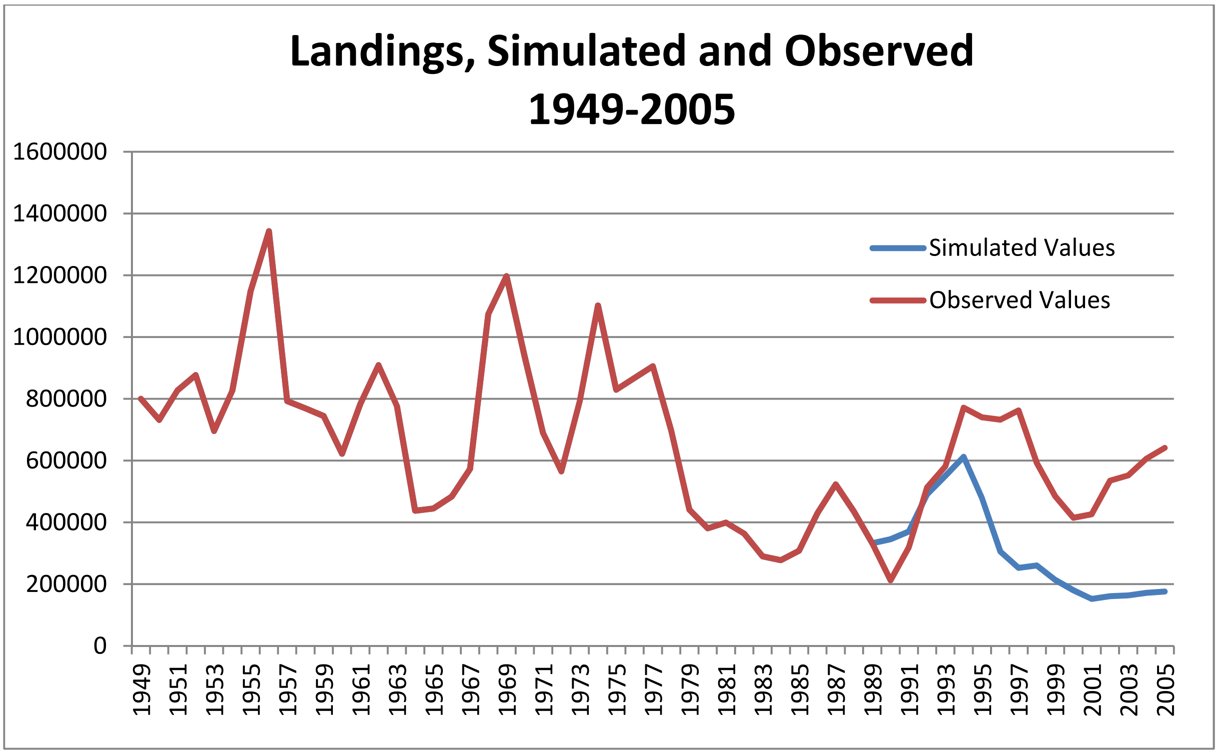

Figure 8: Landings 1949-2005. Tons.

Figure 8 shows the historical context of the simulated landings. Simulated Landings are higher than observed in the years immediately after 1990. In the long run, they approach the actual level of landings in the «crises year» 1989. This is consistent with lower simulated Total biomass; a higher proportion of the fish is caught each year, and thus the simulated stock is lower than the observed. From 1992 this leads to lower absolute Landings. As seen from Figure 8, the simulated landings fall below the observed after only a few years, and stay lower for the rest of the period.

3.6 Adjusted Landings for Individual Fisher

In section 4 a dataset containing data on landings for individual fishers is described. In order to adjust the landings to get counterfactual landings, the following equation will be used in section 5 (in order to not get confused, $Landings$ is called $Total\ Landings$ in equation (3.20)):

$$Contra\ factual\ Individual\ Landings_t = \frac{Simulated\ Total\ Landings_t}{Observed\ Total\ Landings_t} * Observed\ Individual\ Landings_t \qquad (3.20)$$

4 Individual Data on Boats Economy

The dataset used contain individual data on Norwegian coastal fishers. It is obtained from the Directorate of Fisheries, and is gathered from the Profitability Survey.[21] Details on the survey are obtained from different surveys as well as the webpage of the Directorate of Fisheries.[22] If no source is mentioned, the information is taken directly from the dataset.

The purpose of the survey is stated in the subtitle: "for common well run and well equipped vessels larger than 8 meters, fishing all year", (Survey, 1999, front page; own translation). In the period 1985-1997 the survey was self sampling; fishers was encouraged, but not forced to participate. The survey has might therefore be seen as a survey covering all boats, but with a large dropout rate. From 1998 all boats were first stratified according to group, length and homeport. Then the boats were stratified according to revenue, so that more boats are picked from the high earners. And at last the sample was randomly chosen from each stratum. The survey covers very few boats in Group 2, those without quota (Survey, 2012, p 87).

The dataset contain 3009 observations over 21 fishing seasons. Figure 9 show the number of observations for each size class of vessels:

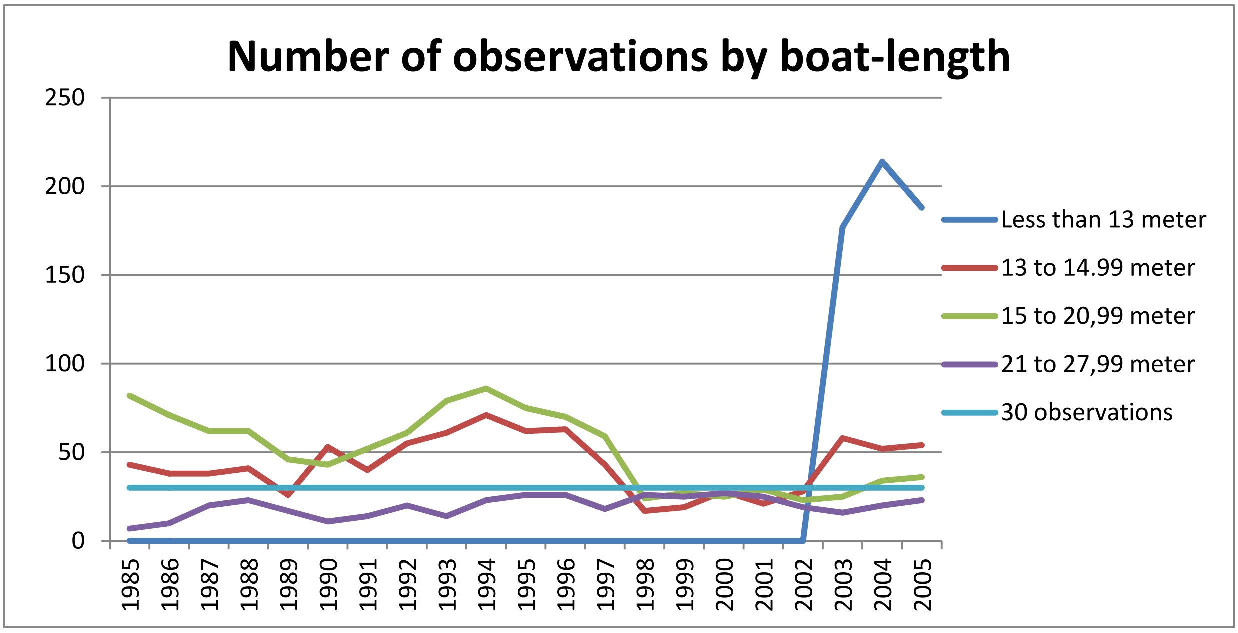

Figure 9: Number of Observations each year, by length of vessel.

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[21] NOR: Lønnsomhetundersøkelsen

[22] Points to Directorate of Fisheries web-page, retrieved on January 31st 2012. In the following, this is just referred to as "Web". See Literature for the complete link.

Figure 9 indicates that the number of observations in each group seldom is very many; the straight turquoise line is 30 observations. Prior to 2002, there are no boats less than 13 meters, as these were treated in a separate survey. These are excluded in the analysis. A large part of the boats are fishing solely for demersal fish.

The variables year and identification make it possible to analyse the data with panel data tools. The boats are given an industry code; identifying them as for ex. Pelagic coastal fisher below 10 meters.

4.1 Variables

Revenue is the sum of income to the boat. This consists of revenue from fishing and other activities. Subsidies are included in this, and not listed as a separate variable. In the years 1985-1986 direct subsidies for operation are included in revenues. In other years other subsidy are included, but it is not known when and in what magnitude (Tove Aasheim, direct communication) This is a source of error later, since revenue is used to measure profitability.

The boats are often run in a share system; the fishermen split the revenue, after some basic costs are paid. This gives the fishermen the incentives to work hard. If revenue is only the share to the skipper, obviously revenue would have been a bad measure of income, as discussed in McConnell and Price (2005). In this dataset this is not a problem, as revenue to the boat is reported.

Many different costs are included. These include input such as fuel and wages, taxes and financial costs. Capital per se is not reported. Net Finance,[23] which is the net of financial revenue and costs, is the only reported value. In the years 1988-1992 and 1999-2000 this includes subsidies to pay of interest.

Volume and value of landings are given for nine species.

Measures of effort include the days at sea and number of men. These will later be used to explain profitability.

4.2 Measures of Profitability

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[23] NOR: Nettofinans

Three measures of profitability are used later. These are defined in the Survey (2012, p 94), along with measures not used here.

The first is profits, which is simply revenue minus costs. These values are adjusted for inflation using CPI with value 100 in 1998.

The second is Profit margin. The Profit Margin is the Profit divided by the Revenue:

$$Profit\ margin = \frac{Profit}{Revenue} * 100 \qquad (4.1)$$

Thus, the Profit margin show how many NOK the fishers earn for each 100 NOK they receive in revenue.

Wage-ability[24] is another measure of profitability; by withdrawing all cost and a standard interest to capital from revenue, a residual sum that hypothetically could be paid in wages is obtained.

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[24] NOR: Lønnsevne

5 Counterfactual Prices

5.1 Why?

In section 3 the counterfactual development of the stock was described. By making some assumptions about the landings of cod, it was shown how the landings and the stock could have developed without a quota regime.

The purpose of this section is to show the possible development in prices that would have occurred without a quota regime. In section 6 both these simulated and observed prices are used to calculate counterfactual profit margins.

In this section the simulation made in section 3 is not questioned. Section 5.2 develop adjusted mean price and section 5.3 use this to adjust the price received by the individual fisher.

5.2 Adjusting Mean Prices

5.2.1 Mean Prices and Inflation

In the dataset described in section 4, there are year-specific data on each boats' landed volume and received payment for different species. Prices are found by dividing received payment by volume, for each fisher. By averaging this for all fishers within a given year, a mean price of cod is returned for each year. In order to make a comparison between years, this mean price is adjusted for inflation.[25] This is defined as Price Adjusted for Inflation, PAI.

5.2.2 Regressing prices on landings

For use in section 5.2.3 a regression of PAI on observed landings is done. The model is:

$$Observed\ PAI = \beta_0 + \beta_1 * Observed\ Landings \qquad (5.1)$$

---

[25] Data on inflation in Norway is obtained from the web-page of Statistics Norway, see Literature for full link. Standard CPI is used, with a base of 100 in 1998.

Nothing is known about demand for cod, and what are known from the data are only the prices and landings caused by supply and demand. In equation (5.1) however, static demand is implicitly assumed. This is a simplification, as not all observations are drawn from a single year. It is necessary to make conclusions about the market for cod.

The data on landings is the same as in section 3. This might be a source of error in this approach, as the prices stem from landings of all types of cod in Norway, while the data on landings are on a specific species of cod, landed in all countries. However, this error should not be too big, as there is major overlap between landings of NEA cod and aggregate landings of cod in Norway.

Results of the regression are shown in Table 1:

xtreg Inf_price observed_Landings , fe			
	Estimate	Standard Error	t-value
Constant	12.91897	0.137361	94.05
Observed Landings	-0.00000583	-2.43e-07	-23.97
R-squared		0.1832	
Prob > F		0.0003	
Rho (fraction of variance due to u_i)		0.43144	

Table 1: Regressing PAI on Observed Landings. Price is adjusted for inflation.

As seen in Table 1 the results on steepness and constant term seem robust. The R-squared is low, but the marginal effect is what matters, and this is very significant.

5.2.3 Counterfactual Price

In equation 5.1 and in Table 1, the main trend in the relationship between landings and price is described. β_1 = (-)-0.00000583, so when the landings increase by 100000 tons, the PAI falls by 0.581 NOK. This is reasonable; more fish on the market should lead to lower prices.

The counterfactual PAI is found by replacing observed landings with simulated landings in equation (5.1) and using the estimates for β_0 and β_1:

$$Contra\ Factual\ PAI = \beta_0 + Simulated\ Landings * \beta_1 \ =$$

$$12.91897 + Simulated\ Landings * (-)0.00000583 \quad (5.2)$$

Results of this procedure are shown in Figure 10.

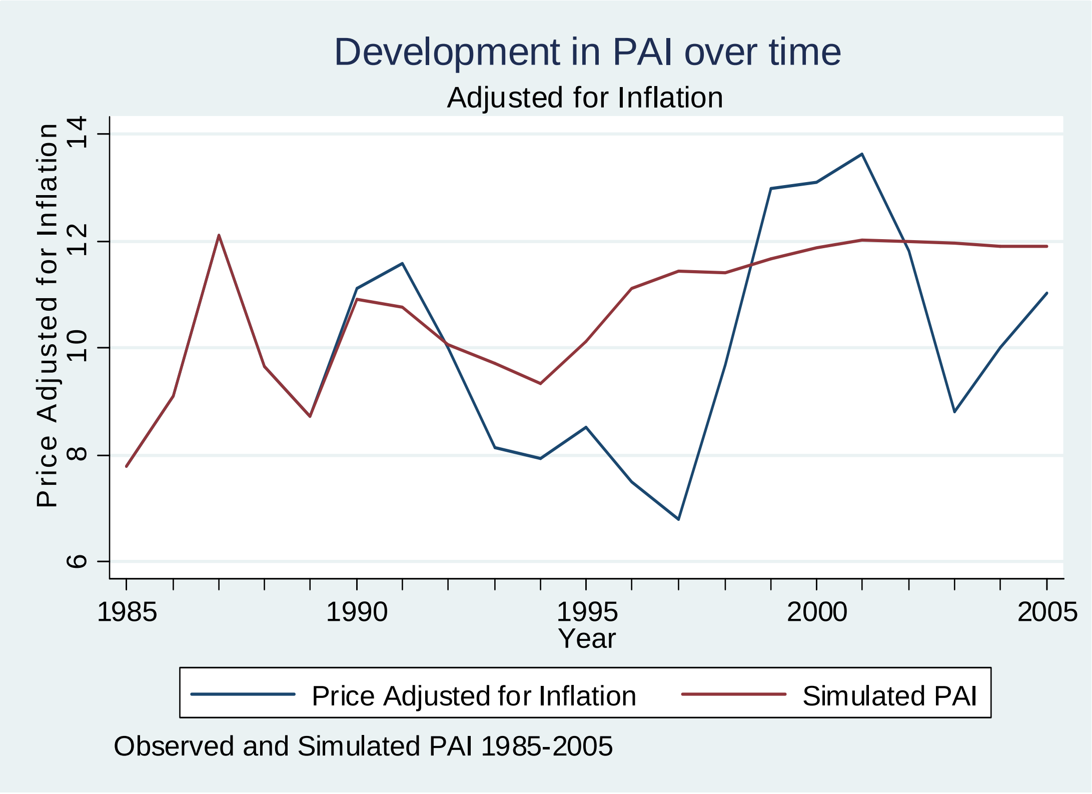


Figure 10: PAI over time, Observed and Counterfactual. Price adjusted for inflation.

From Figure 10 it is seem like prices behave like a mirror image of the landings - compare to Figure 8. For the observed case, landings increased in the early 1990s, peaked in 1997, and then fell. The opposite is seen for the price.

Simulated landings are higher than observed in the early 1990s, and counterfactual prices are lower than observed. When the simulated landings stabilize/fall slightly from 1997, the counterfactual prices do to, and stay on the same level for the rest of the period.

These simulated prices are used in section 5.3 to adjust the price to the fisher. The counterfactual price is adjusted from real to nominal. The counterfactual nominal price from this section is then called $Contra\ factual\ Nominal\ Mean\ Price$ and observed price is called $Observed\ Nominal\ Mean\ Price$.

5.3 Adjusting price to the Fisher

For later use in the analysis of profits, counterfactual price to fisher is needed. Therefore, these prices are adjusted using the adjusted mean prices. In order to adjust, the following equation is used:

$$\begin{aligned}&\mathit{Adjusted\ Price\ to\ Fisher}\\&\quad=\left(\frac{\mathit{Contra\,factual\ Nominal\ Mean\ Price}}{\mathit{Observed\ Nominal\ Mean\ Price}}\right)*\mathit{Price\ to\ Fisher}\end{aligned}\qquad(5.3)$$

Thus, the prices to the fisher are adjusted up or down in proportion with the difference between counterfactual and observed mean prices. The result is shown in Figure 11:

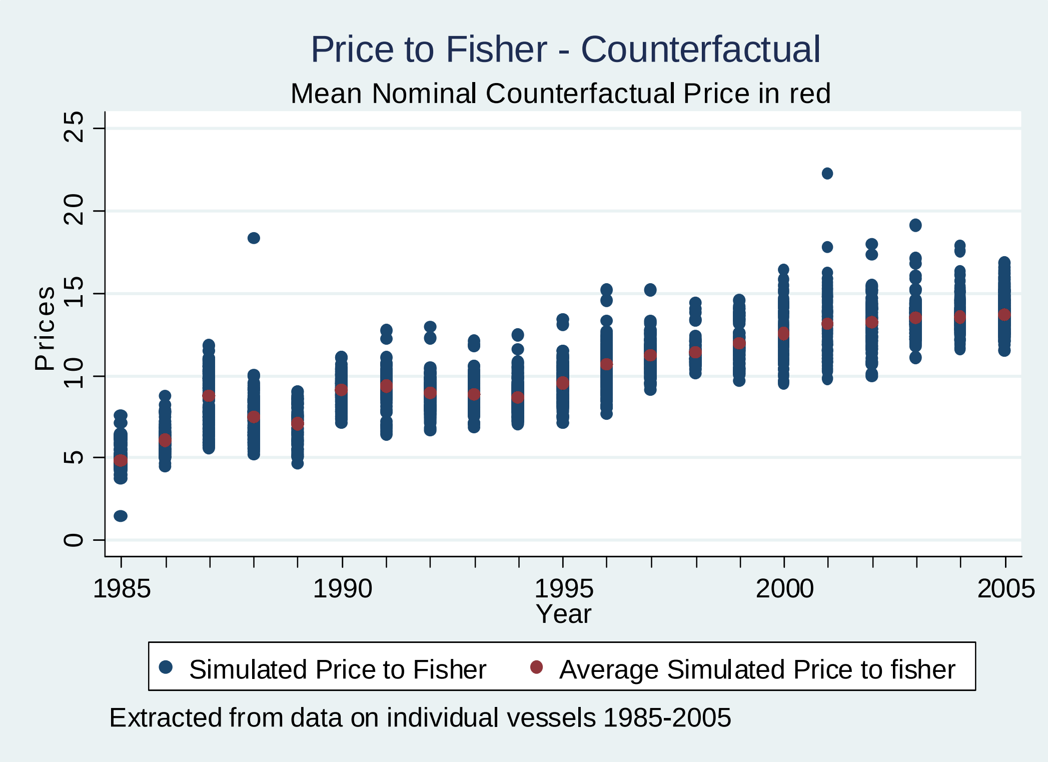


Figure 11: Adjusted Price to fisher. Nominal NOK.

6 Counterfactual Profits

This section draws on the data described in section 4 to describe the development in fishers' profitability. The simulations of landings in section 3 and prices in section 5 are used to simulate how the profits could have developed.

6.1 Observed Values

6.1.1 Revenue, Costs and Profit

Observed average values of revenue, costs and profit are shown in Figure 12.The values are adjusted for inflation.

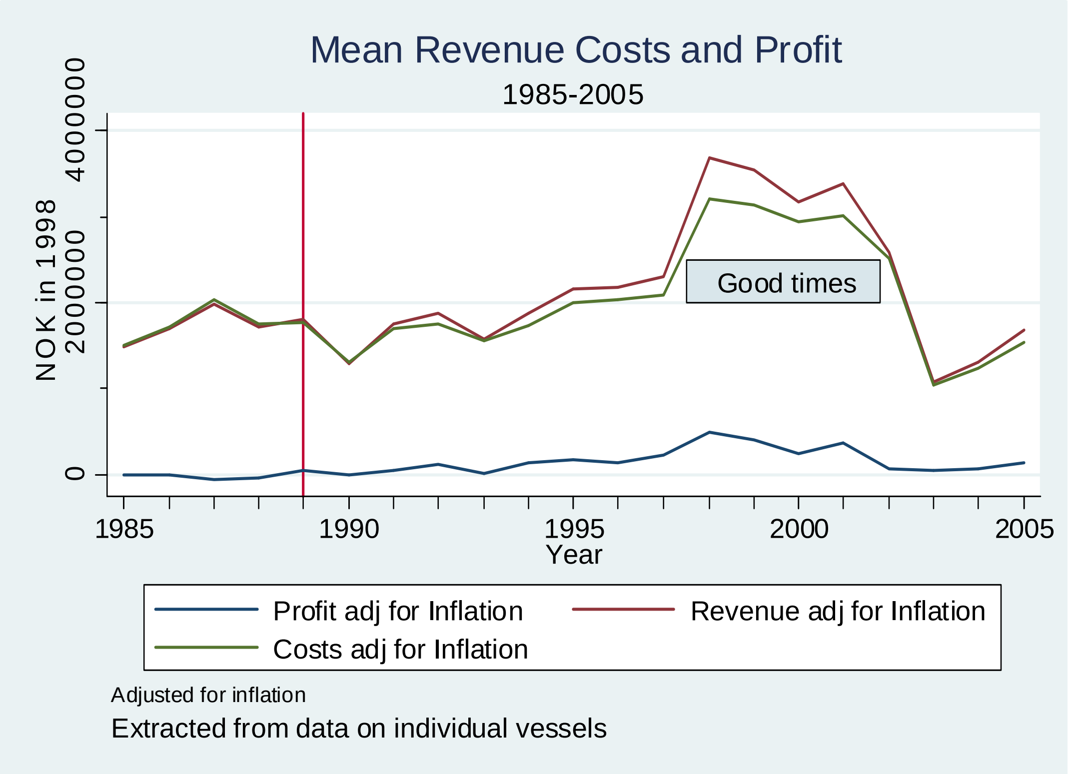


Figure 12: Observed Revenue, Costs and Profit. Adjusted for inflation. Red vertical line mark 1989. NOK in 1998.

As seen from Figure 12, the revenue and costs increased slightly in the period 1985-1997. "Good times" might be said to be 1997-2002, because revenues increased sharply in these years. Costs do not increase as much as the revenue and this created profits. Profits are close to zero in the period 1985-1990, but increase slightly in the period after. This is an indication that the quotas actually limited the access to the fishery and increased the profits for those still fishing.

6.1.2 Profit Margins

Profit margin is a measure of how well the fishers are doing, regardless of inflation and the size of revenue and costs.

Figure 13 shows observed average profit margins for the years 1985-2005:

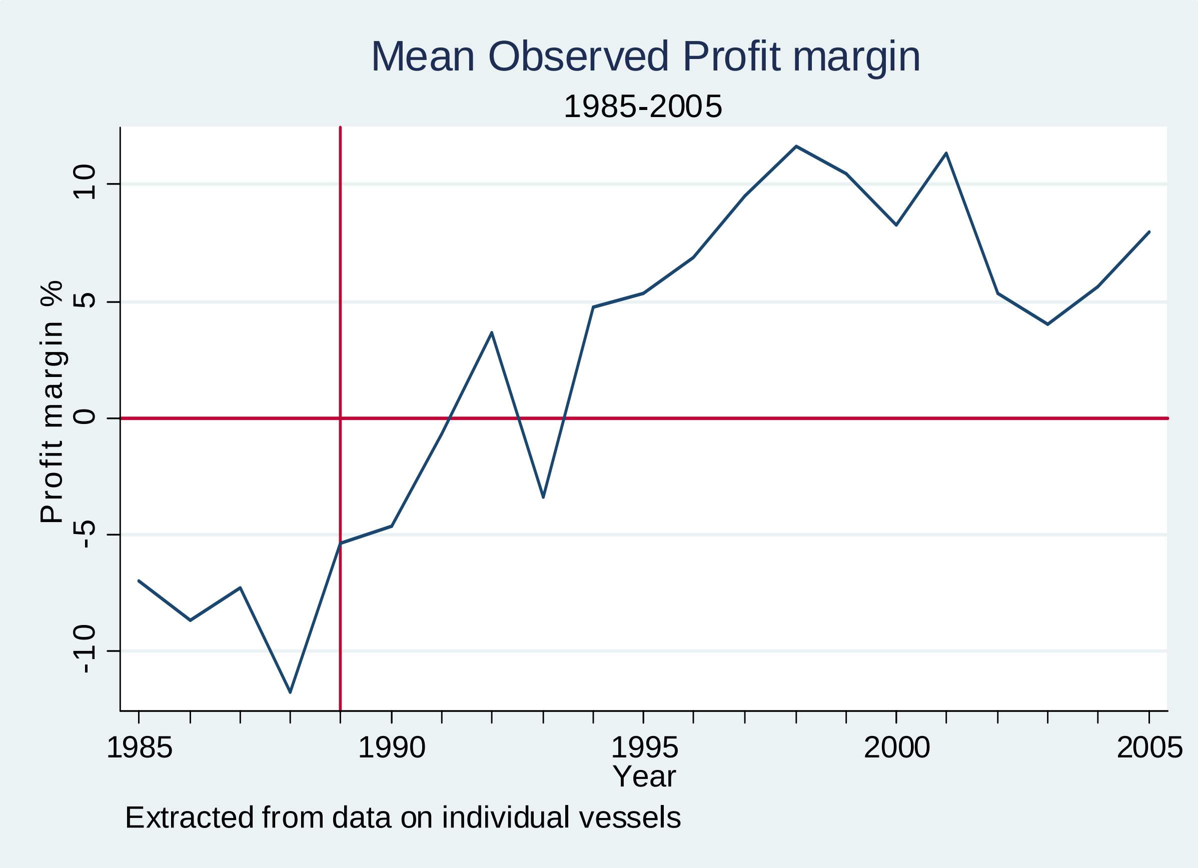


Figure 13: Observed Profit margin. Red vertical line mark 1989, horizontal 0%. Percentage.

From Figure 13 it is evident that profit margins increased dramatically in the period. From 1985 to 1994, the average varied below and around zero. 1992 is the first year it is positive, and from 1994 it stayed positive. This is another indication that the quota regime caused an increase in profitability in the fisheries.

It is quite stunning how many years the average fisher made a loss. One thing that could be interesting is to look at separate data on subsidies and its part in revenues. But since subsidies are not included as a separate variable, this is not possible.

6.1.3 Did quotas Cause Profits?

As discussed in 2.2, when a quota regime is introduced, profits should increase over time. Figure 14 show that high landings partly co-vary high profit margins. It seems like the overall trend in both is positive in the period 1985-2000, but after this landings fall much sharper than profit margins.

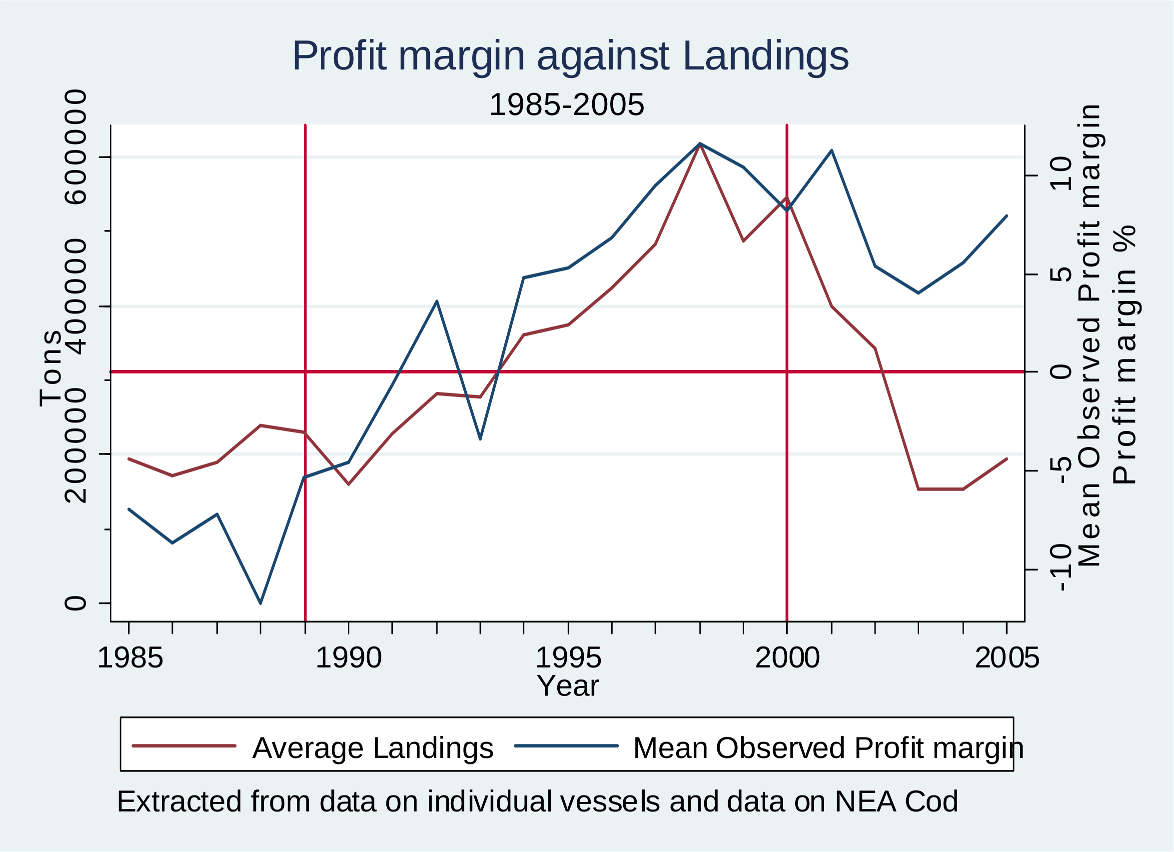


Figure 14: Profit margins and landings. Red vertical lines mark 1989 and 2000, horizontal 0%. Percentage on the left axis, Tons on the right.

An interesting comparison between Figure 12 and Figure 14 is that "good times" in terms of revenue actually does not vary perfectly with the variation in landings. Landings increased a few years before the revenues did, and they declined before revenues did. This is caused by the variation in prices.

This theoretical approach does not count in external factors. If good environmental conditions make the stock grow fast, the landings and profits will increase with or without a quota regime. A measure of environmental conditions is the parameter “a” from section 3. Figure 15 show that the landings and environmental conditions three years earlier are practically detached. This is an indication that something else caused the high landings – perhaps the quotas.

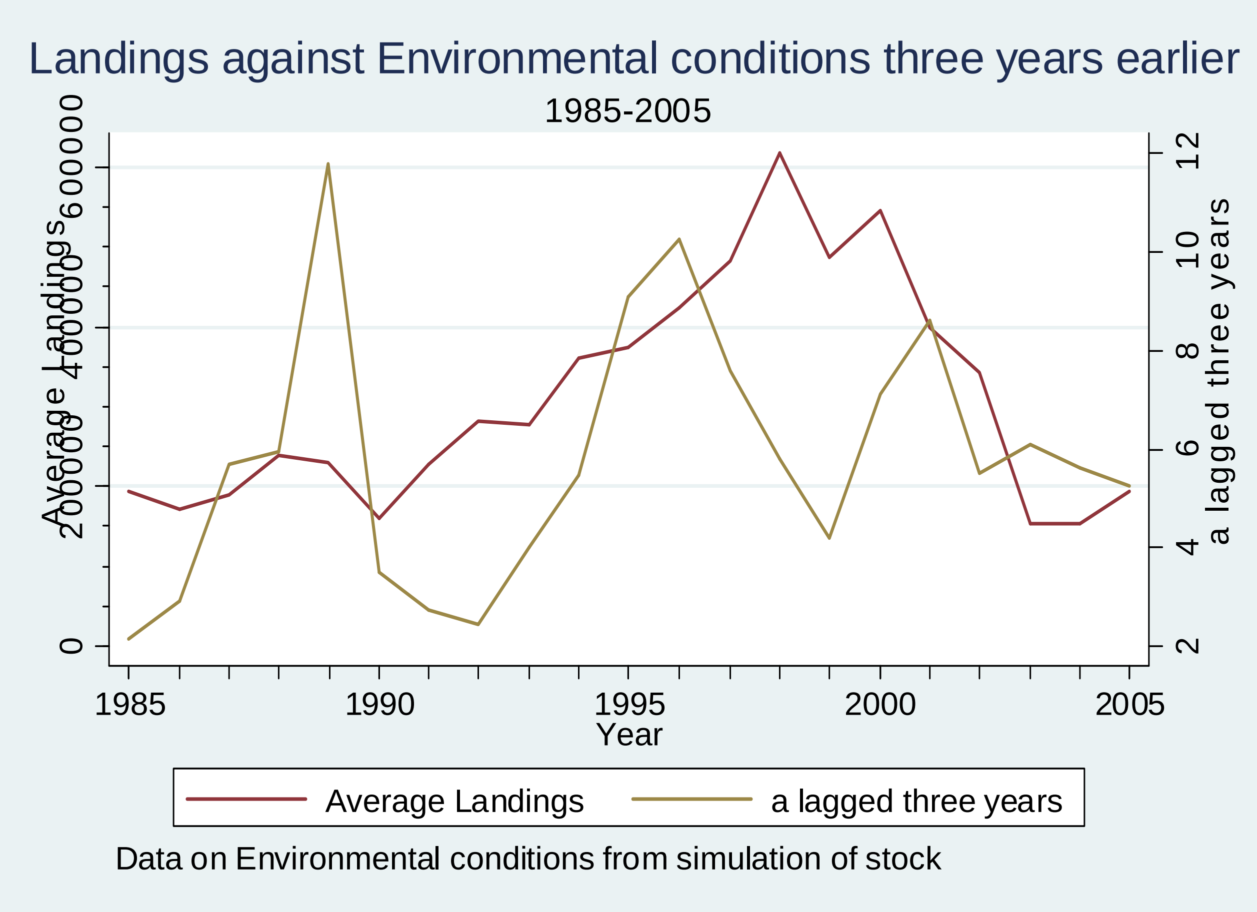


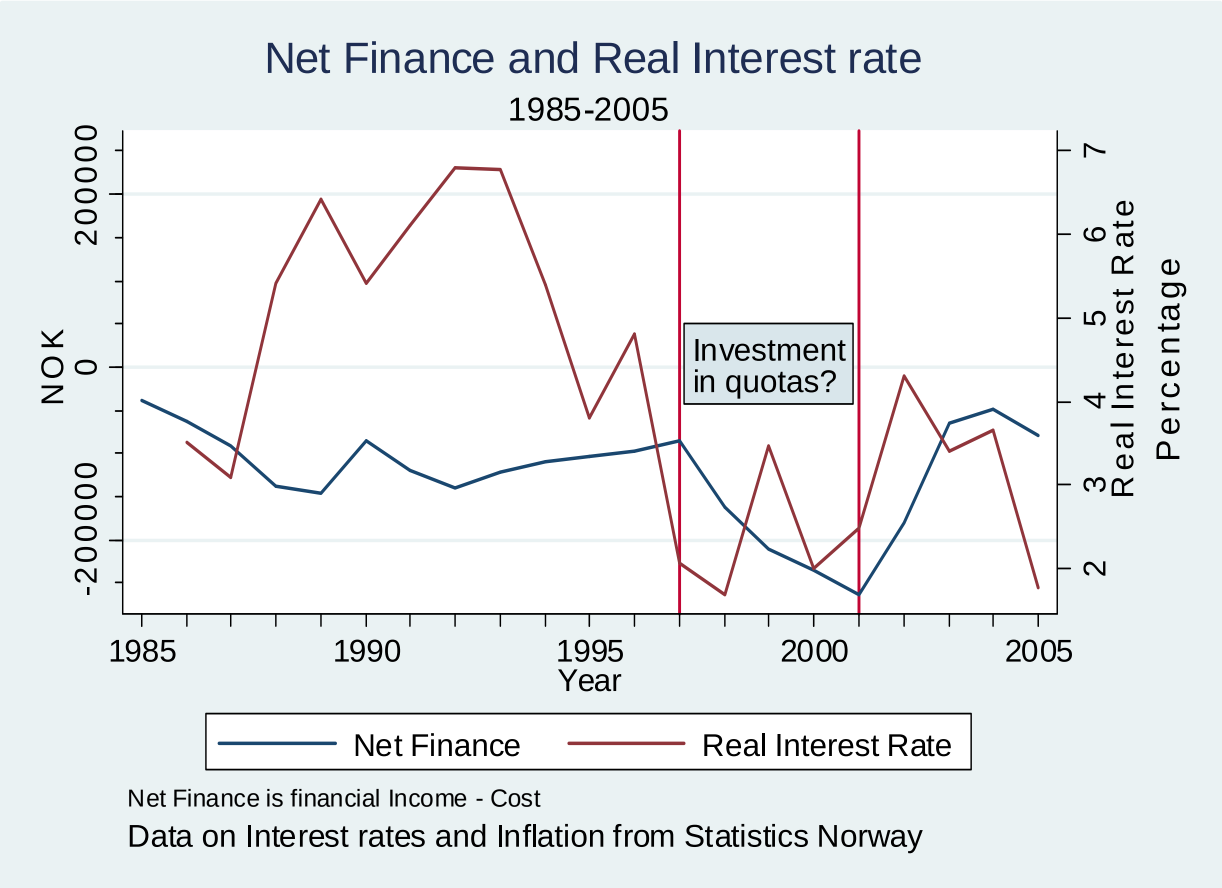
Figure 15: Landings and Environmental conditions. Tons on the left axis, a on the right.

6.1.4 Did the Fishers Trade in Quotas?

One explanation for the stabilization of profit margins can be that the quota regime was well established in 2000, and perhaps had evolved into an ITQ regime as discussed in section 2.3.3. If this was the case, the fall in landings could lead to sales of quotas from those who could not manage to make profit under the worse times, to those who could. Thus, the profit margin for those in the fishery could stay at the same level.

Profit margins as a measure of profitability disregard the fact that the quotas had to be purchased. Since the Directorate of Fisheries does not measure the value of quotas, a purchase will show as a pure financial loss. Data on capital has not been acquired from the Directorate. But a way of looking into this is to look at the development in Net Finance. This is the net of financial income and cost. If trade in quotas occurred Net Finance should drop, since the sellers fall out of the dataset.

Figure 16 show that Net Financial actually fell in the period 1997-2001, indicating that the fishers actually invested harder in this period. However, it is quite speculative to say that this increased investment was in quotas, and that the purchases of quotas again lead to more robust profit margins for those staying in the fishery.


Net Finance and Real Interest rate

1985-2005

Net Finance is financial Income - Cost

Data on Interest rates and Inflation from Statistics Norway

Figure 16: Net Finance and Interest rate. Red vertical line mark 2000. NOK on the left axis, Percentage on the right.

Variations in Net Finance can also be caused by other investments. But a major driver behind the costs of capital is real interest rate. If this co-varies well with Net Finance, one could argue that there was no increase in investments that caused the higher cost of capital, just increased interest rates.

The development in real interest rates is also shown in Figure 16. This is based on the interest in the States bank for Fishers and CPI. It does not seem co-vary with Net Finance. If anything, real interest seems to fall in the period of the supposed investment in quotas. This would make it cheaper to buy quotas. But on the overall, the two are so detached that it is not possible to conclude with this. Thus, this argument may support that trade in quotas occurred 1997-2001.

6.2 Simulated Revenue and Costs

In this section, profits are simulated. Four alternative simulations are presented. Revenues can be calculated with observed or simulated prices, and Costs can be adjusted for changes in effort or not. Landings are anyway simulated, so even if prices and costs are kept as observed, the simulations will get different results than the observed profit.

6.2.1 Adjusted Revenue

In section 3.6 the counterfactual landings of cod for the individual fisher is calculated. This is multiplied with the simulated price from section 5.3 or observed price in order to get counterfactual value of landed cod. Both things are done, so it is possible to see what effects is has on profits. Then counterfactual value of landed cod is added with the value of all other fish landed.

Value of all landings and revenue is not always the same. Fishers also have other income. Therefore revenue has to be calculated. This is done with two different methods, which affect the simulated revenue in different ways.

The first method is adding the difference between adjusted and observed total value of landings to revenue:

$$\begin{aligned} &Adjusted\ Revenue \\ &\qquad = Observed\ Revenue + (Adjusted\ Value\ of\ Landings \\ &\qquad - Observed\ Value\ of\ Landings) \quad (6.2) \end{aligned}$$

This method does not adjust the value of other income. For real activities, like taking tourists on a cruise, this is good. There is no reason this should vary with the amount of cod in the sea.

The question is how subsidies would have behaved under the counterfactual case. This is a cause of error in the $Adjusted\ Revenue$, but it is probably not too big. As discussed in section 2.3.6, subsidies largely disappeared in the 1990s.

The second method is increasing all revenue in the proportion of the change in value of landings:

$$Adjusted\ Revenue = \frac{Adjusted\ Value\ of\ Landings}{Observed\ Value\ of\ Landings} * Observed\ Revenue\ (6.\mathbf{3})$$

This method adjusts the value of all activity of the fisher. For real activities this is not good. But if the difference between observed and adjusted landings stem from underreporting of the value of the landed fish, this method takes it into account.

Results of the second method seem less trustworthy. They are not discussed in the text, but are shown in Appendix 6.1. In the following, adjusted revenue and simulated prices refer to the first method. Observed prices refer to the same method, using observed prices.

6.2.2 Adjusted Costs

Costs are divided into fixed and those depending on the activity. Higher or lower landings should lead to a proportionate change in variable costs. These are adjusted in the following way: First, the volume of landings of cod is replaced with its simulated value, see section 3.6. This is added to the quantity of landings of other species. Then the variable costs are adjusted proportionally:

$$\begin{gathered} Ajusted\ variable\ cost \\ = \frac{Adjusted\ volume\ of\ landings}{Observed\ volume\ of\ landings} * Observed\ variable\ cost \quad (6.4) \end{gathered}$$

Finally, adjusted total cost is calculated as the sum of fixed costs and the adjusted variable costs. In the following, this result is referred to as adjusted costs. Observed costs are the total costs reported in the dataset.

Under the assumption that costs are adjusted, it is implicitly assumed that effort is adjusted. Effort, measured in days in operation and days at sea, can obviously not increase above 365 days in a year. In order to see if simulated effort is within reason, the adjusted number of days at sea is calculated in the same way as adjusted costs in equation (6.4). This reveals that in no year the average effort is simulated to be more than 126 days at sea, which must be all right.

6.3 Simulated Profits

Sections 6.2.1 and 6.2.2 give two opportunities each for the simulation of profit: using simulated or observed prices in calculating the revenue, and using simulated or observed costs. Landings are always simulated.

When simulating these different measures, one should take into account that the error terms grow each year. This stem mainly from the simulation of landings, since each year of predictions is based on the one the year before. Thus, a small error at the start can propagate through the whole time series of landings. This again can cause disturbances to the calculation of prices, revenues, costs and in the end profit.

Figure 17 show these four different simulations of profit. All the values are adjusted for inflation. Beforehand, 127 observations with profit margins lower than 100% were dropped in order to make more sound graphs.

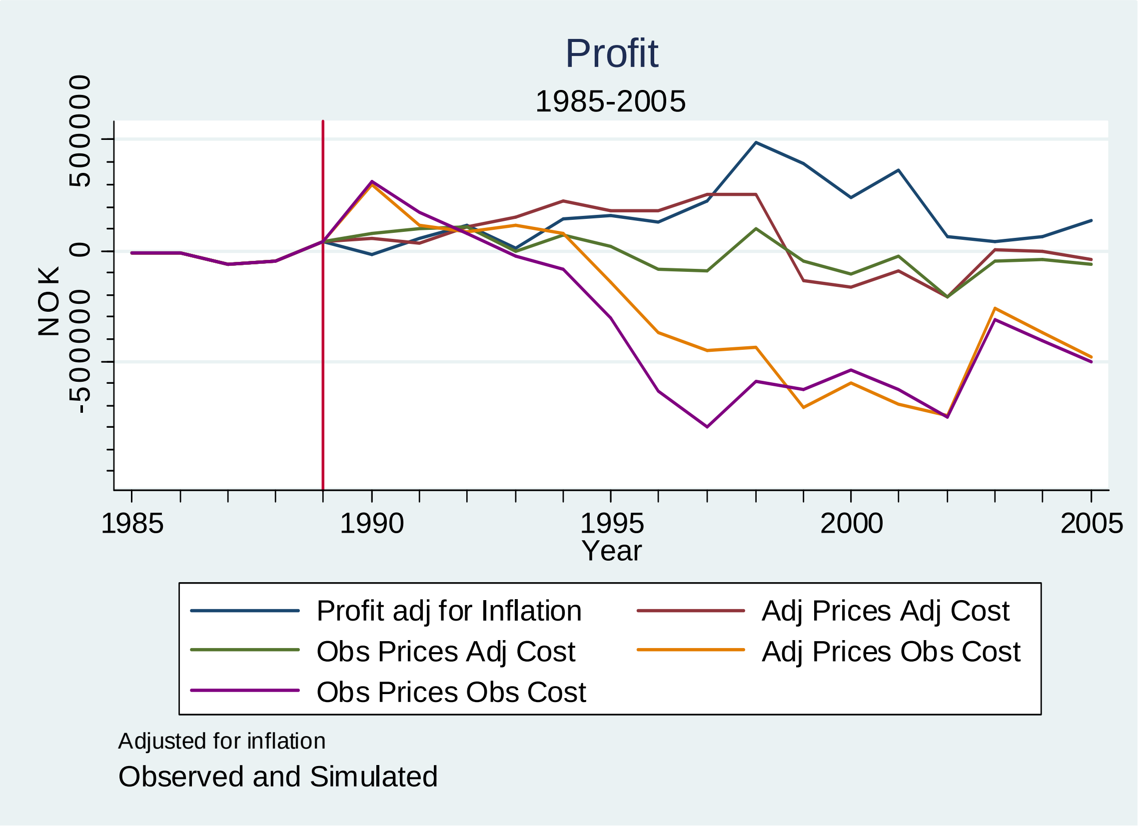


Figure 17: Profit, observed and simulated. Adjusted for inflation. Red vertical line marks 1989. NOK in 1998.

Figure 17 show that the profits take on quite different values. Starting on top in 2005, observed profits are highest. Then comes the two cases of adjusted costs, first adjusted and then observed prices. And at the bottom observed costs, first adjusted and then observed prices. All in all, observed profits seem to be highest with a good margin.

6.3.1 Effort-effects

The two cases using observed costs need some discussion. The case with adjusted prices in the calculation of the revenues is shown in orange in Figure 17, observed prices in purple. In 1990 both are higher than observed profits, shown in blue. Then they show a negative trend for many years. After 1990 the average observed profit is 131948 NOK (1998). The comparing figures for the case with adjusted prices is (-) 237878 and (-) 315466 for observed prices.

In order to explain this, one has to remember that the revenues are based on counterfactual landings in all simulations. As seen from Figure 8 in section 3.5.2, simulated landings are larger than observed in 1990-1993 and lower in every year after. If observed prices are used to simulate the revenues, it is obvious that the simulated profits are deviating from the observed. The fisher is getting the same price, and spending the same money catching it, but delivering more than observed in 1990-1993 and less after. Figure 17 show that the effect on profits from keeping the observed costs is large. The same case with simulated prices, shown in orange does not deviate much from the case with observed prices.

Now consider the two cases with adjusted costs as one, and the two with observed costs as one. The latter is higher at start, but lower from 1993. This is the effort-effect. Judging on the distance between the lines, this is the most important effect. Adjusting the prices –in effect, simulating the market - does not matter as much as adjusting the costs.

This is a reasonable result, as the cases where observed costs are used in effect deny the fishers to limit their effort in bad times and to increase it in good ones. This makes a strong case for considering the two cases where the effort is adjusted more seriously than the two where it is not. Market-effects are discussed in the next section.

6.4 Simulated Profit margin

If only the cases with adjusted costs are considered, only adjustment of prices separates the simulations. Figure 18 show the observed profit margin and these two simulations, in colors corresponding to the ones in Figure 17. The simulation with adjusted prices is shown in red, observed in green.

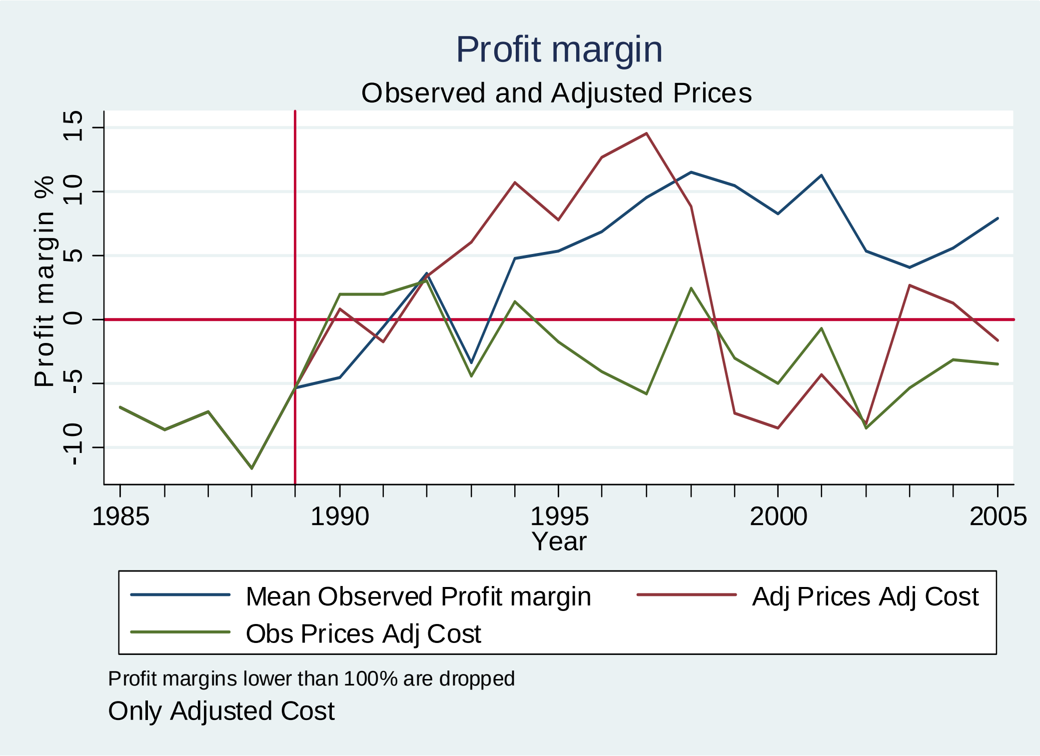


Figure 18: Profit margins. Only adjusted costs. Red vertical line marks 1989, horizontal 0%. Percentage.

Figure 18 shows that the choice of adjusting the prices as described in section 5 have large effects on profit margins. The case with observed prices start out better than observed in 1990, but then hover around zero, mostly on the negative side, for the rest of the period. For the years 1990-2005 it has an average of (-) 2,31%, as compared to the observed value of 4,95%.

The red line shows the most heavily simulated case. Both costs and prices are simulated. Its development is more dramatic than the other simulation. Initially it grows with the same speed as the observed case, and approach 15% in 1997. After this it plunges to the same negative levels as the case of observed prices. For the years 1990-2005 it has an average of 3,21%.

6.4.1 Market-effects

As discussed in section 6.3.1, adjusting the individual's effort seems reasonable. This is done in both cases in Figure 18. The thing separating the two cases is the adjustment of the market described in section 5. Adjusting the effort and the market is two quite different things. The first seem safe. If the simulation of the stock in section 3 is treated as factual, costs obviously has to increase and decrease with landings. Creating a market effect through adjusting the prices is more speculative. It makes some assumptions about demand that is a best guess, but perhaps not perfect.

Thus, it is not obvious that the best simulation of the counterfactual profit margins is the red line, where prices are adjusted. The actual profit margins as they would have developed if quotas were not introduced is probably somewhere between the red and the green line. It is not reasonable to argue that it should be below the green one. If this was the case, lower landings would cause strictly lower prices and vice versa.

It is therefore reasonable to assume that the actual case would lie closer to the red line, where the market is simulated and prices are higher from 1993. They could be below, because under the open access regime more boats will join the fishery when profit margins are positive. This drive profit margins down over time, as there is less fish for every fisher, and the costs of catching it will increase.

But the actual profit margins can also be higher than the red line. There is no variation in the simulation of prices, and thus extreme values are not very well simulated. The highest observed prices occur in 1999-2001. As seen from Figure 19, in these years simulated prices are considerably lower than the observed ones. This shows that the simulation is good for the average price, but not for the extreme values.

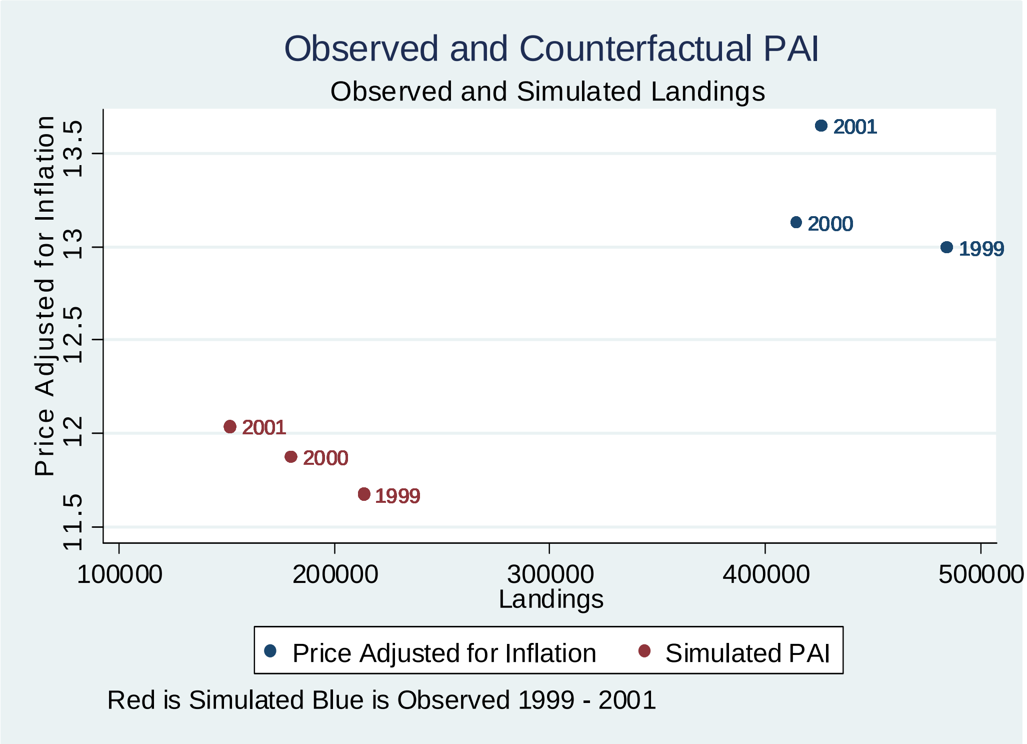


Figure 19: Observed and Counterfactual PAI in 1999-2001.

To sum up, the way prices are simulated is consistent, but the drop in the red line in Figure 18 in the years around 2000 might not be a good simulation. Further it is not obvious that the profit margin that would have occurred under open access is lower than the red line, it could be higher. Thus, the statement that observed profits beat all the simulations might have to be taken with a grain of salt.

6.5 Wage-ability

Wage-ability is another measure of profitability, used by the Directorate of Fisheries. Its calculation is described in section 4.2. In essence it show how much the fisher could get if all profits went to wages.

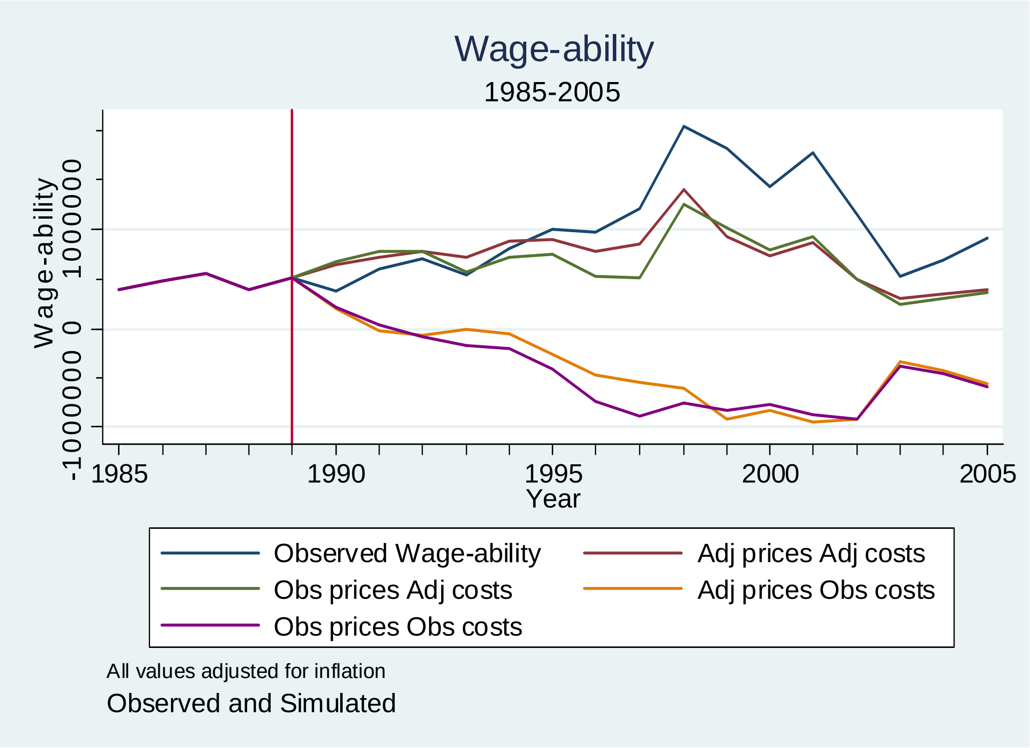


Figure 20: Wage-ability. Red vertical line marks 1990. NOK in 1998.

Figure 20 shows the wage-ability and the four ways of simulating it. All colors correspond to the same case as in the figures showing profit.

Wage-ability basically tells the same story as profits. The simulations do not beat the observed values in the long term; perhaps the distance is greater than for profits. Observed costs causes the simulations to take on lower values than adjusted costs. The market-effect is perhaps smaller; the red line does not seem to deviate as much from the green one, and the orange is quite close to the purple.

As discussed in section 6.3.1, there are reasons to disregard the two cases where costs are observed. This is done in Figure 21, which shows wage-ability as a percentage of the observed value in 1989:

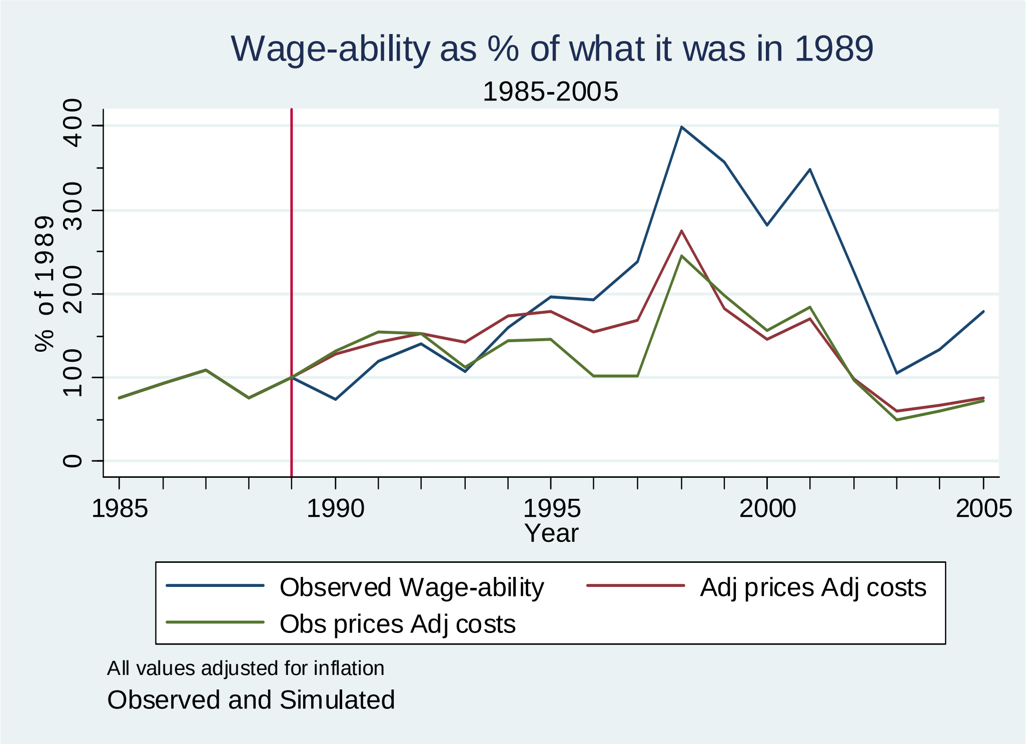


Figure 21: Wage-ability as percentage of observed in 1989. Red vertical line marks 1990. Percentage.

In the early 1990s, wage-ability seems to take on higher values than observed. But after 1994, observed values outgrow simulated and reach almost 400%. The interesting thing about this is that there are not big differences between the simulation where prices are adjusted and observed. They follow each other pretty much the whole way, and end up on the same value in 2005.

This is caused by the share of wages in costs, between 40 and 50 percent in the period. Adjusted costs without wages thus deviate less from the observed values than when profits are simulated.

7 Regression Analysis

Did the quotas cause profits to rise? Section 6 described a simulation of the profits, based on simulations of the stock in section 3 and prices in section 5. In this section a panel data analysis is described. As opposed to the simulations, such an approach can also try to answer if any of the changes in policy caused a rise in profits. It is possible to tell whether the introduction of quotas, the Structural Quota System, the Quota Exchange System or the proposed gliding change to an ITQ system had significant effects on profits. The software used is STATA. The regressions made in this section and elsewhere is based on econometric theory, see for example Greene (2012) chapter 11.

7.1 Regressions

The basic purpose of the regressions is to see how the performance of the fishers varies with effort and opportunities:

$$Performance_{i,t} = \alpha + \beta_1 * Effort_{i,t} + \beta_2 * Opportunites_{i,t}$$

Performance is measured in profits. Effort is operationalized as Days at sea and (Number of) Men. Opportunities are measured in the size of the stock. Thus, the basic regression is:

$$Profit_{i,t} = \alpha + \beta_1 * Days\ at\ sea_{i,t} + \beta_2 * Men_{i,t} + \beta_3 * Stock_t$$

As quotas are introduced to the fishery, it is predicted from theory that the stock and profit should rise. The interesting question is what happened to profits, *ceteris paribus*. A higher stock will have an effect on profits, as it is less costly to catch a given harvest. This makes it necessary to replace Stock with Simulated Stock in the above equation. Thus, the effect from the change in stock on profits is removed. The Simulated Stock is the same as Simulated TBM from section 3.

$$Profit_{i,t} = \alpha + \beta_1 * Days\ at\ sea_{i,t} + \beta_2 * Men_{i,t} + \beta_3 * Simulated\ Stock_t$$

After doing this, it is possible to include the binary variables described in section 2.4. The estimated effects of these dummies will be the effects of changing policy and market conditions on profits.

$$Profit_{i,t} = \alpha + \beta_1 * Days\ at\ sea_{i,t} + \beta_2 * Men_{i,t} + \beta_3 * Simulated\ Stock_t + \beta_4 * D_x$$

7.2 Method

Panel data estimation with Fixed effects is used. Fixed effects imply that there are non-random effects between the boats. The simple truth is that some skippers and crews are more efficient than others. An approach with Random effects is also possible. This would give more efficient estimates, with lower standard errors. But since the Fixed effects between the boats are assumed, Random effects is not consistent. It therefore seems safer to use Fixed effects and loose some significance of the results. The significance of the effects of binary variables are unaffected by this. In order to take care of groupwise heteroskedasticity, robust standard errors are used throughout.

7.3 Results of basic regression

The results of the two methods mentioned are shown below. The first column shows Fixed effects with robust standard errors, Random effects are shown in the second. Stars indicate the level of significance; one is on 10 % level, two is 5% and three are on 1% level.

```
+-----------------------------------------------+
|        Variable |   FE_robust   |      RE      |
|-----------------+---------------+--------------|
| Profit          |               |              |
|     Days_at_sea |  398.67722*** |  338.78233*** |
|             Men |  -8803.097    |  42106.346*** |
| Simulated_Stock | -.06835893*** | -.11478052*** |
|           _cons |  141154.52    | -469.67158    |
|-----------------+---------------+--------------|
             legend: * p<.1; ** p<.05; *** p<.01
```

The first column shows that the Fixed effects gives varying results. The effect of Days at sea is very significant at 399. This means that working another day increase the profit with 399 NOK. Number of men is negative and not significant. The stock has a negative effect of 0.07, and is significant on a 1% level. This means that a stock which is one ton larger, decrease the profit with 0.07 NOK. The constant term is not significant.

The effects in the Random effects regression are all significant on a 1% level, except for the constant term. The effect of another day at sea is lower than under Fixed effects, at about 339. Number of Men has turned in to a positive effect. Adding another man to the crew adds about

42000 NOK to profits. The effect of the stock has decreased further, to 0.11. And the constant term has turned negative.

7.4 Regressions with Binary Variables

7.4.1 Did the initiation of quotas cause profits?

Using the binary variables discussed in section 2.4, a number of dummies are used to test whether the changes in policy and in the market changed the profitability of the fleet.

The binary variable D1 tests whether or not the introduction of quotas caused profits. The result of including it is listed below. The first column show the same result as the first column in the results listed before. The second column includes the dummy D1. In order to save space, the results from including D2 and D3 are included in the third column. These results are discussed in section 7.4.2. In each column, the estimate is listed first, and its t-value below it.

The F-statistic is a test of the hypothesis that the model predicts zero steepness of the curve. As seen from all reported results, the statistic is large enough to reject this hypothesis.

```
+-------------------------------------------------------+
|        Variable |     FE     |     D1     |     D2     |
|-----------------+------------+------------+------------|
|     Days_at_sea |  398.67722 |  306.76079 |  309.38821 |
|                 |       3.70 |       3.15 |       3.20 |
|             Men |  -8803.097 |  10329.016 |   10880.27 |
|                 |      -0.35 |       0.46 |       0.48 |
| Simulated_Stock | -.06835893 | -.07185395 | -.06939462 |
|                 |      -3.65 |      -3.85 |      -3.28 |
|              D1 |            |   141968.4 |            |
|                 |            |       3.75 |            |
|              D2 |            |            |  141240.28 |
|                 |            |            |       3.61 |
|              D3 |            |            |  145786.73 |
|                 |            |            |       3.49 |
|           _cons |  141154.52 | -29213.472 | -34345.289 |
|                 |       1.62 |      -0.40 |      -0.44 |
+-------------------------------------------------------+
|         F-value |      16.95 |      15.75 |      12.64 |
+-------------------------------------------------------+
                                            legend: b/t
```

As seen from the results, the estimated effect of including the binary variable D1 is highly significant with a t-value of almost 4. The effect is estimated at around 142000 NOK. This is a remarkable result; if it is close to true it says that the effect of the introduction of quotas in 1990 increased the profits in the fleet with a large amount. Notice that the effect of Days at sea has fallen with 90 NOK. The effect of the stock is now significant on a 1% level. The other effects from the basic regression are not significant.

7.4.2 Did the system change to an ITQ Regime?

Did the profits rise in the late 1990s? In section 2.3.2 the possibility of a silent change from an IVQ regime to an ITQ regime in 1998 was discussed. This is tested with the dummies D2 and D3. If the effects of the dummy D3 is positive and significant, this show that profits rose in the late 1990s.

The results are listed in the previous subsection, column on the right. The effect of the dummy D2 is about 140000, and very significant. D3 is slightly larger, and highly significant. It is therefore possible to state that profits rose in the late 90s. This is a strong indication of a silent change to an ITQ regime.

Notice again that the effect of Days at sea has fallen with 90 NOK. The other effects from the basic regression are not significant.

7.4.3 Did SQS and QES have effects on profits?

As discussed in section 2.4, the effects of introducing SQS and QES should be positive, since it gives the fishers more flexibility to trade quotas. There is only data available for the two last years in the dataset on this, so it would have to be very large effects in order to be significant.

In the same way as the results for D1, D2 and D3 were listed above; the following results give the regression of D4 and D5 in the second and third columns.

```
+-----------------------------------------------------+
|        Variable |     FE     |     D4     |     D5     |
|-----------------+------------+------------+------------|
|     Days_at_sea |  398.67722 |  398.76504 |  402.32545 |
|                 |       3.70 |       3.71 |       3.77 |
|             Men |  -8803.097 | -8386.2884 | -7056.8258 |
|                 |      -0.35 |      -0.33 |      -0.28 |
| Simulated_Stock | -.06835893 | -.06750594 | -.06435046 |
|                 |      -3.65 |      -3.62 |      -3.35 |
|              D4 |            |  7592.1796 |            |
|                 |            |       0.11 |            |
|              D5 |            |            |  19288.503 |
|                 |            |            |       0.45 |
|           _cons |  141154.52 |  138350.75 |  128331.31 |
|                 |       1.62 |       1.56 |       1.40 |
+-----------------------------------------------------+
|         F-value |      16.95 |      12.71 |      12.72 |
+-----------------------------------------------------+
                                           legend: b/t
```

The effect of SQS is seen in the estimator for D4. The effect of QES is seen in the estimator for D5. The effects of the dummies are positive, but not significant. Thus, the impact of the change in policy is not strong enough to support the hypothesis that the boats earned more because of the easing of the policy. In order to say something more about the effects of SQS and QES, a longer time series would be needed.

7.4.4 Did the largest vessels earn more?

Redistribution of quotas was discussed in section 2.3.3. In essence, the largest boats got quotas from the smaller ones in the years 1990-2002. This should cause them to increase their profits more than the smaller ones.

In order to capture the redistribution of quotas, the dummy D6 take on the value one in the period 1990-2002. But since it is not possible to know how large a boat has to be to be “large”, the regression must be with different length classes. The regression is done four times. The first regression includes only boats with length between 25 and 28 meters. The further regressions include smaller and smaller boats. Since the largest boats had most to gain from the redistribution of quotas, the first regression should have the largest and most significant effect on profit margins, with gradually falling magnitudes for the other dummies.

```
+------------------------------------------------------------------------------+
|       Variable |     FE     |   25-28 m  |   22-28 m  |   19-28 m  |   15-28 m  |
|----------------+------------+------------+------------+------------+------------|
|    Days_at_sea |  398.67722 |   1177.907 |  1905.5575 |  442.3811  |  470.17658 |
|                |       3.70 |       1.77 |       3.72 |       1.57 |       2.97 |
|            Men |  -8803.097 | -261462.08 | -140461.12 | -14074.178 | -32252.818 |
|                |      -0.35 |      -2.25 |      -0.79 |      -0.22 |      -0.85 |
| Simulated_Stock | -.06835893 |  .07986728 |  .40087912 | -.12860895 | -.11662861 |
|                |      -3.65 |       0.29 |       1.78 |      -1.87 |      -3.82 |
|             D6 |            |  346265.49 |  330454.52 |  231708.46 |  179349.62 |
|                |            |       0.86 |       0.70 |       2.98 |       3.61 |
|          _cons |  141154.52 |  1716488.2 |  725903.94 |  225930.42 |  208475.68 |
|                |       1.62 |       2.15 |       0.64 |       0.61 |       1.36 |
+------------------------------------------------------------------------------+
                                                                  legend: b/t
```

The results are listed above. Estimated effects are decreasing monotonous as smaller and smaller vessels are included. This supports the hypothesis from section 2.3.3. But significance of the results is increasing as more boats are included. Only the two last regressions, which include almost all boats in the dataset, are significant on acceptable levels. These dummies are so similar to D1 that they probably pick up the quota effect, not the effect of quota redistribution. In other words, the statement that the largest boats increased their profits compared to the smaller in the 1990s is only true if you include almost all boats. This can hardly be said to be a strong result.

The effects from the basic regression are varying enormously in both magnitude and significance.

7.5 Predictions

It seems unnecessary to try to predict the profit margins for all the models, as some effects are very insignificant. After getting the residuals for predicting the profits using all binary variables, it turn out that using D2 and D3 together give the smallest residuals.

As seen from Figure 22 the prediction of mean profits using the results from the basic regression – in red - is not very good. It is higher than the observed values early in the dataset, and lower later. Observed values are shown in blue.

It is also seen from Figure 22 that the rise in the predicted profits when D2 and D3 are included – in yellow - comes in the change from 1989 to 1990 and 1997 to 1998. Thus, D2 captures the rise in profit from the 80s to the 90s, and D3 a change in the late 1990s. A histogram of the residuals is shown in Appendix 7.1.

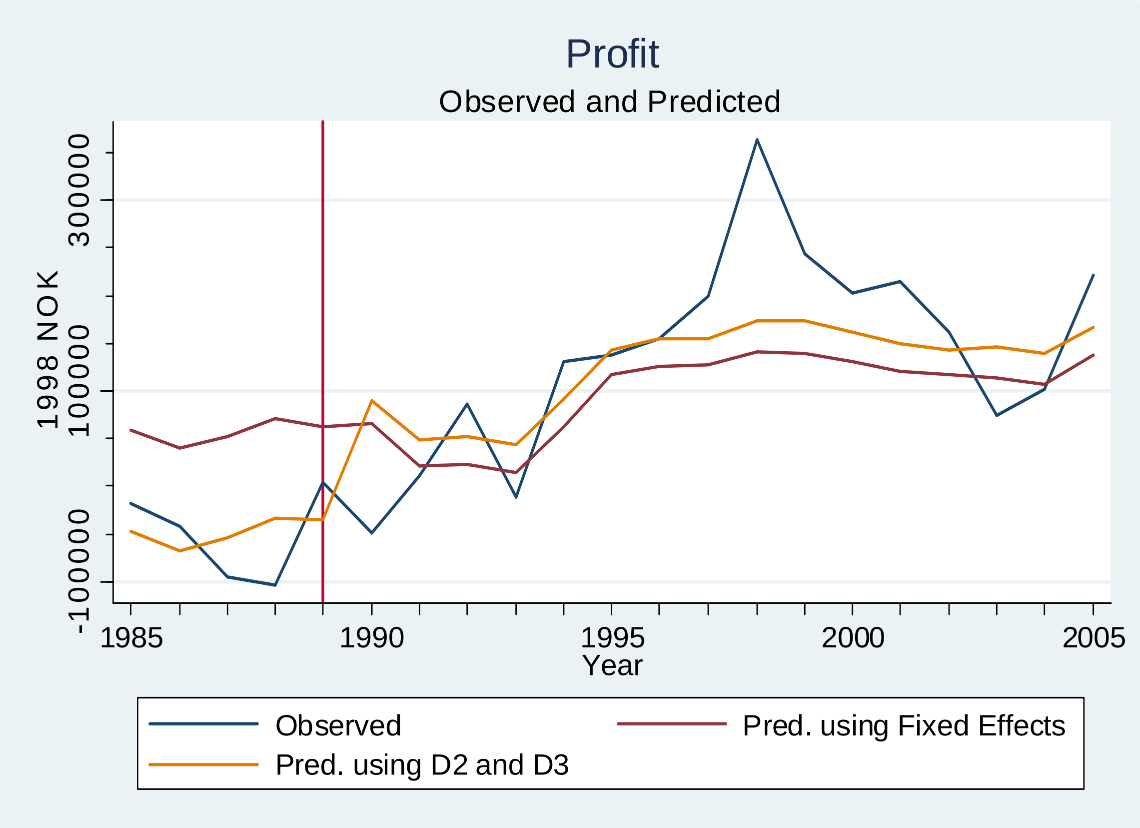


Figure 22: Predicted Profit margins using basic model and model with D2 and D3.

8 Concluding remarks

8.1 Stock, Effort and Landings

Section 8 discusses the results and concludes. One of the predictions from theory is that the size of the stock should increase when quotas are introduced. The simulated stock in Figure 8 in section 3.5.2, show that the prediction is supported.

8.2 Simulated Profits

The observed profit, profit margins and wage-ability show a clear upward development. There is little doubt that the fishers earned more money in the post 1990-era than before. The question remains what caused this rise. Sections 6 and 7 present different analysis of the development in profitability. In this section these results are discussed.

The simulations in section 6 give an indication that a rise in profitability would have occurred if the pattern of landings seen in the years before 1990 had continued. Over time the simulated profit margins are lower than the observed. This could be caused by the quotas.

Knowing this for certain is something else. Landings are simulated, and all subsequent simulations of landings for the fisher, prices and profits are based on this. The simulation of landings has an error term which grows over time. This makes the simulated profits more trustworthy in the early years and less so in the last years.

This is especially true for the simulated profits where landings, prices and costs are simulated. The error term can propagate through all these factors and make the result more uncertain over time. Thus, the “real” counterfactual profits which would have been seen if the quotas had not been introduced could be higher or lower, and at the end of the period the simulation is probably quite far of.

However, the method used is consistent. It is based on logical use of economic theory and the data. The most heavily simulated case is the best guess offered of the counterfactual profits. If this simulation is trusted, the average profit margin in the 15 years after 1990 was 1.74% higher than it would have been without quotas. Thus, the simulation gives answers to both of the main questions stated in the introduction.

Section 6.1.3 discusses the possibility that higher landings per se explain higher profits. The result is ambiguous, but it may seem like the increased landings, caused by profits or not, are unable to explain profits late in the period. Thus something else must explain them, for example quotas.

In section 6.1.4 fishers investments were discussed. Since data on boats capital are not obtained, and the values of quotas are not collected by the Directorate of fisheries, this discussion looked at costs of capital. These costs have a marked increase from 1997, without being explained by the real interest rate. Higher volume of debt is the plausible explanation, and this debt must stem from investment in something. This something is likely to be boats. Since quotas followed the boats, buying boats was the only way fishers could acquire higher quotas. Speculative as it may seem, this is an indication that fishers invested heavily in quotas in the late 1990s. Thus, Tradability seems to be an important aspect of quotas, no matter if they are IVQ. Fishers find a way to trade them, even if it's not the intention of the state.

8.3 Regressed Profits

The regressions in section 7 test the data for different changes in policy. One regression that has a clear result is the one controlling for a regime change in 1990, D1. This has an estimated effect on profits of almost 142000. Thus, it seems safe to say that the profits rose because of the introduction of quotas.

However, quotas may not explain the whole increase in profits. As discussed in section 2.3.3, full-time fishers were given larger quotas than part-timers in the 1990s, and new entrants had a hard time getting full quotas. Both these effects limited the number of full-time fishers in Group 1. Theoretically, profits are driven down under open access because new entrants come into the fishery when profits are positive. Since entry was limited, any positive resource rent would remain with those already fishing, regardless of regime. This speaks against the statement that quotas alone caused profits to increase.

On the other hand, the quotas seem to be the most radical change to the fishers' reality in the early 1990s, not the division of fishers into Group 1 and Group 2. Fishers were full-timers or part-timers ahead of this division, and even noted as such in the Directorates' register over fishers.

Further, subsidies where removed in the same period as the introduction of quotas. The rise in profitability at the same time is an indication that the effects of quotas outweighed the subsidies by a large margin.

Section 2.2 argued that there are separate effects on profits from the quotas being Individual and being Tradable. At first quotas were Individual but not Tradable. In theory they are so to this day. The initial effect on observed profit margins seen in Figure 13 reflects this Individual ownership. Fishers did no longer have to maximize their effort in a short period. Instead their effort was limited. This increased profits because prices rose and costs fell. In addition, fishers could plan their own season and deliver better quality.

This thesis, along with other literature, argues that there is a significant effect on profits from the quotas becoming de facto Tradable in the course of the 1990s. This is tested in section 7.4.2, and results for the binary variables are high and significant. The effect of D2 captures the Individuality. This is strong and significant. But the same goes for D3, which is meant to capture the effect of the quotas becoming Tradable. The strong effect on D3 may be caused by better environmental conditions, or that the fishers needed time to adjust their effort after the new policy was introduced. But at least part of the increase might stem from the increased efficiency that occurs when quotas become Tradable. Thus, the results support the ideas of Hersoug et.al (2000b).

The idea that SQS and QES increased profitability is tested in section 7.4.3. The effects are not significant. As mentioned, the dataset on this development is not very long. It would be interesting to do the regressions again when a longer dataset is available.

In section 2.3.3 the growth of the large coastal vessels were discussed, and its impact on profits tested in section 7.4.4. The results are not very strong. Hersoug (2005), which is the basis of this discussion, argue that the investments rose, not the profitability. Nevertheless, investments should be made because the fishers expect profits to rise. If profits are expected to rise, this should be linked to some growth in profits at the present. Thus, there should be some link between present investments and profits. Since the analysis does not support higher present profits for the fishers, it seems vague to say that the large investments were based on real experiences of profits.

8.4 Change to ITQ?

As argued, the quota system became more market oriented, through market powers and through government easing of the regulation. The results of these changes are estimated to be positive on profitability. In the same period subsidies shrunk to very low levels. This systematic change and the graph of the observed profits tell us that fishers are better of in a closed fishery than in an open where they receive subsidies.

One might say that the fisheries in 1985 depended on the state, and depended only on the amount of cod in 2005. Is it not only fair to say that this has been a healthy development for the fisheries?

Today Norway has a de jure IVQ system with some regulations that make it possible to lease for a couple of years quotas etc. This system approaches a de facto ITQ system. The results from this paper show that any change towards a freer market of quotas has been good for the fishers. Is it not time for the government to take the final step, and introduce ITQs by law?

This would have positive effects on profitability. This is not necessarily an argument that sounds good for Norwegians, because of the special place rural policy has in politics. As mentioned before, the fisheries policy try to cover many goals, and a central idea is to keep fisheries spread along the whole coast. This is not necessarily the result if quotas are traded free of restrictions.

But politicians should also see the opportunities that higher profitability gives. The Norwegian oil industry pay a resource tax of 50% on top of the regular corporate tax. The argument behind this is that the oil belongs to the people, and its value should go back to the people. If the same logic is applied to cod as to oil, fishers should pay a corporate tax and a resource tax on top. Fisheries do not experience a profitability that justifies a resource tax of 50%, but that percentage could be specified for the industry.

8.5 Conclusion

This paper has tried to describe the development in profitability of Norwegian coastal demersal fishers in the period 1985-2005. The big change in policy in this period was the introduction of quotas in 1990. As argued, the profitability increased, and this was most likely caused by the introduction of quotas in 1990.

8.6 Suggestions for further research

Suggestions for further research would include better controls for subsidies. This is included in revenues in the dataset used in this paper. By withdrawing them, it would be possible to make a better analysis of profitability based on real activity.

By including individual data on capital it would be possible to use different measures of profitability. If capital included financial value of quotas, some interesting analysis of the value of quotas could be done.

In the simulations of profit, costs are adjusted linearly. Since costs probably have a falling marginal increase in landings, they could arguably be adjusted non-proportionally. The results of this would have been interesting to see.

And finally, it would be interesting to look at how high a resource tax the fishers could pay and still make enough money to keep the effort on todays level. This would have to take profitability into account, as well as the effects of changing or withdrawing existing taxes.

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Appendices

Appendix 3.1: The regression of Landings$_t$ on TBM$_{t-1}$

$$Basic\ Model: Landings_t = \beta_0 + \beta_1 * TBM_{t-1}$$

Results:

reg Landings TBM_1 in years 1960-1989			
	Estimate	Standard Error	t-value
Constant	38623.58	57875.14	0.67
TBM_1	.3447801	.0314481	10.96
R-squared		0.8111	
Degrees of freedom		29	
Root MSE		1.2e+05	

Residuals:

```
————————————————————————————————————————————————————————————————————————
  Variable  |    Obs   |    Mean     |  Std. Dev. |    Min     |   Max    |
————————————————————————————————————————————————————————————————————————
  Plandings |     61   |  644541.8 |   201438.9   |352845.9   | 1157774  |
————————————————————————————————————————————————————————————————————————
```

Several other relationships were tested on the time-period 1960-1989, before choosing the Basic Model. They include quadratic terms for the Total biomass and years since 1960. The later term is included in order to model technological change. The models are easily replaceable in the simulation. Models:

$$Model\ 1: Landings_t = \beta_0 + \beta_1 * TBM_{t-1} + \beta_2 * (TBM_{t-1})\hat{}2$$

$$Model\ 2: Landings_t = \beta_0 + \beta_1 * TBM_{t-1} + \beta_3 * year\_after\_1960 + \beta_4 * (year\_after\_1960)\hat{}2$$

$$Model\ 3: Landings_t = \beta_0 + \beta_1 * TBM_{t-1} + \beta_2 * (TBM_{t-1})\hat{}2 + \beta_3 * year\_after\_1960 + \beta_4 * (year\_after\_1960)\hat{}2$$

$$Model\ 4: Landings_t = \beta_0 + \beta_1 * TBM_{t-1} + \beta_3 * \ln\ \_year\_after\_1960$$

$$Model\ 5: Landings_t = \beta_0 + \beta_2 * \ln\ \_TBM_{t-1}$$

$$Model\ 6: Landings_t = \beta_0 + \beta_2 * \ln\ \_TBM_{t-1} + \beta_3 * \ln\ \_year\_after\_1960$$

Results: For each estimator, the estimate is listed first, then standard-error, and then t-value.

```
+------------------------------------------------------------+
|            Variable |  Model_1     |  Model_2     |  Model_3     |
|---------------------+--------------+--------------+--------------|
|               TBM_1 |   .36552714  |   .37123514  |   .50429066  |
|                     |   .15195817  |   .04431422  |   .18395389  |
|                     |        2.41  |        8.38  |        2.74  |
|            TBM_1_sq |  -5.621e-09  |              |  -3.272e-08  |
|                     |   4.025e-08  |              |   4.388e-08  |
|                     |       -0.14  |              |       -0.75  |
|     year_after_1960 |              |   13788.611  |   13806.053  |
|                     |              |   9386.8992  |   9468.1186  |
|                     |              |        1.47  |        1.46  |
|  year_after_1960_sq |              |  -332.20708  |  -288.01238  |
|                     |              |   333.47915  |   341.54546  |
|                     |              |       -1.00  |       -0.84  |
|               _cons |   22146.912  |  -111862.72  |  -241676.79  |
|                     |   131865.16  |   109459.72  |   206151.03  |
|                     |        0.17  |       -1.02  |       -1.17  |
+------------------------------------------------------------+
R-sq:                 |     0.8112   |     0.8330   |  0.8366      |

+------------------------------------------------------------+
                                              legend: b/se/t
```

```
+------------------------------------------------------------+
|            Variable |  Model_4     |  Model_5     |  Model_6     |
|---------------------+--------------+--------------+--------------|
|               TBM_1 |   .36902442  |              |              |
|                     |     .034168  |              |              |
```

```
|                    |     10.80 |            |            |
| ln_year_after_1960 | 17609.877 |            |  36982.471 |
|                    | 27664.727 |            |  31292.186 |
|                    |      0.64 |            |       1.18 |
|            ln_TBM_1 |           |  543425.59 |  603637.92 |
|                    |           |   54861.77 |  62146.259 |
|                    |           |       9.91 |       9.71 |
|              _cons | -36955.486 | -7125522.6 | -8066439.5 |
|                    |  110109.2 |  783181.74 |  929656.61 |
|                    |     -0.34 |      -9.10 |      -8.68 |
+-----------------------------------------------------------+
R-sq:                |   0.8468  |   0.7780   |   0.8184   |

+-----------------------------------------------------------+
                                             legend: b/se/t
```

As seen from the estimates, other models have better R-squared, but the standard-errors for estimates are much larger. t-values are not very good for all estimates in any model.

Residuals:

```
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
Basic_Resi~1 |        30   -.0010417    114366.3  -235663.3   249510.2
Residuals_~1 |        30   -.0020833      114325  -250348.3   234737.3
Residuals_~2 |        30           0    107524.9  -211904.4   201495.5
Residuals_~3 |        30     -.00625    106348.8  -218769.1   196168.4
Residuals_~4 |        29    .0032328    104814.3  -235976.7   206534.9
Residuals_~5 |        30    .0005208    123974.8  -247841.6   244059.1
Residuals_~6 |        29    .0021552    114113.1  -247994.7     202750
```

As seen from this, other models have equal or smaller residuals. Still, the t-values for the estimates are best for the Basic Model. This is why this model is chosen.

Appendix 3.2: Stata-codes for chapter 3:

```
*Get the data from ICES. It is available from http://www.ices.dk/datacentre/StdGraphDB.asp
*Download the database
*Find NEA cod in the database, and download / extract from database.
*Load data into stata 11 or newer version.
```

```
*Copy and paste this code into the do-file, and execute:

*Rename variables, in order not to get confused:
rename  age3 N3
rename total_bm TBM
rename  ssb SSB
rename landings Landings
rename yieldssb YieldSSB
rename  fbar M
label variable YieldSSB "Landings / SSB"
label variable year "Year"
label variable M "Mean Fish Mortality"
tsset year
gen SSB_3 = l3.SSB
label variable SSB_3 "Stock of Spawning Biomass Three Years earlier"
keep if year>1948
sum

*Non-linear regression of Beverton-Holt relationship:
nl (N3 = {a}*SSB_3/(1 + {b}*SSB_3))
*Initial Steepness
di 7.143362/(8.32e-06 ) // =858577.16 Recruitment approach this value asymptotically when
SSB_3 approach infinity

*Regression for Landings:
reg Landings TBM_1 if year in 12/41

*Calculating a
gen a = N3*(1+(8.32e-06)*SSB_3)/SSB_3
```

Appendix 6.1: Profits using the second method of calculating revenues

Figure 23 shows the profit using the second method of calculating revenues, as discussed in section 6.2.1.

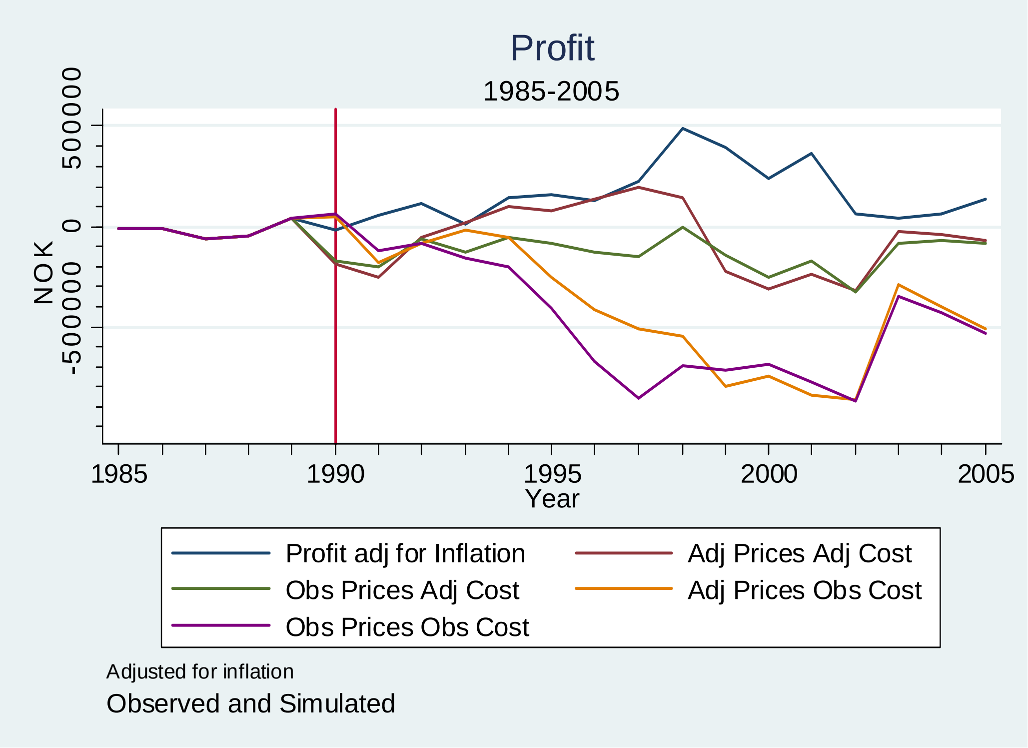

Figure 23: Profit, observed and simulated. Adjusted for inflation. Red vertical line marks 1990. NOK in 1998.

The figure shows that simulated profits take on smaller values than when method one is used. Observed profits are highest in almost each single year. Thus, method two does not adjust the revenues as much upwards as method one. This could mean that there is not a proportionate factor between value of landings and revenue, as method two suggests. Underreporting of landings might not be a problem.

Appendix 7.1: Histogram over residuals from predicting profits with D2 and D3

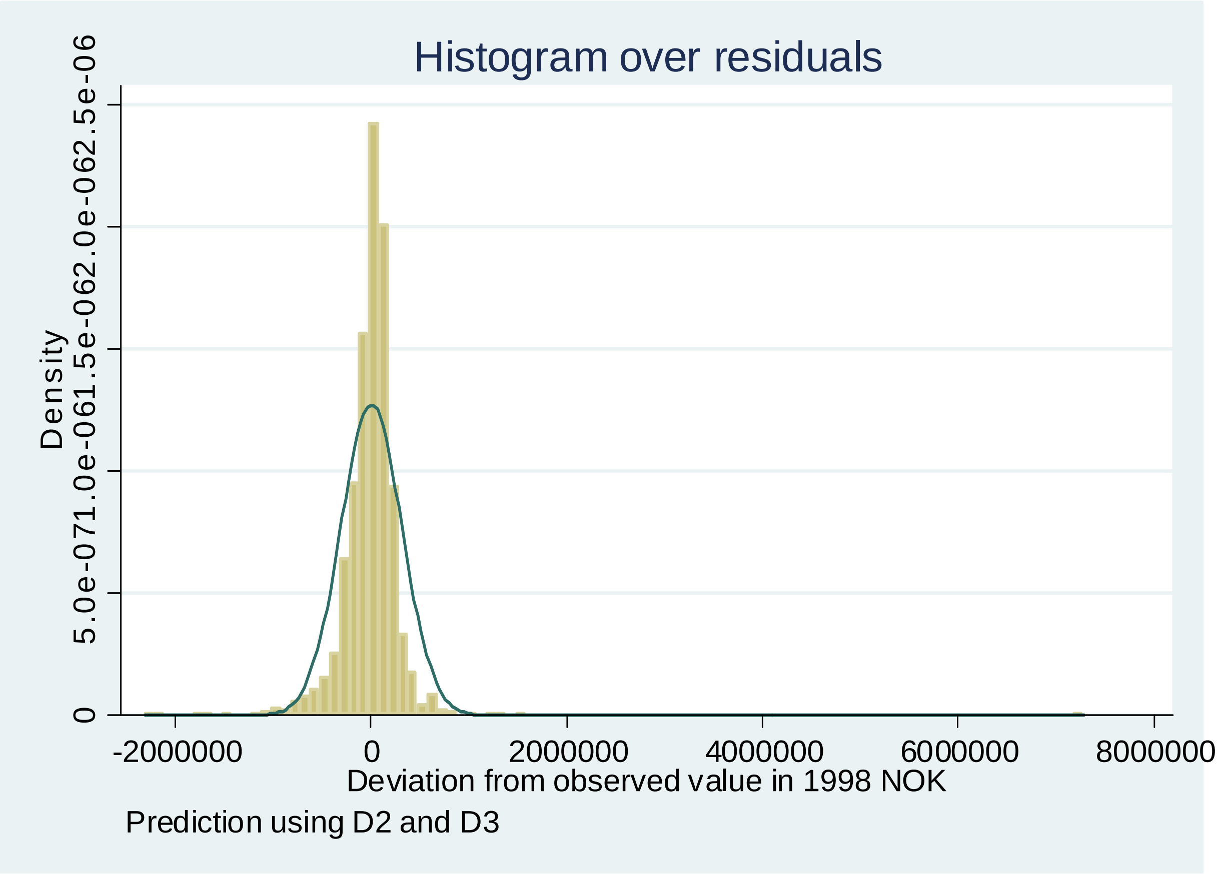

Figure 24: Histogram showing the density of residuals from predicting profits with D2 and D3

Figure 24 shows that the prediction has residuals which are close to normally distributed, perhaps with a too large kurtosis.