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Capacity adjustment and drivers of investment in a fishery with tradable output quotas

by

Linda Nøstbakken

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Capacity adjustment and drivers of investment in a fishery with tradable output quotas*

Linda Nøstbakken†

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Abstract

In this study, I analyse what drives investment and capital development, and, hence, the development of fishing capacity in a well-managed fishery. An empirical analysis of drivers of firm-level investment in the Norwegian purse seine fishery is conducted. The industry is regulated by tradable production quotas that entitles the holder to a certain share of the total allowable catches of various pelagic species. Considerable investment in physical capital has taken place in the industry over the last decade, and the fleet has realised large resource rents. Both quotas and physical capital are crucial to the operation of the firm. For this reason a multiple capital good model is used in the analysis. The empirical results suggest that few economic variables significantly affect firm-level investment in the fishery. Firm-specific effects are, however, found to be important determinants of investment, particularly in quota. Furthermore, the empirical results indicate that when introducing transferrable quotas, auctioning may be superior to grandfathering, as firms otherwise may not take the full opportunity cost of the quota into account.

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†University of Alberta School of Business, Business Building, Edmonton, Alberta T6G 2R6, Canada, and SNF, Norway. Email: linda.nostbakken@ualberta.ca

1 Introduction

The problem of managing world fisheries efficiently is a well-known and important issue. In fact, the decline and collapse of many commercial fisheries is widely believed to be the result of fisheries mismanagement (Costello et al., 2008). The problem is typically that management instruments do not sufficiently deal with the fundamental problem of common property resources; the lack of property rights. Recent work indicates that the most successful fisheries are those in which property rights to catch shares have been established (Costello et al., 2008). The idea behind this is that property rights provide individual fishing firms with incentives that make them act in a manner closer to what is socially optimal. Still, efficiency is not necessarily restored when property rights are established either (Grafton, 1996).

The purpose of this study is to analyse investment behaviour in a well-managed fishery with well-established property rights. It is widely known that if fisheries are unregulated or regulated with command-and-control type regulations such as input and output controls, excess fishing capacity may be a serious issue (Kirkley et al., 2002). This occurs because the individual fishing firms are not given the incentives to invest in capacity in a socially optimal manner. Individual transferable quotas (ITQs) is an incentive based management system that has been proposed to deal with this. The introduction of property rights that corrects the bias in the firms' incentives to invest sub-optimally is a relevant option in most fisheries. Hence, it is important to know what happens once such regime is in place. It is essential to understand what drives investment to understand how capital and capacity develop over time. Furthermore, such knowledge is crucial to the understanding of what policies may be effective or ineffective in the management of investment (fishing capacity). Notice, though, that in a well-functioning ITQ fishery it should not be necessary to regulate capacity or investment as fishing firms do not have incentives to overinvest in fishing capacity.[1] This is nonetheless done in many, and perhaps even most, fisheries today.

The Norwegian purse seine fishery has recently realised relatively large resource rents (Steinshamn, 2005) and is managed by individual vessel quotas that are transferable, although not perfectly transferable. There are certain restrictions on trade in quotas, which means that the system could be made more efficient by relaxing some of the restrictions.[2] Nonetheless, the fishery has been by far the most profitable fishery in Norway over the last decade (Steinshamn, 2005) and should therefore be considered a fairly well-managed fishery.

The questions I ask are what drives investment in a fishery where good property rights have been established, and what characterises firms that increase (or decrease) their share in such industry. A panel of data on the purse seine fleet covering the years 2001-2005 is used in the analysis. I distinguish between two main types of capital, physical production capital and quota capital. Both types of capital are necessary

[1] For instance, if illegal fishing is an alternative to the firms, their incentives to invest in capacity may no longer be socially optimal.

[2] The restrictions on quota trade are, as in many other fisheries, present to ensure that the various non-economic objectives for fisheries management in Norway are achieved, such as maintaining current settlement patterns, etc.

for production, and in the long run the levels of the two types of capital should be proportional (i.e., no excess fishing capacity or quotas).

The empirical results show that few economic variables have significant impact on investment in quota and physical capital in the fishery. Thus, only relying on variables typically used in economic models of investment does not suffice to explain the variation in investment. The modest impact of economic variables may partly be a result of large resource rents being realised by the fleet, which has allowed agents in the industry considerable financial flexibility. Furthermore, firm-specific effects are found to be important determinants of investment, particularly in the case of quota investment. Thus, two firms that are identical in terms of e.g. production and profitability may consistently choose very different investment strategies. This has important policy implications. First, firms do not respond as well to economic incentives as one would expect based on economic theory. Second, it is not necessarily the case that the most efficient firms remain in the industry while the less efficient firms sell out upon introduction of transferrable quotas. Third, the result that firms are not driven entirely by economic incentives can be explained by the fact that grandfathering was used when quotas were initially distributed to firms in the industry. As long as firms received some or all of their quotas below market price, they are not forced to take into account the full opportunity cost of the quotas. Hence, firms in the industry that have realised large resource rents, have the financial freedom to not have to act in the most economically efficient manner. This is a new argument in favor of using auctions rather than grandfathering in the initial allocation of permits or quotas. The existing literature typically focuses on tax distortions, under which auctioning is superior to grandfathering (see e.g. Goulder et al., 1999; Fullerton & Metcalf, 2001).

There are numerous studies of investment in the economic literature. For a good, yet not very recent survey, see Chirinko (1993). Few empirical studies, however, analyse drivers of firm-level investments when firms, in addition to physical production capital, also have to invest in production quotas or similar assets. This is the focus of the current study. The underlying theoretical model is similar in nature to other models of multiple capital goods, such as models of investment in R&D and physical capital, human and physical capital, and abatement technology and production capital. Many industries are regulated with tradable production quotas or similar instruments that are aimed at restricting the use of certain inputs, the level of production, or the output of harmful byproducts of the production process. Thus, the analysis and the results are therefore relevant also beyond the fishing industry.

The seminal work on investment theory in fisheries was developed in the late 1960s by Smith (1968, 1969) and during the 1970s by Clark et al. (1979). The latter work combined the previous work of Clark and Munro on the use of capital theory to analyse the investment in natural capital (see e.g. Clark & Munro, 1975; Clark, 1976) with theories of investment in physical capital, particularly focusing on the irreversibility of fishing capital. There are, however, few firm-level empirical studies of capital development and drivers of investment in fisheries. The related topic of fishing capacity has, on the contrary, received much attention.[3] Numerous papers have been published on measuring capacity and capacity utilisation in fisheries (see e.g. the work by Kirkley et al., 2002; Dupont et al., 2002; Segerson & Squires, 1990, 1993). Several comprehensive reviews of this literature are available, such as Kirkley & Squires (1999). Given the close relationship between capital investment and fishing capacity development, it is striking that relatively little empirical work has been done on firm-level investment in fisheries. To properly understand what drives capacity development one must also understand the drivers of firm-level investment in the industry.

Previous empirical work of relevance to the current study includes Wilen (1976) and Bjørndal & Conrad (1987). This early work in the area focuses on the estimation of parameters measuring the speed at which fleets respond to changes in the average profitability of fisheries in terms of vessel entries and exits. Wilen (1976) studies the dynamics of the North Pacific fur seal fishery. He develops a model that described the cycles of the open-access fishery in terms of stock dynamics, harvesting, and profits. Following a similar approach, Bjørndal & Conrad (1987) conduct an empirical analysis of capital dynamics in the Norwegian North Sea herring fishery focusing on the purse seine fleet and the period 1963-1977.

Weninger & Just (2002) present a theoretical study of entry and exit in a natural resource industry where firms must invest in an output permit to enter the industry. In order to produce, firms must have physical capital and output permits. Their focus is on the effects of uncertainty in the permit price, particularly in terms of entry and exit behaviour, and therefore differs from the focus of the current study.

The paper is organised as follows. I start out by outlining the theoretical basis for the analysis. Then, in section 3, a description of the fishery and the regulatory framework is given. I also describe the data set and how it was constructed. In section 4, the empirical analysis is described and the results are presented and discussed. Subsequently, an empirical analysis based on vessel-level rather than firm-level data is carried out. The main findings are summarised and discussed in section 6. The final section concludes.

2 The theoretical model

In this section, a model is developed based on the optimisation problem that faces a typical fishing firm. I present a fairly general model of a firm operating in an industry where output is limited by tradable output quotas (ITQs). The case of the fishery is considered, but the model can easily be applied to other industries in which output is restricted by tradable production quotas. The model is also easily modified to account for other management regimes, such as tradable effort regulations.

The main implication of introducing tradable quotas is that in addition to investing or disinvesting in physical production capital, the firm must decide on investment/disinvestment in quota units. Quota capital is as important in the production process as physical capital. In fact, without quota the firm cannot produce at all,

[3] Indeed, some may claim that too much attention has been focused on this topic. See Wilen (2007) for a critical discussion of this literature.

independently of the stock of physical capital and other production factors. For this reason a multiple capital good model is used.

The model focuses on the optimisation problem of the firm. The firm, which is a price taker in all relevant markets, seeks to maximise the net present value of future cash flows. Thus, the cash flow in any period t can be expressed as:

$$CF_t = p_t Y_t - w_t L_t - g(J_t) - c(I_t), \tag{1}$$

where p_t is the price of fish, Y_t is quantity landed, w_t is the price of variable inputs L_t, $g(J_t)$ is the cost of net investment in quota units, with J_t representing net quota investment in period t.[4] Similarly, $c(I_t)$ gives the cost of investment in physical capital as a function of investment I_t. Notice that all right-hand side parameters and variables in equation (1) can be interpreted as vectors: output prices, output quantities and quotas by outputs (e.g. fish species), and input prices and quantities by variable inputs.

The function $g(J_t)$ accounts for the fact that the buying price and the selling price of quotas may differ, e.g. due to transaction costs or regulations.[5] If quotas are perfectly transferrable, $g(J_t)$ is strictly linear (quota price multiplied by net quota investment). Similarly, for investment in physical capital, $c(I_t)$ is not necessarily strictly linear in I_t. This is to allow for e.g. non-malleability of capital (see Clark et al., 1979). The price of physical fishing capital is typically considerably higher for investment than for disinvestment.

The net present value of future cash flows must be maximised subject to several dynamic constraints. The dynamics of physical capital are given by:

$$K_{t+1} = f^k (I_t, K_t), \tag{2}$$

where K_t is the level of physical capital at the beginning of period t, and I_t is investment in physical capital in period t. Typically, physical capital depreciates over time. Notice that there may be delivery lags that affect the time taken from an investment decision is made until the new capital is in place. This issue is thoroughly dealt with in the literature (see e.g. the early survey by Jorgenson, 1971). In the capital dynamics equations (2), it is for simplicity assumed that investments made in period t become available in period $t+1$. This assumption is relaxed in the empirical analysis. It is important to note the implication of possible delivery lags. It is clear that if the new capital that becomes operational in period $t+1$ was contracted in period $t-1$, the firm did not have knowledge about input prices, output prices, etc. in period t when making the investment decision (in period $t-1$). Consequently, such variables can not have had any impact on the investment decision. Thus, knowledge about delivery lags is important to determine the appropriate lag structure of the empirical model. The same applies to the dynamics of quota capital. I return to the issue of delivery lags in the empirical analysis below.

[4] It might be reasonable to assume that the price of quota units depend on the status of the stock and thereby the current allowable catches, but to keep the model simple this is ignored.

[5] In the Norwegian fishery a 20% deduction rule is applied, which means that the price per unit of quota obtained by the buyer is higher than the price obtained by the seller. The deducted share is redistributed among all vessels in the fleet based on their quota holdings.

The dynamics of the firm's quota holdings evolve according to:

$$Q_{t+1} = f^q\left(J_t, Q_t\right). \tag{3}$$

There is typically no depreciation of quota holdings. Thus, if a firm does not buy or sell quotas, quota holdings are constant.

The harvesting technology of the firm is given by a production function, which relates the level of variable inputs, physical capital, and the size of the fish stock, to production:

$$Y_t = F\left(L_t, K_t; x_t\right), \tag{4}$$

where x_t represents stock size in period t (or a vector of stock sizes). The firm must also obey its quota constraint.[6] A total allowable catch (TAC) of $\bar{Q}_t$ is set at the beginning of period t. A quota holding of Q_t entitles the firm to a certain share of $\bar{Q}_t$. It is further assumed that the TAC is a function of the period's stock size x_t denoted $\bar{Q}\left(x_t\right)$. The current stock size depends on the previous period's stock size and total harvest, and on possible random variation, denoted by z_t: $x_{t+1} = f^x(x_t, y_t, z_t)$.

Introducing the quota constraint into the basic production function (4), the production of the firm can be expressed as

$$Y_t = \min\left[F\left(L_t, K_t; x_t\right), Q_t \cdot \bar{Q}(x_t)\right], \tag{5}$$

where $Y_t \geq 0$. It is clear that there must be a close relationship between investment in physical capital and in quotas. With production determined by a minimum condition, as in equation (5), efficient production is found where production according to $F\left(L_t, K_t; x_t\right)$, which depends on *inter alia* physical capital, equals quota production ($Q_t \cdot \bar{Q}(x_t)$), regardless of input prices. However, with random fluctuations in the variables of the model, this is not necessarily accomplished in every period.

With this in place, we can set up the firm's dynamic optimisation problem.

$$\begin{aligned} \max_{\{L_t, I_t, J_t\}} & E\left\{\sum_{t=0}^{\infty} \beta^t \left[p_t Y_t - w_t L_t - g\left(J_t\right) - c\left(I_t\right)\right]\right\} \\ \text{s.t.} \quad & Y_t = \min\left[F\left(L_t, K_t; x_t\right), Q_t \cdot \bar{Q}(x_t)\right] \\ & K_{t+1} = f^k(I_t, K_t) \\ & Q_{t+1} = f^q(J_t, Q_t) \\ & x_{t+1} = f^x(x_t, y_t, z_t), \end{aligned} \tag{6}$$

where β is a discount factor, and E indicates that we take the expectation over possible realisations of x.

The firm seeks to maximise the expected discounted value of future cash flows subject to certain constraints presented above. The control variables of the firm are investment in physical capacity (I_t) and in quota units (J_t), and the level of variable inputs L_t. The biomass of the resource stock x_t, is exogenous.

[6] Real-world fishing firms have the option to violate quotas and land fish illegally. However, the issue of non-compliance is beyond the scope of the current study and in the following it is assumed that the firm complies with quota regulations.

Consider the min operator in the production constraint of the maximisation problem in (6). If the inputs in the production function are substitutes, it is never optimal to use more variable inputs than exactly what is needed to harvest the full quota. Any increase in inputs beyond this comes at cost, as inputs are costly, but cannot yield any revenue since the quota restricts further increase in the output level of the firm. Within any given period, K_t and x_t are given. Thus, the firm chooses the level of variable inputs to ensure that the production level does not exceed the quota level of production. Consequently, as long as the inputs in the production function are substitutes, the min term in equation (6) can be rewritten as a constraint $F(L_t, K_t; x_t) \leq Q_t \cdot \bar{Q}(x_t)$.

The relationship between investment in the two types of capital and other model parameters is characterised by the optimality conditions of the problem shown in (6), and can be stated as follows:

$$I_t = I\left(K_\tau, Q_\tau, p_\tau, w_\tau, x_\tau, \bar{Q}_\tau, Y_\tau, z_\tau, \Phi\right) \tag{7}$$

$$J_t = J\left(K_\tau, Q_\tau, p_\tau, w_\tau, x_\tau, \bar{Q}_\tau, Y_\tau, z_\tau, \Phi\right) \tag{8}$$

where subscript τ denotes one or more time indices prior to time period t (i.e., $t-1, ..., t-\tau$), and Φ denotes other parameter values. That is, the decisions behind new investments in capital that become operational in period t (I_t and J_t) may depend on the status in periods $t-1$, $t-2$, etc. The number of lags of each variable to include (τ) depends on the functional forms of the functions in the maximisation problem (6).

Even without specifying functional forms and finding the analytical solution of the model, it is clear that an increase in input prices, a decrease in output prices, and a decrease in stock size would weaken the firm's incentives to invest, both in quota and in physical production capital. This is because, all else equal, such change in model parameters decreases the firm's expected return per dollar invested.

In the empirical analysis below, the empirical model will be based on equations 7 and 8.

3 Data set

In this section, I give a brief description of the industry to be analysed, and I present the data set used in the empirical analysis.

3.1 Description of the fishery

All purse seiners larger than 90 feet or 1500 hectolitres cargo capacity must have a special licence to operate. These licences specify the size of the boat, measured in hectolitres of cargo capacity. When individual vessel quotas were introduced in the purse seine fishery in 1973, they were determined through a formula calculating a vessel's "base quota" as an increasing but concave function of its cargo capacity. The vessel's share of the total allowable catch was then determined by dividing the vessel's base quota by the sum of all base quotas. This ensured that large vessels got relatively smaller quotas than small vessels. There were, however, sufficient economies of scale in the purse fishery to ensure a higher profitability for large vessels, despite the regressive allocation of quotas. These economies of scale soon led to trading in fishing licences and indirectly to trading in shares of the total allowable catch. A vessel owner could purchase the fishing license of a vessel being retired from the fishery, add the licensed cargo capacity of that vessel to his own, and buy a bigger vessel. Considerable rationalisation of the fleet took place in this way, but there was also considerable retirement of licences financed by government subsidies in the 1980s.

Since 1996 fishing firms have been permitted to add the quota allocation of a vessel purchased for retirement from the fishery, to the existing quota allocation of the firm. There has, however, been a time limit on how long these quotas can be retained (13-18 years). This arrangement was put on hold in the fall of 2005 by a new government, pending a review of the fisheries policy. Following the review, the arrangement was changed slightly (new time horizon for purchased quotas, 20 or 25 years), and put into effect again in spring of 2007.

Quotas have been transferrable over the full study period, 2001-05, although certain restrictions applied. One such restriction was that a share of 20% of the purchased quota was deducted and the buyer only got 80% of the quota purchased. The 20% deduction was indirectly reallocated among the remaining vessels in the fleet, including the buyer of the quota. Thus, even a fishing firm who did not buy or sell any quota units, would see its share of the total quota increase as others traded quotas.

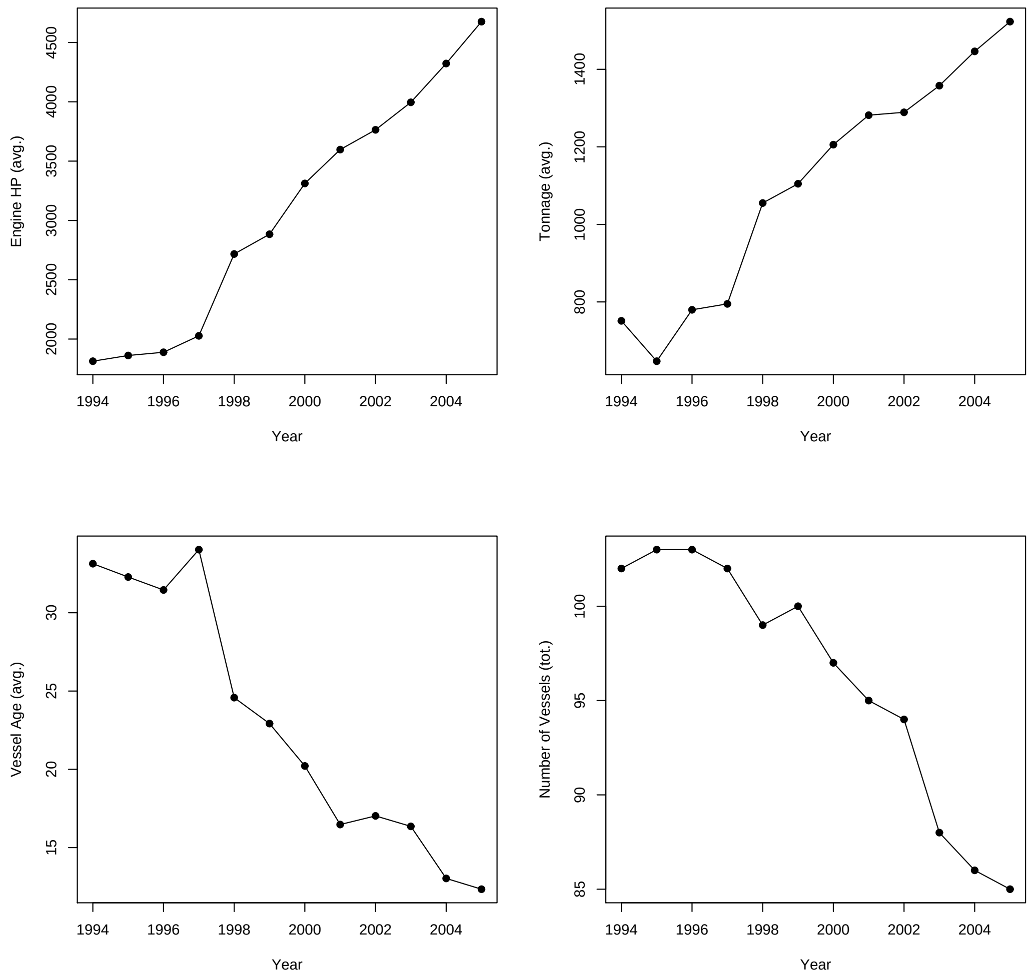
The pelagic purse seine fleet has become by far the most valuable Norwegian fishing fleet. The fleet consists of modern vessels with a very high turnover. Steinshamn (2005) calculates that the resource rent realised by this fleet segment is between 950 and 1,390 million NOK per year.[7] In comparison, the total value of Norwegian landings was 10,190 mill NOK (pelagic and demersal species). Considering the number of vessels in the fishery (< 100), the profitability per vessel is very high.

Considerable investment has taken place in the fleet over the last decade. This is evident in figure 1, which shows the development of engine horsepower, vessel tonnage and vessel age (all sample averages), as well as the number of vessels in the fishery over the period 1994 to 2005. Engine horse power and vessel tonnage have increased steadily, whereas the average vessel age has been decreasing since 1997. Notice also the drastic decline in the number of vessels operating in the fleet, from ca 102-103 vessels in the late 1990s to 85 vessels in 2005.

The fleet typically accounts for approximately 85% of the Norwegian landings of North Sea herring, and also accounts for significant shares of other pelagic species. In terms of quantity landed, blue whiting is the most important species for the average vessel. However, in terms of value of landings, herring is the most important species (mainly Norwegian spring-spawning herring and North Sea herring), followed by mackerel and blue whiting. These three species accounted for approximately 90% of the landings in 2005 (both in terms of quantity and value). Capelin is also harvested by the fleet, but landed quantities of capelin vary considerably. Total value of landings per vessel has been increasing steadily over the 1994 – 2005 period, from an average of 12.6 million in 1994 to 41.3 million in 2005 (nominal NOK), an increase of approximately

[7] The calculations are based on data from 2002. With an exchange rate of 6.5 NOK/USD, these amounts are equivalent to USD 146-214 mill.

Figure 1: Fleet development, 1994-2005: Engine horsepower, tonnage, vessel age, and the number of vessels



226%. Over the same period, landed quantity per vessel doubled. Consequently, the large increase in operating revenues is also a result of an increase in the average price obtained for the fish landed.[8]

3.2 The data set

Data have been obtained from the Norwegian Directorate of Fisheries and are based on their annual surveys of costs and revenues of fishing vessels. In addition to cost and revenue data, the data set contains information on other variables such as catch quantities and values by species, physical vessel characteristics, annual investment, and

[8]The rate of inflation was low over the period 1994-2005 (on average 2% per year). Consequently, there was a significant increase also in real output prices.

the capital value of the vessel. Data on investment and capital value are only available from 2001, and I therefore focus on the five-year period 2001-2005. In addition, the Directorate of Fisheries has made a complete data set of quota holdings per vessel available.

In the Directorate's annual survey of costs, revenues, and profitability, a random sample of vessels is surveyed every year. The share of vessels that take part in the survey has increased over the last decade from approximately 35% of the population in the mid-1990s, to approximately 80% from the late 1990s. Consequently, data are available for most vessels every year during the study period.

To complete the investment data series it was necessary to calculate the value of new investment in cases where new vessels were not surveyed in their first year. This was done based on data on when the vessel was built, the value of the vessel in subsequent years, and a capital depreciation formula. A similar method was used to estimate the value of vessels transferred between companies in the industry in cases were survey data were not available. After filling in the gaps according to this procedure, all investments in new and used vessels during the 2001-2005 period were identified.[9]

Many vessel owners in this fishery control more than one vessel. As investment decisions are expected to be made at the owner level, data were aggregated over vessels by owners. To do this, information on the firm(s) controlling each vessel in the data set was checked up against the public Register of Company Accounts (RCA) in order to trace the persons, or in some cases large companies with numerous shareholders, that own each vessel (i.e., identifying those on top of the ownership hierarchy). Based on the findings it was fairly easy to identify different groups of owners. Vessels for which the same person or group of people had the majority share were grouped. The average number of vessels per owner group over the period is 1.3, and consequently most groups are small.[10]

The data show that many vessels are transferred between firms operating in the fleet. Actions that would not have been evident if focusing on vessel level data can easily account for the majority of investments occurring in the industry. Upgrades of existing vessels only account for a small share of the total investment in the firms over the period 2001-2005. To conduct reliable analyses of investment, it is crucial that the analysis is carried out at the level where the investment decision is actually made. Capital investment is perhaps the most important decision of a firm, as it determines the future of the firm as well as the scale of operations. It is therefore reasonable to assume that such decisions are made at the firm level, although it may be correct to assume that smaller investments are dealt with at the vessel level.

The data set does not contain all desirable information on all variables since each vessel is surveyed approximately 80% of the years. Some information is still available for every year, such as the physical characteristics of the vessel. Nonetheless, most economic data are missing in the instances where a vessel was not surveyed. To fill in these gaps in the survey data set, the multiple imputation method was used (Rubin,

[9] As data on actual payment for new/used vessels are not available, there is a potential problem of measurement error. However, the estimates are expected to be reasonably close to the actual values.

[10] In the following I use the terms firm, owner, group, and owner group interchangeably to refer to the owner group as defined here.

1976, 1987). Multiple imputation is a technique that relies on Monte Carlo simulations to replace missing values in a dataset by a (small) number of simulated values. When using the simulated and complete datasets in estimation, inference is obtained by analysing each dataset by standard methods, and then combining the results to produce estimates and confidence intervals that account for missing-data uncertainty.[11]

The panel structure of the data set is taken advantage of when imputing missing values. This is done by using information on a vessel from other years in addition to information from that specific year when imputing missing values. Five replicates of the data were created. After creating the five sets of imputed values for missing values in the vessel level data set, the data were aggregated over firms.[12]

It should be noted that as the owner-level data set is constructed by aggregating data over vessels, the variables only cover the activity of the firms in the purse seine fishery. In some cases, these firms also operate in other industries and other fisheries. Thus, the data set only accounts for the purse seine activity of the firm.[13]

Before turning to the empirical analysis, I present the main variables to be used in the empirical model. The focus of the empirical analysis is on explaining what drives investment in physical capital and in quota units. The variables to be explained are *F.InvPhysCap*, which is the lead of the variable *InvPhysCap* (investment in physical capital), and *FD.Quota*, which is the lead of the change in the total holding of quotas (*Quota*).

The explanatory variables are taken from the theoretical model outlined above. Unfortunately, data on some model variables are not readily available. This is the case for input factor prices and the price obtained for quota units. However, although input prices *per se* are not available, the total expenditures by cost type are. Based on this, two input prices are constructed; a fuel price per operating day and a proxy for labour costs. The latter was defined as the share of total revenues that is paid directly and indirectly to the crew (salary and other social costs). Such proxy for the cost of labour makes sense as the share system of remuneration is used in the fishery. Consequently, the crew is paid a certain share of the total value of landings.[14] The input price proxies for fuel and crew remuneration are denoted *FuelDay* and *SalaryShare*, respectively.

As neither the value of traded quotas nor good proxies of their value are available, investment in and holdings of quota are measured in number of quota units, not value.

[11] The main alternative to multiple imputations is to drop observations with missing data. However, to analyse investment it is important to have complete data on several consecutive years. By dropping all observations for which data are missing, much information is lost. Furthermore, as the vessel level data are aggregated to firm-level data, observations would also have to be dropped in cases where data are missing on one or more vessel within the firm. Hence, the method of multiple imputations is preferred as it makes it possible to keep all the information available in the original data set, in addition to accounting for the missing-data uncertainty.

[12] The Stata module ICE (Royston, 2004, 2007) is used to impute multiple values for the missing observations in the data set.

[13] This implicitly means that the empirical analysis below is based on the assumption that investment in the purse seine fleet is independent of other firm activity.

[14] If instead remuneration was based on e.g. wage per unit of labour supplied, the labour proxy used herein would not be suitable.

PhysCap is the value of physical capital (Directorate of Fisheries estimate), and, as mentioned above, *Quota* refers to the total holding of quota units. For each firm there are optimal levels of the two capital stock variables (that may change over time). Most likely a gradual approach to the optimal level is preferred.[15] In an attempt to account for this, the square of the two variables are also included in the empirical model (*PhysCapSQ* and *QuotaSQ*).

The sizes of the targeted fish stocks should also be included. The availability of fish affects both how much each quota unit entitles one to catch, and the costs of harvesting. Instead of including several different biomass variables, a stock index is constructed and included in the model (*StockInd*).[16] The variables *pherring*, *pmackerel* and *pother* are output prices (average price obtained by firm over the year) for herring, mackerel, and all other species, respectively. The variable *IntRate* is the the nominal Norwegian Inter Bank Offered Rate (NIBOR) as reported by Norges Bank, which is used as a proxy for the interest rate the firms face. Furthermore, according to the theoretical model, output levels may impact investment. This is accounted for by including *qtot*, which is the total quantity of fish landed, as an explanatory variable in the empirical model. The variable *debt* is the value of the firm's total debt. This is controlled for in the model as capital markets may not be perfect and therefore the debt of the firm may restrict investment possibilities.

With this in place, I turn to the empirical analysis.

4 Empirical analysis

Using the aggregate, firm-level data set introduced above, drivers of investment can now be investigated. The causal effect of the model can be analysed by estimating the reduced form of the theoretical model outlined above. The estimated model is a linear approximation of the first-order conditions for investment in physical capital and in quota units (equations 7 and 8) from the problem presented in (6), and is of the form:

$$I_{it} = \alpha_1 + \beta_1 X_{it} + \rho_{1i} + \epsilon_{1it} \quad (9)$$

$$J_{it} = \alpha_2 + \beta_2 X_{it} + \rho_{2i} + \epsilon_{2it}, \quad (10)$$

where I_{it} and J_{it} are investment in physical capital and quotas by firm i in year t, respectively, and X_{it} is a vector of explanatory variables. In both equations α represents a constant term, β is a vector of coefficients, ρ is an owner specific constant term, and ϵ is the error term. The vector of explanatory variables, X_{it}, should include all relevant variables from the optimisation problem of the owner as presented above, as well as other exogenous variables that must be controlled for. Recall that variables from the optimisation problem of the owner include prices of inputs, outputs and capital (both

[15] This is because the solution to the underlying dynamic optimisation problem is the most rapid approach path only in the special case of linear controls.

[16] The stock index is the weighted average of current stock sizes relative to the largest stock sizes for North Sea herring, Norwegian spring-spawning herring, and mackerel, respectively, over the 2001-2005 period. Each species' share of total value by firm were used as weights, and the stock index therefore varies both over time and by firm.

quotas and physical capital), depreciation and interest rates, current stocks of capital, which also includes natural capital (fish stocks), and production levels. The estimation procedure is described in detail below.

The time period from one decides to invest until one can start using the new capital (e.g. a new vessel) may be several years. Depending on the delivery lag, the appropriate number of lags of decision variables should be included in the model. Whereas some investment decisions are likely to be realised soon after the decision is made, such as vessel upgrades or quota acquisitions, other investment decisions may have a longer time horizon, such as acquiring a new vessel. In the empirical model, lagged values of variables are included to account for this. Lags of one and two periods are included. Thus, the model accounts for delivery lags by allowing for the decision to acquire a vessel becoming operational from year $t + 1$, to have been taken in years t, $t - 1$ or $t - 2$. This should be sufficient to identify the decision drivers in the fishery in question (Bjørndal & Conrad, 1987).[17]

The two investment equations to be estimated are likely to be related. Consequently, systems estimation could yield a gain in efficiency. However, when using systems estimation, any misspecification in one equation will affect both equations. Furthermore, it is difficult to correct for autocorrelation in the panel data model when using systems estimation. For these reasons, and because there are no cross-equation constraints, single-equation estimation is used for each of the two equations. The resulting estimates should then be consistent, but may not be as efficient as if systems estimation had been used.

Multiple imputation estimation results are shown in tables 1 and 2 (see Li et al., 1991, on making statistical interference from multiple imputed data sets).[18] The empirical models in tables 1 and 2 differ only in the lag structure.[19]

Table 1: Estimation results, one lag

	Physical Capital Investment		Quota Investment	
	Coeff.	(Std. error)	Coeff.	(Std. error)
PhysCap	-0.317	(0.217)	0.00000296	(0.00000365)
PhysCapSQ	9.41e-10	(7.16e-10)	-1.17e-14	(8.36e-15)
Quota	4499.4	(13941.2)	-1.072**	(0.223)
QuotaSQ	-7.080	(8.023)	-0.0000324	(0.000104)
StockInd	-4174534.1	(37662693.5)	543.6†	(306.4)
pherring	-1521940.6	(5214108.3)	-4.855	(67.89)
pmackerel	-2735107.8	(4771132.3)	-154.7*	(68.76)

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[17]A potential problem of including several lags of variables in the empirical model is that the value of the variables in period t could be correlated with the corresponding values in period $t - 1$, which could cause multi-collinearity issues. This is investigated below.

[18]All multiple imputation estimates presented below are calculated using the Stata package MIM (Carlin et al., 2008).

[19]The notation *L*.VAR and *L2*.VAR indicate first and second lag of a variable, respectively. The notation VAR*MAX* refers to the maximum value of the variable across vessels owned by the same firm.

	Physical Capital investment		Quota investment	
pother	4533335.7	(4419577.3)	85.86	(51.63)
FuelDay	-416.2	(1302.7)	0.0165	(0.0173)
SalaryShare	-72071577.5	(85795405.4)	-879.8	(1249.1)
IntRate	-14536628.6	(125415246.2)	1886.2†	(1030.6)
debt	-0.199†	(0.109)	0.00000100	(0.00000114)
qtot	0.841	(0.654)	-0.0000244*	(0.0000105)
AgeVesMAX	1413484.0	(1110268.3)	40.87**	(12.80)
L.pherring	433636.0	(5488988.9)	-24.36	(99.78)
L.pmackerel	-4665918.8	(8586831.0)	-35.17	(114.9)
L.pother	5246246.4	(10899809.6)	-57.60	(164.2)
L.FuelDay	2758.4	(1632.3)	0.0224	(0.0186)
L.SalaryShare	23638354.1	(71972311.6)	-346.2	(1261.5)
L.qtot	-0.382	(0.285)	-0.00000211	(0.00000514)
N	195		195	
Hausman χ^2	34.479		40.833	
Fixed or random effects	FE		FE	
R-Sq within (min, max)	(0.264, 0.311)		(0.719, 0.723)	
R-Sq between (min, max)	(0.003, 0.008)		(0.217, 0.235)	
R-Sq overall (min, max)	(0.018, 0.030)		(0.180, 0.183)	

Significance levels: † *0.10, * 0.05, ** 0.01*

Table 2: Estimation results, two lags

	Physical Capital Investment		Quota Investment	
	Coeff.	(Std. error)	Coeff.	(Std. error)
PhysCap	0.00308	(0.139)	0.00000363	(0.00000427)
PhysCapSQ	1.00e-10	(2.97e-10)	-2.07e-14†	(9.90e-15)
Quota	16468.2†	(8985.1)	-1.503**	(0.394)
QuotaSQ	-5.921	(3.728)	-0.00000774	(0.000204)
StockInd	-25093754.4	(33364501.7)	8085.8†	(4429.0)
pherring	-188015.9	(10052807.5)	143.5	(233.3)
pmackerel	-7257423.7	(5940069.2)	-138.9	(158.9)
pother	1286782.1	(2533514.6)	101.4	(83.63)
FuelDay	-339.3	(705.7)	0.000295	(0.0408)
SalaryShare	-76756441.3	(52774034.6)	-1081.1	(2677.3)
IntRate	-94422155.5	(115029399.8)	28460.3†	(15599.0)
debt	-0.0871	(0.0604)	0.00000229	(0.00000180)
qtot	0.0124	(0.288)	-0.0000223	(0.0000188)
AgeVesMAX	103106.9	(158129.7)	22.40	(19.51)
L.pherring	-57138.2	(5553128.1)	348.0	(301.1)
L.pmackerel	-3340538.4	(7152189.1)	-35.36	(179.4)

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	Physical Capital Investment		Quota Investment	
L.pother	7546436.2	(8402647.8)	130.9	(309.4)
L.FuelDay	679.3	(898.8)	0.0453	(0.0400)
L.SalaryShare	-20906044.2	(44787547.6)	-232.2	(2887.1)
L.qtot	-0.131	(0.247)	-0.00000822	(0.00000937)
L2.pherring	906858.4	(7479775.3)	222.5	(223.2)
L2.pmackerel	10601559.2	(8713759.3)	172.3	(241.0)
L2.pother	-469221.7	(4730393.9)	-31.36	(285.0)
L2.FuelDay	-1185.1	(775.8)	0.0250	(0.0377)
L2.SalaryShare	7528391.0	(56775902.5)	443.8	(3014.8)
L2.qtot	0.392	(0.363)	-0.00000698	(0.0000113)
N	128		128	
Hausman χ^2	19.873		312.560	
Fixed or random effects	RE		FE	
R-Sq within (min, max)	(0.133, 0.196)		(0.908, 0.915)	
R-Sq between (min, max)	(0.217, 0.242)		(0.322, 0.337)	
R-Sq overall (min, max)	(0.178, 0.199)		(0.190, 0.204)	

Significance levels: † *0.10, * 0.05, ** 0.01*

The choice of estimator is determined using the following procedure. After estimation of a basic model, several tests are carried out. First, a Hausman test of fixed versus random effects is performed. The estimation result tables specify whether fixed or random effects estimators are used, along with the test statistic of the Hausman test. Second, a modified Wald statistic for groupwise heteroskedasticity following Greene (2000, p. 598) is calculated for each of the imputed data sets.[20] Firm-specific error variance is the most likely source of heteroskedasticity in the model, and I therefore test for this. Test results suggest that groupwise heteroskedasticity is a problem in both of the estimated equations (physical capital and quota investment). Finally, the Wooldridge test for autocorrelation in linear panel data models is carried out (Wooldridge, 2002, pp. 282–283). Again, the test statistic is calculated for each of the imputed data sets, and the test results suggest that autocorrelation should be controlled for.[21] All estimates are corrected for first-order autocorrelation. Furthermore, the estimator is robust to groupwise heteroskedasticity.

Some variables from the maximisation problem of the fishing firm (equation 6) are not included in the empirical model presented herein. One of these variables is the so-called quota factor ($\bar{Q}_t$), which is determined for each species every year and gives

[20] This was done using the Stata module xttest3 (Baum, 2000).

[21] The test statistics for groupwise heteroskedasticity and autocorrelation are calculated for each of the imputed data sets, and the null hypotheses (homoskedasticity and no autocorrelation, respectively) were rejected at the 5% level for all five imputed data sets. Notice also that due to the reduction in degrees of freedom when including two lags of variables in the model, these tests were only carried out for the one-lag specification (cf. table 1).

the allowable catch of a species per quota unit. The quota factors are highly correlated with stock variables and are left out to avoid problems of multi-correlation.[22]

The user cost of capital is an important determinant of investment. The user cost of capital consists of interest and depreciation on the stock of capital. An interest rate variable is included in the model, but depreciation is not. Capital depreciation is left out because only an estimate of the variable is available from the Directorate of Fisheries and the algorithm used to estimate depreciation depends on other variables already included in the empirical model.

In an attempt to account for changes in quota price over time since the market value of quota units is not available, indicator variables for year were included in the estimation. However, Wald tests confirm that the indicator variables were not significant, and the inclusion of these variables did not have any noticeable impact on other parameter estimates. The year dummies are therefore not included in the empirical models presented herein. This does, however, not necessarily mean that the number of quota units is a perfect proxy for the value of quota capital.

The estimation results presented in tables 1 and 2 show that the overall explanatory power of the models is relatively low. In the one-lag model, the overall R^2 is under 20% for physical capital investment and ca 20% for quota investment. However, the within R^2 of the quota investment model is high (72% and 91% for the two specifications, respectively). This suggests that investment in quota is highly dependent on the owner. In other words, owner specific factors, beyond the economic factors accounted for in the model, drive investment. Thus, two owners that are identical in terms of economic variables such as profitability, size, etc., may still choose completely different investment strategies. Furthermore, total production is limited by the firms' quota holdings, which determine the firm's relative size in the industry and also affect to what degree the physical capital can be employed. Investment in physical capital and quota should be proportional in the longer run, although short run differences may occur.

Another striking result is that few economic variables have a significant impact on investment. Some variables do, however, affect investment significantly. First, total quota holdings is both economically and statistically significant (10% level) in three of four estimated equations. Quota holdings is seen to have a positive impact on physical capital investment and a negative impact on quota investment. The negative impact of quota holdings on quota acquisition indicates that those holding the most quota units are most reluctant to expand further, which suggests that there are limits to how much firms want to or are able to expand within the industry.[23] The positive relationship between quota holdings and investment in physical capital may suggest that the fishery was not in a situation where physical capital and quotas were at optimal long-run levels over the period 2001-2005. Rather, physical capital seem to have adjusted upward to match quota levels. Then, the more quota units a firm has acquired, the more physical capital is needed in order to make full use of the quota. Another interpretation of this

[22] Estimating the models with these variables included does not significantly change the results.

[23] There are certain owner restrictions in place that, among other things, limit how and and to what extent one person can be involved on the owner side of fishing vessels. This could explain why there are limits to how much owner groups can expand within the industry.

finding is that relatively large firms (as measured by quota holdings) invest more in physical capital.

The firm's total debt seems to have a negative impact on investment in physical capital. This could indicate that there are imperfections in the capital market, and that firms with more debt have a harder time financing their investments in the industry than firms with less debt, all else equal. Notice that debt has no significant impact on quota investment. This difference in the impact of debt on investments in quotas and physical capital could be explained by financial institutions considering quotas better securities for loans than fishing vessels. As already mentioned, fishing capital is far from perfectly malleable. Eythórsson (1996) found that after the introduction of ITQs in Icelandic, the fisheries experienced a boost of new capital, which was mainly explained by the new possibility of using quotas as security for loans.

The age of the oldest vessel of the firm, *AgeVesMAX*, is seen to have a significant, positive effect on quota investment in the one-lag model. The coefficient of this variable is still positive in the two-lag model, although it is not significantly different from zero. The estimated coefficients of the *AgeVesMAX* variable are high and positive for investment in physical capital, but are not significant. Still, it is possible that the the significant relationship between vessel age and quota investment is related to firms with older vessels being more likely to replace these vessels and in doing so also acquiring more quota units, which are oftentimes transferred together with vessels.

Output price is significant in one of the four estimated equations. The price of mackerel is found to have a significant, negative impact on the investment in quota (5% level). Neither first nor second lags of other output price variables are significant. A possible explanation is autocorrelated price series and that the estimates are affected by multi-correlation (since several lags of variables are included). Correlations between different price series within year are lower than correlations within price series over time. The possible effect of this is further investigated below (cf. table 4). The signs of the coefficients of the output price variables are as expected in most cases (i.e., positive signs), but more so in the quota investment models than in the physical capital investment models. This is independent of what lag of the output prices is considered.

Similarly, none of the input price variables are found to affect investment behaviour significantly. The estimated coefficients for the input price variable *SalaryShare* are, as expected, negative in both the physical capital and the quota models (tables 1 and 2). The higher the share of revenues the firm has to pay the crew, the lower the expected, future revenues of the firm. This, in turn, makes it less desirable to invest in the industry. This is in line with the results of Hannesson (2000), who concludes that the share system may lead to biased incentives for investment in fishing vessels.[24] Looking at the signs of the coefficients of the *FuelDay* input price variable, they are correct (negative) in the physical capital investment model, but not in the quota investment model. However, none of these coefficients are significantly different from zero.

[24]Another possible explanation is that firms with relatively large vessels, which on average has a lower *SalaryShare*, invest relatively less than firms with smaller vessels (and higher *SalaryShare*). However, looking at vessel-level data, the correlation between *SalaryShare* and variables such as vessel tonnage and total value of landings show only low to moderate correlation. The corresponding correlations based on firm-level data are even lower.

The stock index is found to have a significant positive impact on investment in quota. This implies that the firm invests more in quota when stock levels are high, which seems reasonable. The effect on physical capital investment is not significant, but the estimated coefficient is negative. Alternatively, one may expect that the agents in the industry act based on their expectations of what is the "normal" stock level, and that they do not care as much about short-term fluctuations when making their long-run decisions, such as investing (or disinvesting) in new vessels. The difference between the physical capital and quota models in terms of the effect of changes in stock size could also indicate that agents think differently about the two types of capital. Quotas are likely more easily traded as the purchase value is fairly close to the sales value. The main difference between sales and purchase values is the quota deduction (20%) described above, which means that for each quota unit a seller sells, the buyer only gets (and pays for) 0.8 quota units. For physical capital the difference between purchase and sales value is likely to be much higher since the second-hand value of vessels and other production capital typically is much lower than the cost of acquiring new production capital. Consequently, investment in physical capital is not as easily reversed as investment in quota. This can explain why firms when considering investment in quota take short-term stock fluctuations into account, whereas when considering physical capital investment, the focus is on long-run stock levels and short-term stock fluctuations are less important.

In many bioeconomic models, capital dynamics are assumed to depend on the profits obtained per firm. A period of high profits is typically assumed to lead to investment in capital, whereas low or negative profits leads to disinvestment (see e.g. Smith, 1969; Wilen, 1976; Bjørndal & Conrad, 1987). This is based on the assumption that current profits are good indicators of future profits. A profit variable *per se* is not included in the empirical model presented above. Instead, the various components of the profit function are included, such as input and output prices, quantity produced, etc. However, few economic variables are found to significantly affect investment. The empirical model was also estimated with an aggregate profit variable replacing the disaggregate values for first and second lags presented above (*L.*VAR and *L2.*VAR). However, replacing the lagged, disaggregate profit variables with lagged values of profit do not significantly affect the results. See table 3.

Table 3: Estimation results, aggregate profits

	Physical Capital Investment		Quota Investment	
	Coeff.	(Std. error)	Coeff.	(Std. error)
PhysCap	-0.155	(0.278)	0.00000212	(0.00000393)
PhysCapSQ	8.57e-10	(9.22e-10)	-1.17e-14	(1.36e-14)
Quota	-5872.8	(30462.0)	-1.559**	(0.350)
QuotaSQ	-11.37	(12.05)	0.0000843	(0.000167)
StockInd	470617552.1	(322301495.1)	$6729.5^{\dagger}$	(3701.6)
pherring	167680.7	(8656213.8)	40.53	(157.1)
pmackerel	-12213099.4	(12044873.8)	-159.4	(167.1)

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	Physical Capital Investment		Quota Investment	
pother	7799704.8	(5630520.3)	85.61	(75.01)
FuelDay	-1536.0	(1485.2)	-0.00779	(0.0192)
SalaryShare	-95390427.9	(119201046.8)	-1045.7	(1371.0)
IntRate	1.65699e+09	(1.13964e+09)	23777.9†	(13081.0)
debt	-0.200†	(0.112)	0.00000243	(0.00000169)
qtot	1.110	(1.321)	-0.0000198	(0.0000146)
AgeVesMAX	1018654.9	(1365542.4)	20.61	(13.83)
L.Profits	-0.135	(0.655)	0.00000129	(0.00000768)
L2.Profits	0.547	(0.748)	0.00000292	(0.0000119)
N	128		128	
Hausman χ^2	21.796		27.626	
Fixed or random effects	FE		FE	
R-Sq within (min, max)	(0.411, 0.457)		(0.886, 0.894)	
R-Sq between (min, max)	(0.078, 0.093)		(0.342, 0.351)	
R-Sq overall (min, max)	(0.021, 0.025)		(0.235, 0.249)	

Significance levels: † *0.10, * 0.05, ** 0.01*

Comparing the models with one and two lags, little seems to be gained by adding a second lag of the variables. In fact, Wald tests of whether all lagged variables are equal to zero support this for all four estimated equations. This could indicate that the time horizon is short from investment is considered and the decision is taken, until the new capital is in place. Whereas it may not take long from a decision to acquire more quota units is made until the new quota units are available, this seems less likely to be the case when investing in physical capital. A large share of the investments in physical capital is investment in vessels. The delivery lag of used vessels may be relatively short, but contracting a new vessel and waiting for it to be built and put into operation take longer. According to the Directorate of Fisheries, the number of new vessels that started operating in the purse seine fishery in the years 2000-2004 were six, five, four, seven, and four, respectively. This is a fairly high number given that there was a total of ca 90 vessels in the fishery (cf. figure 1). Thus, it seems unlikely that only what happens the year prior to new capital becoming operational drives investment, as this implies unrealistically short delivery lags.

Following the reasoning that some investment decisions are realised sooner than others, I wanted to explore whether it made a difference if it is assumed that it takes longer from deciding to invest in physical capital until the new capital is operational than what is the case for quota capital. This would imply that when investing in quota that becomes available for use in period t, one has already made a decision about investment in physical capital that becomes available in period t. Thus, investment in physical capital at time t (i.e., additions to the physical capital stock in period t) can be used as an explanatory variable in the quota investment model. However, including physical capital investment as an additional explanatory variable in the quota investment model does not affect the results significantly.

Another possible explanation for the lack of significance of lagged model variables is that there is correlation between a variable and its lagged values, which are also included in the model. This is investigated further by re-estimating the investment equations only including lagged values of the explanatory variables. The results are shown in table 4.[25]

Table 4: Estimation results, only lags

	Physical Capital Investment		Quota Investment	
	Coeff.	(Std. error)	Coeff.	(Std. error)
L.PhysCap	0.148	(0.157)	-0.00000634	(0.0000128)
L.PhysCapSQ	-3.51e-10	(4.66e-10)	1.48e-14	(3.48e-14)
L.Quota	9158.0	(10605.3)	0.452	(1.109)
L.QuotaSQ	0.444	(3.958)	-0.000327	(0.000403)
L.StockInd	43576067.6†	(24433995.7)	940.7	(1291.5)
L.pherring	381463.2	(4217486.6)	-128.1	(721.1)
L.pmackerel	-3101226.5	(4748784.2)	-56.30	(489.8)
L.pother	9521474.5	(9126851.1)	-609.5	(659.4)
L.FuelDay	1115.1	(945.0)	0.0543	(0.0838)
L.SalaryShare	-59222015.1	(48575459.0)	3389.4	(4525.4)
L.IntRate	147840794.7†	(82957302.1)	3357.3	(4121.3)
L.debt	-0.0409	(0.0471)	0.000000189	(0.00000734)
L.qtot	-0.507	(0.376)	0.0000549†	(0.0000293)
L.AgeVesMAX	218479.0	(167406.8)	-6.774	(36.97)
L2.pherring	-5029419.3†	(2851230.9)	-136.6	(521.9)
L2.pmackerel	10097097.2	(7903917.2)	171.5	(412.0)
L2.pother	-3699190.3	(4459969.3)	-108.4	(551.6)
L2.FuelDay	-1317.8	(889.3)	0.0104	(0.0629)
L2.SalaryShare	-39025031.4	(51420221.0)	2576.7	(3971.0)
L2.qtot	0.274	(0.331)	0.00000582	(0.0000255)
N	128		128	
Fixed or random effects	RE		FE	
R-Sq within (min, max)	(0.233, 0.256)		(0.398, 0.417)	
R-Sq between (min, max)	(0.026, 0.062)		(0.081, 0.130)	
R-Sq overall (min, max)	(0.133, 0.145)		(0.001, 0.005)	

Significance levels: † *0.10, * 0.05, ** 0.01*

Only including lags of the variables does not change the results much, although now some lagged versions of the variables become significant. Furthermore, the signs of the coefficients are similar to what was presented in tables 1 and 2. The results therefore

[25]The models are estimated using the same estimators (fixed or random effects) as above to make the results comparable to the estimation results presented above.

suggest that correlation between different lags of the same variables may cause lagged variables to appear insignificant (cf. tables 1 and 2), particularly in the physical capital equation. Consequently, delivery lags are not necessarily as short as indicated by the results in tables 1 and 2.

One may suspect that the lack of significant economic explanatory variables for investment to some extent may be a result of having included (too) many explanatory variables in the estimated equations. To investigate this, simplified versions of the base models presented in tables 1 and 2 are estimated. In the simplified models, the three output prices *pherring*, *pmackerel*, and *pother* are replaced by the average output price (*OutputPrice*), and the two input prices *FuelDay* and *SalaryShare* are replaced by the average operating cost per operating day (*OpCostDay*). The results are presented in tables 5 and 6. Although the number of explanatory variables has been reduced significantly, the results are very similar to the results of the original models. The estimated coefficients are similar both in signs and magnitude to the coefficients of the base models. There are some minor changes in what coefficients are significant. First, the lagged input price (*L.OpCostPerDay*) is seen to have a negative and significant impact on investment in physical capital. Second, *L2.qtot* is found to have a significant negative effect on quota investment (10% level). There is, however, no large increase in the number of significant economic explanatory variables. Hence, the result that few economic variables are important drivers of investment in the industry is confirmed.[26] Furthermore, the fact that some of the lagged variables now are significant supports that delivery lags are longer than one period, that is, that what happens further back in time than the period prior to new capital becoming operational affects investment.

Table 5: Empirical results, one lag, parsimonious model

	Physical Capital Investment		Quota Investment	
	Coeff.	(Std. error)	Coeff.	(Std. error)
PhysCap	-0.250	(0.236)	0.00000272	(0.00000385)
PhysCapSQ	8.07e-10	(6.03e-10)	-1.13e-14	(9.27e-15)
Quota	4869.5	(14413.8)	-1.084**	(0.237)
QuotaSQ	-8.276	(8.190)	-0.0000603	(0.000118)
StockInd	-10180596.3	(29575044.7)	220.4	(270.7)
OutputPrice	2953214.3	(7192241.6)	-67.96	(100.8)
OpCostPerDay	67.78	(247.5)	-0.00244	(0.00433)
IntRate	-35426993.5	(100722000.8)	786.2	(917.1)
debt	-0.191†	(0.108)	0.00000116	(0.00000121)
qtot	0.749	(0.793)	-0.0000209†	(0.0000119)
AgeVesMAX	1821339.2†	(1088043.5)	41.98**	(12.97)
L.OutputPrice	60020.7	(4709489.0)	-45.76	(89.74)
L.OpCostPerDay	578.3†	(334.9)	0.00338	(0.00606)
L.qtot	-0.250	(0.274)	-0.000000374	(0.00000650)

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[26]The simplified models were also estimated including dummy variables for year, but none of the coefficients of the dummy variables were significantly different from zero.

	Physical Capital Investment	Quota Investment
N	195	195
Hausman χ^2	22.283	37.185
Fixed or random effects	FE	FE
R-Sq within (min, max)	(0.218, 0.253)	(0.682, 0.689)
R-Sq between (min, max)	(0.002, 0.005)	(0.212, 0.220)
R-Sq overall (min, max)	(0.013, 0.018)	(0.173, 0.177)

Significance levels: † *0.10, * 0.05, ** 0.01*

Table 6: Empirical results, two lags, parsimonious model

	Physical Capital Investment		Quota Investment	
	Coeff.	(Std. error)	Coeff.	(Std. error)
PhysCap	-0.0741	(0.342)	0.00000254	(0.00000395)
PhysCapSQ	1.04e-09	(8.31e-10)	-1.48e-14	(9.02e-15)
Quota	-14297.0	(25370.0)	-1.567**	(0.322)
QuotaSQ	-3.109	(10.93)	0.0000570	(0.000158)
StockInd	490659086.1	(372310398.2)	8146.1†	(4114.9)
OutputPrice	3606707.4	(6852241.9)	-110.7	(98.29)
OpCostPerDay	-521.0	(517.0)	-0.00371	(0.00652)
IntRate	1.73961e+09	(1.32009e+09)	28941.4†	(14583.7)
debt	-0.141	(0.120)	0.00000282	(0.00000166)
qtot	0.636	(1.447)	-0.0000235	(0.0000176)
AgeVesMAX	874321.4	(1409234.1)	24.35†	(13.32)
L.OutputPrice	8122000.8	(16091273.1)	-147.8	(146.0)
L.OpCostPerDay	151.0	(822.4)	0.00514	(0.0114)
L.qtot	0.439	(0.763)	-0.00000243	(0.00000846)
L2.OutputPrice	4098761.2	(15395171.2)	-132.7	(186.0)
L2.OpCostPerDay	-148.2	(694.2)	0.00568	(0.00983)
L2.qtot	0.934	(1.023)	-0.000000643	(0.0000123)
N	128		128	
Hausman χ^2	26.635		52.819	
Fixed or random effects	FE		FE	
R-Sq within (min, max)	(0.403, 0.433)		(0.888, 0.896)	
R-Sq between (min, max)	(0.096, 0.119)		(0.356, 0.360)	
R-Sq overall (min, max)	(0.029, 0.037)		(0.220, 0.230)	

Significance levels: † *0.10, * 0.05, ** 0.01*

5 Vessel-level analysis

For comparison and to emphasize the difference between vessel level and owner level analyses of investment, the firm-level model presented above is estimated using the disaggregate, vessel level data set. Both the procedure and the model specifications are the same, but the data set is different. Since there are no longer more than one vessel per observation, the variable *AgeVesMAX* that refers to the maximum vessel age over all vessels owned by the same owner is replaced by the variable itself (*AgeVes*). As above, first-order autocorrelation is controlled for and groupwise heteroskedasticity robust estimators are used. Below I give a brief presentation of the results from the vessel-level analysis.

It should be noted that the left-hand side variables in the vessel and owner level equations for physical capital investment do not measure the same investments. Consequently, a comparison of the two models' statistical power is problematic. The majority of physical capital investments accounted for at the vessel level is vessel upgrades. In the owner level data set, however, the majority of investments is trade in vessels.[27] The quota investment variable, on the other hand, is the same independently of whether vessel level or owner level data are used.

Contrary to when the investment model was estimated at the owner level, Hausman test results indicate that the random effects estimator is inconsistent in both physical capital equations, and, consequently, the fixed effects estimator is used. There is no indication of fixed effects in the estimated quota equations. This is interesting as fixed firm-specific effects were found to be very important in the firm-level analysis of quota investment.

Table 7: Empirical results: Vessel-level data, one lag

	Physical Capital Investment		Quota Investment	
	Coeff.	(Std. error)	Coeff.	(Std. error)
PhysCap	0.00885	(0.0938)	-0.000000223	(0.000000602)
BookValSQ	2.000	(1.781)	-0.00000953	(0.0000122)
Quota	-11731.4	(20897.0)	-0.379**	(0.0997)
totbquotaSQ	28.53	(27.92)	0.000197†	(0.000105)
StockInd	8642637.1	(8852949.0)	-103.1	(84.76)
pherring	-652454.4	(1479067.9)	12.39	(26.26)
pmackerel	-58469.4	(1970378.9)	11.02	(19.22)
pother	1294579.6	(1978069.9)	9.341	(24.45)
FuelDay	37.99	(557.9)	-0.00681	(0.00465)
SalaryShare	9579986.7	(38852248.3)	-327.0	(385.2)
IntRate	29266693.0	(29280861.0)	-357.0	(283.2)
debt	0.0162	(0.0711)	0.00000110**	(0.000000320)

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[27] Using vessel-level data, many of the investment decisions in the industry are not identifiable. An example of such unidentifiable investment is the (common) situation of a vessel being sold from one firm to another while continuing to operate in the fishery.

	Physical Capital Investment		Quota Investment	
qtot	-0.519	(0.481)	0.00000175	(0.00000366)
AgeVes	-70309.5	(486271.9)	1.011	(1.873)
L.pherring	-761069.9	(2900469.1)	12.07	(29.35)
L.pmackerel	1219701.5	(2307568.9)	32.77	(40.07)
L.pother	1020624.3	(2430023.0)	2.378	(39.90)
L.FuelDay	-965.6*	(463.6)	0.00792†	(0.00444)
L.SalaryShare	-23581609.5	(29269242.7)	5.548	(283.3)
L.qtot	0.436	(0.363)	-0.00000324	(0.00000375)
N	243		243	
Hausman χ^2	29.302		9.833	
Fixed or random effects	FE		RE	
R-Sq within (min, max)	(0.193, 0.206)		(0.188, 0.202)	
R-Sq between (min, max)	(0.052, 0.087)		(0.228, 0.243)	
R-Sq overall (min, max)	(0.125, 0.141)		(0.158, 0.168)	

Significance levels: † *0.10, * 0.05, ** 0.01*

Table 8: Empirical results: Vessel-level data, two lags

	Physical Capital Investment		Quota Investment	
	Coeff.	(Std. error)	Coeff.	(Std. error)
PhysCap	0.0871	(0.145)	-0.000000936	(0.00000108)
BookValSQ	1.356	(2.135)	-0.00000841	(0.0000211)
Quota	-29456.0	(19646.1)	-0.431**	(0.131)
totbquotaSQ	53.75†	(31.02)	0.000137	(0.000132)
StockInd	19382944.8	(25063004.1)	-72.85	(134.3)
pherring	-1999822.0	(3444102.2)	-27.10	(64.57)
pmackerel	4384912.8	(3220864.4)	11.63	(30.71)
pother	4256742.7	(3381208.5)	33.78	(29.75)
FuelDay	217.2	(826.7)	-0.00701	(0.0102)
SalaryShare	9359069.8	(33879978.9)	-618.2	(597.6)
IntRate	69383920.1	(84307651.0)	-262.0	(485.6)
debt	0.0437	(0.0832)	0.00000171**	(0.000000566)
qtot	-0.602	(0.741)	0.000000292	(0.00000601)
AgeVes	656606.8	(624135.3)	2.194	(2.882)
L.pherring	959082.0	(6403341.3)	31.28	(55.24)
L.pmackerel	6905170.9†	(3666257.0)	44.09	(53.63)
L.pother	5252810.2	(8740862.5)	-165.4*	(79.39)
L.FuelDay	-1502.3	(914.6)	0.00651	(0.0103)
L.SalaryShare	-13029015.3	(30463967.3)	-302.9	(492.8)
L.qtot	0.339	(0.415)	5.41e-08	(0.00000642)
L2.pherring	-1743704.0	(5640388.9)	-22.68	(47.34)

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	Physical Capital Investment		Quota Investment	
L2.pmackerel	-1154523.5	(4464663.6)	-31.92	(70.00)
L2.pother	2185458.3	(4576050.0)	40.77	(70.48)
L2.FuelDay	-1079.7	(826.6)	0.0129†	(0.00655)
L2.SalaryShare	17276999.1	(33765146.5)	444.5	(684.7)
L2.qtot	1.181†	(0.698)	-0.00000840	(0.00000708)
N	146		146	
Hausman χ^2	42.995		17.944	
Fixed or random effects	FE		RE	
R-Sq within (min, max)	(0.621, 0.642)		(0.431, 0.478)	
R-Sq between (min, max)	(0.027, 0.054)		(0.136, 0.179)	
R-Sq overall (min, max)	(0.142, 0.161)		(0.240, 0.262)	

Significance levels: † *0.10, * 0.05, ** 0.01*

The results from the estimation of the vessel-level versions of the models are presented in tables 7 and 8. The explanatory power is lower when using vessel-level data, with the exception of the two-lags model for investment in physical capital. This may indicate that smaller investments, such as vessel upgrades, which is what the investment variable mainly consists of in the vessel-level data set, at least to some degree depend on vessel-level variables. Furthermore, few economic variables are significant. There are nonetheless some exceptions.

The vessel-level estimation results confirm the importance of total quota holdings as an important determinant of quota investment. This variable is significant at the 10% statistical level in all estimated equations, independently of the level of analysis (firm or vessel). Total quota holdings seem to have a negative effect on investment in physical capital in the vessel-level model, although the coefficients are not significant. In contrast, the results based on owner-level data show a positive effect of this variable on investment in physical capital. It should be noted that a firm with several vessels may allocate the allowable catch according to total quota holdings over its vessels. Thus, care must be taken when interpreting the point estimate for the quota variables in the vessel-level analysis.

Another variable that was found to drive investment in the owner-level analysis is debt. In the vessel-level analysis, the point estimates of the debt variable are positive both for investment in physical capital and for quota investment. However, only the quota equation coefficients are significant. The lack of significance of debt in the physical capital equation seems reasonable, as if capital availability is constrained, it is the firm's total debt that is important, not the debt of the vessel. Still, for several of the firms in the data set, there is no difference between the two, as the firm only owns one vessel. The finding that debt has a significant and positive effect on quota investment may be a result of analysing firm-level decisions using vessel-level data. If a firm seeks to gradually expand their share in the industry (c.f. firm-specific effects from firm-level analysis), it may have already invested in quotas (and/or physical capital) assigned to other vessels belonging to the firm. This could explain a relatively higher debt level for all its vessels.

As was done above in the firm-level analysis, simplified versions of the base models are estimated also here. The results are shown in tables 9 and 10. The definitions of the variables are as above. The results from estimating the simplified models are very similar to the results from the full models. Two differences worth noticing is that the estimated coefficient of the quota variables in the two-lag physical capital equation now are significant at the 10% level, and that total production (*qtot*) becomes significant in the one-lag physical capital equation. However, the estimated coefficients of these variables are not significantly different from the coefficients of the full models. Comparing the simplified vessel-level models to the corresponding firm-level models, the same conclusion can be drawn as when comparing the full models: despite some similarities, the results from the vessel-level analysis are generally different from the results of the firm-level analysis.

Table 9: Estimation results: Vessel-level data, parsimonious model, one lag

	Physical Capital Investment		Quota Investment	
	Coeff.	(Std. error)	Coeff.	(Std. error)
PhysCap	-0.0200	(0.107)	-0.000000674	(0.00000225)
PhysCapSQ	2.198	(1.694)	-0.0000265	(0.000615)
Quota	-10979.2	(19998.3)	-0.999**	(0.224)
QuotaSQ	25.92	(25.94)	0.000257	(0.000187)
StockInd	3941805.6	(6120311.7)	-118.2	(106.4)
OutputPrice	-5041380.5	(3200393.1)	26.30	(72.04)
OpCostPerDay	110.8	(144.2)	-0.00173	(0.00299)
IntRate	13447577.1	(20941892.9)	-375.9	(357.9)
debt	0.0125	(0.0700)	-0.000000275	(0.000000517)
qtot	-1.002†	(0.528)	0.00000445	(0.0000108)
AgeVes	-186964.9	(488590.6)	39.36	(88.57)
L.OutputPrice	2732266.0	(4262617.8)	-14.93	(78.45)
L.OpCostPerDay	-249.2*	(116.3)	-0.00165	(0.00325)
L.qtot	0.431	(0.408)	0.00000192	(0.00000980)
N	243		243	
Hausman χ^2	33.270		15.390	
Fixed or random effects	FE		FE	
R-Sq within (min, max)	(0.197, 0.212)		(0.354, 0.363)	
R-Sq between (min, max)	(0.054, 0.086)		(0.073, 0.092)	
R-Sq overall (min, max)	(0.132, 0.153)		(0.044, 0.048)	

Significance levels: † *0.10, * 0.05, ** 0.01*

Table 10: Estimation results: Vessel-level data, parsimonious model, two lags

	Physical Capital Investment		Quota Investment	
	Coeff.	(Std. error)	Coeff.	(Std. error)
PhysCap	-0.0117	(0.0544)	-0.00000116	(0.00000105)
PhysCapSQ	1.572	(1.288)	-0.0000279	(0.0000178)
Quota	-20295.8†	(12253.4)	-0.389**	(0.124)
QuotaSQ	38.16†	(19.46)	0.000138	(0.000137)
StockInd	7253853.9	(8932820.0)	-106.1	(117.0)
OutputPrice	-1433025.6	(1512386.3)	54.09	(50.90)
OpCostPerDay	71.58	(127.1)	0.00128	(0.00241)
IntRate	25412095.8	(32213219.2)	-332.7	(413.0)
debt	-0.0228	(0.0527)	0.00000167**	(0.000000603)
qtot	-0.376	(0.396)	0.00000441	(0.00000529)
AgeVes	99453.9	(95887.8)	0.368	(3.055)
L.OutputPrice	3331127.9	(2658035.8)	-43.59	(64.02)
L.OpCostPerDay	-170.0†	(92.66)	0.000319	(0.00319)
L.qtot	0.370	(0.273)	0.00000135	(0.00000769)
L2.OutputPrice	1158870.0	(3932426.0)	-43.80	(56.89)
L2.OpCostPerDay	-118.3	(121.0)	0.00304	(0.00202)
L2.qtot	0.407	(0.535)	-0.0000116†	(0.00000641)
N	146		146	
Hausman χ^2	-0.165		5.622	
Fixed or random effects	RE		RE	
R-Sq within (min, max)	(0.406, 0.458)		(0.384, 0.408)	
R-Sq between (min, max)	(0.173, 0.186)		(0.115, 0.137)	
R-Sq overall (min, max)	(0.291, 0.300)		(0.218, 0.228)	

Significance levels: † *0.10, * 0.05, ** 0.01*

Despite some similarities, the main findings from the owner-level analysis are not replicated when analysing the vessel-level data. The importance of fixed firm effects that was discussed above cannot be found using data on the vessel level. Some of the variables were found to be important in both models (*Quota* and *debt*), but not even for these variables were the impact on investment in quota and physical capital consistent between the two models (owner and vessel level). Drawing conclusions based on vessel-level analysis about how fishing firms react to changes, such as increased input or output prices or to specific regulations, may therefore yield false conclusions. The severity of this issue depends on the owner structure in the industry in addition to at what level investment decisions are in fact made in the particular industry.

Finally, the fact that there is no evidence of vessel level fixed effects on investment behaviour supports one of the main conclusions from the firm-level analysis, namely that fixed effects on investment are (only) at the owner level.

6 Discussion

Based on the empirical results it is striking how few economic variables are found to have a significant impact on investment. Thus, only relying on the variables typically used in economic models of investment does not suffice to explain the variation in investment in the industry. Particularly in the case of quota investment, which in fact is the determinant of a firm's share of production in the fishery, are owner specific effects found to be important.

Some economic drivers of investment were also identified. First, the firm's stock of quota capital was seen to affect both investment in physical capital and investment in quota units. The more quota units a firm holds, the higher the investment in physical capital and the lower the investment in quota. Second, the point estimates of the physical capital coefficients are approximately zero in most cases. This may suggest that for most firms, the quota investment happened prior to investment in additional physical capital. If this is in fact the case, quota investment drives investment in physical capital, as the two must correspond in the longer run.

A third variable that is found to significantly affect investment is the total debt of the firm. Interestingly, total debt has a significant, negative impact on investment in physical capital in most model specifications, while it has no impact on investment in quota. A plausible interpretation of this is that quota capital is seen as a better security for loans than production capital. In that case, it would be easier to finance investment in quota than investment in physical capital. This is consistent with the findings of Eythórsson (1996) and also with the observation that fishing capital is far from perfectly malleable.

Fourth, the estimated coefficients of the input price proxy for crew remuneration were consistently negative for physical capital investment, although not significantly different from zero. This is in line with the results of Hannesson (2000), and can be explained by the fact that the higher the share of total value paid to the crew, the lower the future cash flows of the owner. Since the owner, and not the crew, invests and carries the cost of the investment, lower investments result from higher shares paid to the crew.

Another interesting finding is that a large share of the variation in quota investment can be explained by firm-specific effects. This means that after controlling for all the (economic) variables included in the empirical model, other firm-specific factors have a significant effect on investment. Thus, two firms that are identical in terms of production and profitability, may consistently choose completely different investment strategies. There are several possible explanations for this. First, different owners may have different expectations about the future profitability of the industry. Those with relatively high expectations will then have a higher willingness to pay for shares of future total production (quota units). There is a large literature on expectations and asset pricing. Smith et al. (1988) use asset price experiments and find that even in their fairly simple setting, there is significant risk of bubble formation. The case of the fishery is far more complex than a stylised lab experiment, and it follows that the expectations of the agents may lead to quota prices that are too high or too low, both relative to the actual, underlying value and relative to the believes of individual agents.

Secondly, firm-specific effects may be due to differences in risk aversion. It is often assumed that firms are risk neutral as they may use capital markets to hedge against risk. However, it is not necessarily the case that all agents operating in this industry are sophisticated enough to fully hedge against all risk nor that they have the same risk preferences. As risk preferences affect the willingness to pay for quotas that entitles one to uncertain future payoffs, this may explain some of the firm-specific effects, since a firm's preference to risk does not change much over time.

A third possible explanation for why firm-specific effects are important is related to the drastic change seen in this particular industry in recent years. The development has gone from owner-operated fishing vessels (i.e., one vessel per owner), to larger units that in many cases are managed from shore.[28] It seems plausible that the skills (and interests) that were required of a successful fishing-firm owner some years ago, are not the same as what is required today. Thus, the change of the organisation and nature of the fishery may have led some agents to want to increase their share in the fishery, whereas others reduced their share or simply ignored the development and continued with business as usual.

Finally, there may be norm-based drivers of investment. It is possible that among different groups of people there exist different attitudes to trade in quota units, etc. If a purse-seine firm is located in an area with relatively high resistance amongst people to the concept of quotas being transferable, it may very well be that going against this by investing in quotas comes at a relatively higher personal cost to the owners of the firm.[29] Similarly, if ones neighbour suddenly goes ahead and invests and increases the scale of his/her operations, this alone may be an incentive for oneself to do the same thing. Thus, there may be social factors in play that causes groups of agents to act in similar manners, perhaps by forming each others expectations of the future of the fishery, but also in terms of what is the 'appropriate' investment strategy. In a recent paper, Akerlof (2007) discusses what he refers to as the missing motivation in macroeconomics. He mentions several normative factors that may affect the behaviour of firm managers, and he also specifically discusses the case of investment.

Without more information on the different owners operating in the industry it is, however, not possible to do more than speculate as to why firm-specific effects are so important for investment in the industry and what these effects represent. Regardless of why firm-specific effects seem to be crucial to understanding investment behaviour, this insight is interesting as it goes against the arguments typically used to explain quota trade in such industries. The standard explanation offered by economists as to why, following the introduction of transferable production quotas, certain firms increase (decrease) their share of total production, is that the more cost efficient firms buy quotas from the less efficient firms. The empirical results presented herein suggest that there is little or no difference in efficiency or profitability between firms that increase and firms that decrease their share of total production (by buying or selling

[28]Notice, though, that the regulations of vessel ownership and the owner's activity level have not changed significantly. Still, it is possible to be exempted from this, and there are also other ways to deal with this in order to operate in the fishery as a larger unit.

[29]The attitudes to quota transferability and the establishment of private property rights in fisheries seem to vary considerably along the coast of Norway.

quota units). Rather, other firm-specific factors are important in explaining firm-level investment behaviour.

Finally, a note on the dynamic aspect. The quota price should take into account future resource rents, which means that for those in the industry who had to buy quota units to get access to the fishery, their earnings may not be much higher than what is considered normal earnings in other industries. Many firms have paid far less than the current market value for their quotas. Still, the opportunity cost of the quotas should be taken into account. It seems reasonable to assume that over time, economic performance and profitability must play a greater role in the firms' investment decisions, as the firms operating in the industry are forced to take into account the opportunity cost of their quota. This also implies that the industry was not at its long run equilibrium level over the study period (2001-2005). Over time, more and more of the agents in the industry will have had to pay the full cost of their quotas (discounted value of all expected future resource rents), and in such situation there is far less room for not focusing on profitability and economically efficient decision making.

7 Concluding remarks

The purpose of this study was to answer the question of what drives investment in a well-managed fishery with well-defined property rights. Data on the Norwegian purse-seine industry covering the years 2001-2005 were used to empirically investigate this. The investment activity in the industry was considerable over this period, and with the fairly recent introduction of the unit quota system that to a certain degree opened up for trade in quota units, the industry makes an interesting case study.

The empirical analysis shows that economic variables with few exceptions are not important determinants of investment in this industry. However, the analysis shows that a large share of the variation in investment can be explained by firm-specific effects. This is particularly the case when looking at investment in quotas. Thus, to understand what drives firm-level investment, one must focus on firm-specific factors and not merely look at economic variables including the economic performance of the firm.

The paper also provided a vessel-level empirical analysis of investment. The results show that using vessel-level data may lead to significantly different conclusions about investment behaviour, when each firm in the industry may own or operate more than one vessel. Thus, it is important to carry out the analysis at the appropriate level of aggregation.

The focus of the paper was on a well-managed fishery, and particularly on what drives investment and capital dynamics in such fishery. Indeed, the finding that traditional economic variables seem to be of little importance in explaining investment can perhaps be explained by the fact that this fishery is well-managed. With no tax on resource rents one can realise large rents in a well-managed resource industry that add to the normal earnings. The fact that many firms in the industry made above normal profits due to resource rents over the study period, may have enabled them to not have to focus only on economic performance when making investment decisions. If they wanted to invest, they had the financial liberty to do so, and they could therefore afford not to let current economic conditions dictate their behaviour. In a longer time perspective, however, most firms would have to pay the full price of their quotas, which includes the present value of all expected future resource rents.

The results presented in the paper also has important policy implications. First, there are the consequences in terms of what incentives and regulations to use to motivate certain actions by the firms. Clearly, if economic incentives are not strong determinants of behaviour, such incentives would be less effective than what is usually assumed. Second, the results imply that whether and how much a firm increases or decreases its share in the fishery depend on firm specific effect, rather than economic factors. Hence, it is not necessarily the case that the most efficient firms remain in the industry while the less efficient firms sell out upon the introduction of transferrable production quotas in an industry. Third, the empirical results suggest that it may in fact matter whether quotas are auctioned off rather than grandfathered, as auctioning forces the firms to take into account the full opportunity cost of the quotas and thereby act in a more economically efficient way. Thus, auctioning may be more efficient than grandfathering if firms earn above-normal profits, which is typically the case in natural resource industries. Furthermore, this result contradicts the Coase theorem, which states that efficiency is independent of the initial allocation of quotas (Coase, 1960).

The analysis presented herein identifies drivers of investment in the industry, as was the objective of the study. However, the analysis also raises new questions, and many of these are yet to be answered. There are therefore many possibilities for further work. Clearly, a more thorough analysis to identify the firm-specific effects, as discussed above, is necessary to fully understand investment behaviour in the industry. This calls for collection of qualitative data, e.g. through interviews or similar techniques, as the economic data already obtained do not suffice to explain the observed variation in investment. Another interesting question that arises is related to the finding that the economic variables typically used in such models do not explain much of the variation in investment. Is the Norwegian purse-seine industry a special case, or are there perhaps other factors that should generally also be taken into account, in addition to the traditional economic factors, when explaining firm-level investment in well-managed resource industries?

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