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RESEARCH ARTICLE

Do efficient small-scale fishers stay active in eras of introducing individual transferable quotas? Evidence from Denmark

Ayoe Hoff*, Max Nielsen and Rasmus Nielsen

Department of Food and Resource Economics, Faculty of Science at the University of Copenhagen, Rolighedsvej 25, DK-1958 Frederiksberg C, Denmark

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Abstract – Theory suggests the use of individual transferable quotas (ITQs) as a solution to overcapacity and to keep efficient fishers active. While the reduction of overcapacity under ITQ implementation is well documented, empirical evidence on the role of capacity utilisation in adjusting the labour force is scarce. This article analyses whether the capacity utilisation of the vessels that fishers own/work on influences their probability of continuing fishing or whether factors such as fishing income and pension are more important. Danish small-scale fisheries with vessels less than 17 m in length, in which ITQs were introduced in 2007, are studied using a multinomial logit regression based on a unique dataset of individual income and socioeconomic characteristics of Danish fishers in the period 2002-2012 as well as individual vessel data. Together with other relevant socioeconomic variables, vessel capacity utilisation is included in the regression. The latter is identified in a productivity analysis of all commercial active vessels using Data Envelopment Analysis. It is found that increasing vessel capacity utilisation both significantly and positively influences the decision to stay in a small-scale fishery. Increasing income from fisheries also significantly influences the probability of staying in the fishery business. The Danish results provide evidence that the most efficient fishers are those who remain active when ITQs are implemented.

Keywords: Fisheries / ITQs / capacity utilisation / logit model / stay-leave decision

1 Introduction

Based on the increasing introduction of individual transferable quotas (ITQs) in fishery management, an important question arises: Which factors influence a fisher's decision to stay in a fishery instead of leaving? Economic theory dictates that capital is aggregated and consolidated on the most efficient vessels after an initial adjustment phase following the introduction of ITQs. Thus, it can be argued that a prominent factor influencing whether a fisher (owner or hired) stays in or leaves the trade is the performance of the vessel on which the fisher works, i.e., to which degree the vessel utilizes its full capacity potential. On the other hand, other factors may also influence a fisher's decision to stay in the fishery, e.g., the absence of alternative job opportunities and specialist skills as well as the fishers' lifestyle preference for their job. Some of these factors correlate with the performance of the vessel on which the fisher works, while others are independent of vessel performance and may even counteract the influence of vessel performance on a fishers' decision to stay in or leave the fishery. If the latter is the case, fishers on vessels with lower capacity utilisation may remain in the fishery and thus maintain these vessels in the fishery. This will, in effect, undermine the ability of the ITQ system to improve welfare compared to other management systems, although some benefits of reduced capacity might remain. Thus, knowledge of whether it is fishers working on/owning the best performing vessels that remain active in the fishery following the implementation of ITQ reforms improves the foundation for introducing such fishery policy reforms.

The purpose of this paper is to identify the main reasons why small-scale fishers stayed in or left the Danish demersal fishery after the introduction of ITQ management in 2007. A unique dataset covering all Danish fishers who owned or were hired by commercial active small-scale vessels in the 2002–2012 period was used for the analysis. Factors influencing the decision to stay or leave are identified using a multinomial logit regression, including income from fisheries and other sources together with performance, represented by full capacity utilization of the vessels the fishers own/work on as explanatory variables.

Factors influencing the efficacy of ITQ systems in fisheries are studied in three dimensions in the literature, all focusing on

*Corresponding author: ah@ifro.ku.dk

what influences whether the operating unit, i.e., the vessel, remains in or exits the fishery. The first dimension departs from Costello and Deacon (2007), who show how heterogeneity of fish stocks, varying distance from fishing grounds to ports and differences in fish density both geographically and over time prevent the marginal fishing costs for operators (vessels) from becoming equivalent, i.e., prevents an economically optimal allocation of quotas, thus reducing the efficiency of the ITQ system.

The second dimension focuses on the factors that induce deviations from the optimal adjustment path, thus delaying rent capture and inducing a larger-than-optimal fleet size under ITQs. Weninger and Just (1997) analyse ITQ implementation under uncertainty and find that fishers may keep cost-inefficient vessels active longer than necessary because they are waiting for higher quota prices. Moreover, barriers to the entry or exit of vessels also affect efficiency. Clark et al. (1979) show that when exit restrictions exist in the form of constraints on disinvestment of capital, there will be excess capacity in the fishery in the short run. Furthermore, Vestergaard et al. (2005) find that 'sunk costs and a firms' entry-exit decision in a traditional deterministic investment model may give an explanation of the slow transition to the optimal fleet structure following the introduction of ITQs'. Thus, non-malleability of capital delays rent capture and induces a larger-than-optimal fleet size. In contrast, Scott (1955) and Gordon (1954) focus, for an unregulated fishery, on entry with positive profits and exit at negative profits, implicitly assuming free entry-exit.

The third dimension combines productivity analysis with logit estimation. Felthoven (2002) uses a logit model to estimate whether pre-rationalization efficiency and capacity utilisation influenced the likelihood of a vessel staying in the fishery following the introduction of the American Fisheries Act in the Bering Sea pollock fleet. The results indicate that the most efficient vessels are the most likely to stay. Brandt (2007) estimates the probability that a vessel exits after ITQs in the Mid-Atlantic surf clam fishery and then uses this estimated probability to determine vessel efficiency. The results indicate that the most inefficient vessels were the most likely to exit. Finally, Schnier and Felthoven (2013) jointly estimate technical efficiency and the decision to stay in or exit the fishery with rationalization in the case of the Bering Sea and Aleutian Island crab fisheries. The results indicate that technical inefficiency is a significant and positive predictor of vessels exiting the crab fishery. Moreover, the entry-exit decision of vessels is studied empirically by Ward and Sutinen (1994) and Pradham and Leung (2004), who estimate multinomial logit models of the entry-exit decision in two fisheries: the Gulf of Mexico shrimp fishery and the Hawaiian longline fishery. Ward and Sutinen (1994) find vessel entry or exit to be independent of stock variability but strongly affected by crowding externalities, while Pradham and Leung (2004) find that resource abundance is significant, as is vessel earning potential.

While the above studies focus on factors affecting whether a fishing vessel remains in or exits a fishery given ITQ reforms, other studies focus more generally (i.e., independent of management reforms) on the individual fisher and discuss factors influencing efficient wage formation in fisheries. Anderson (1980) argues that non-monetary benefits ('worker satisfaction bonuses') can lead to fishers accepting low wages. Likewise, Pollnac et al. (2001) show that factors other than economic considerations can keep small-scale fishers in the Philippines, Indonesia and Vietnam in trade. For example, fishers stay in fishing because fisheries are an easy source of food and thus they do not need to buy food, tradition, and simply 'job satisfaction'. Pita et al. (2010) show that the willingness to move to occupations other than fisheries depends not only on economic factors for small-scale European fishers (exemplified by Scottish, Portuguese, and Greek small-scale fishers) but also on attachment to the trade (Portuguese fishers) and the community (Greek fishers), and that fishers who especially value the community (Scottish fishers) are more willing to change occupations to stay in the fishery. Likewise, Marshall et al. (2007) observe that a strong attachment to the fishing industry may prevent fishers from seeking other occupations, independent of the resource or economic basis for the fishery trade. Conversely, Cooley and Doney (2009) note that the workload in fisheries is high and the job is dangerous, making high wages necessary to attract fishers.

The above studies suggest that factors not expected to be directly correlated with vessel performance may influence a fisher's decision to stay in or leave the fishery. However, none of these studies combines the analysis with how the fisher's decision to remain in or leave the trade is influenced by the performance of the vessel the fisher works on compared to the other vessels in the fishery and how large this influence is compared with other factors. As such, this study is the first to provide knowledge on individual fishers' decision-making under reforms, where socio-economic factors and relative vessel performance, measured through overall capacity utilisation, are simultaneously included in the analysis of what will influence a fisher's decision to remain in or leave the fishery, following an ITQ reform.

The paper is organized as follows. In Section 2, the Danish case is described, and in Section 3, the multinomial logit model is developed in combination with DEA. Sections 4 and 5 provide data and results, while Section 6 contains a discussion of the results and concludes the article.

2 Fisheries management in Denmark

Since 1982, the European Common Fisheries Policy has formed the regulatory framework for Danish fisheries (Holden and Garrod, 1996). Total allowable catches (TACs) are agreed to annually in the Council of Ministers after receiving a recommendation from the European Commission. The TACs are allocated to each member state automatically using a fixed proportion of the single country's catch of each stock based on the relative stability principle. The common fisheries policy further states the rules for technical conservation measures, such as mesh size restrictions and minimum size limits. Total days at sea limits are also determined at the EU level. Finally, the EU provides partial funding for national fishery subsidies that, over time, have been used for new vessels, the modernization of vessels and decommissioning.

The quota and subsidy allocation to individual fishers are the responsibility of the individual member states (Holden and Garrod, 1996). Before 2003, the regulation of all fisheries in Denmark was performed using command and control instruments. The fishery was regulated by weekly and monthly individual non-transferable quotas (Capacity Directive no. 124

of 7 February 2004; Regulation Directive no. 1028 of 11 December 2003). To enter this system, a licence was needed. Rations on days at sea were also in force for the individual vessels, and subsidies were continuously provided to aid capacity reductions, either through decommissioning of fishing vessels or modernization/technology improvements. However, means were also provided to improve logistics for harbours and processors to enhance efficiency throughout the value chain. The subsidy scheme was provided under the Financial Instrument for Fisheries Guidance (FIFG) in the European Union from 2000 until 2006 (Danish Ministry of Food, Agriculture and Fisheries, 2007).

In the 2000–2001 period, it became apparent that the earnings in the sector were low, resulting in huge deficits in the commercially active fleet as a whole after interest and remuneration to owners had been paid (Statistics Denmark, 2002). Substantial overcapacity existed, despite the decommissioning subsidies that had continuously been used (Danish Ministry of Food, Agriculture and Fisheries, 2007). While the TAC setting and fish stock management remained EU-wide responsibilities and management and recovery plans were in force for some fish stocks, something needed to be done at the national level to ensure the earnings and survival of the Danish fishing industry.

On 1 January 2003, ITQs were introduced for herring on a trial basis. Later, ITQs were also implemented for mackerel, and on 1 January 2007, they were introduced for the entire Danish fishery with the vessel quota share system (Danish Ministry of Food, Agriculture and Fisheries, 2005). The commercial active small-scale vessels less than 17 m in length analysed in this paper are regulated by Vessel Quota Shares. All quotas were allocated to the owners of individual vessels using a grandfather principle based on historical catches (Høst, 2015). Each vessel achieved a permanent proportion of the Danish quotas; thus, when the Danish quotas were established, fishers knew their annual allowed landings. In principle, these fishing rights provided an infinite right to fish, although the system included an 8-year notice period (Fisheries Act no. 978 of 26 September 2008). Quotas, both permanent quota proportions and annual quotas, were and continue to be fully transferable between all vessels without limitations, with the exception that one person cannot own an excessively large proportion of each Danish quota to avoid concentration (Fisheries Act no. 978 of 26 September 2008). There are no limitations on transferability, however, either between large and small vessels or between vessels using different gears.

Together with the political agreement implementing ITQs in all fisheries on 1 January 2007, the special treatment of coastal (small-scale) fisheries was agreed upon to ensure the survival of small-scale fishing (Danish Ministry of Food, Agriculture and Fisheries, 2005). However, this agreement postponed the specific design of the coastal fishery arrangement. The coastal fishery arrangement was made voluntary; enrolment was initially only possible for vessels under 16 m in length, which was later changed to 17 m, and only for vessels that made at most 80% of their fishing trips within three days (Nielsen et al., 2013). The fishers that enrolled in the arrangement were allocated minor extra annual quotas for cod and sole in addition to their ITQ (Nielsen et al., 2013). The vessels sign up for the agreement for 1 year and later for 3 years; in this period, they were only allowed to sell permanent quota shares and annual quotas to other fishers in the arrangement (Nielsen et al., 2013). After this period ended, the fishers could sell quotas to all vessels.

This small-scale fishery in Denmark is not protected by quota purchases from larger vessels in the long run. Moreover, Nielsen et al. (2013) find that the extra quotas given to small-scale fishers only result in a small advantage, as they constitute a relatively moderate proportion of the total Danish quotas.

The key numbers for the entire Danish fleet and the small-scale vessels below 18 m are presented in Table 1, revealing the development during the ITQ implementation period.

The total number of commercially active vessels registered fell from 1,409 to 641, corresponding to a decrease of 55% from 2002 to 2012. Vessels in all groups fell, although vessels above 18 m decreased more than smaller vessels below 18 m. The reasons include that the large pelagic vessels had ITQs previously in 2004 and that the stock status of fish for reduction, which is important for medium-sized vessels, had worsened. The total fishing effort, measured in days at sea, decreased by 62%, which is more than the number of vessels because the vessels were used on fewer days per year.

The total turnover of the entire fleet decreased by 23%, and the development was mainly determined by the quotas and prices formed in international markets (Nielsen et al., 2009; Bronnmann et al., 2016). The average vessel turnover increased by approximately two-thirds as a result of larger quotas for the remaining vessels. Total profit increased from 104 to 276 million DKK, with the average profit per vessel increasing nearly fivefold. The rate of return on invested capital, fishing rights excluded, increased from being negative in 2000–2001 to 2.0% in 2002 and 7.4% in 2012. Hence, the economics for fishers improved substantially in the ITQ implementation period.

The development of small-scale vessels below 18 m follows that of the entire fleet, except the average profit per vessel remains largely constant. Possible reasons for this development include that the ITQ system was introduced later for these vessels, the demersal stocks were reduced in the period and the prices of demersal fish, as opposed to pelagic and industrial fish, also fell in the period (Merayo et al., 2018).

Full-time employment fell by two-thirds to 1023 in 2012, which corresponded to a decrease of 2000 persons employed in the Danish fishery. Since the unemployment rate did not increase more in fishing municipalities compared to other areas in Denmark after the ITQ implementation (Merayo et al., 2018), most of these 2000 persons are expected to have found other occupations or to have retired from the labour market. Income increased 13% in nominal terms, but considering inflation, the income level was largely constant. Hence, capital achieved full gain, while labour gained nothing in real terms.

While it has been suggested that ITQs are a main driver of the structural change of Danish fisheries in the period, other factors, such as technological development, fish stock status, fish prices and alternative employment opportunities, also contributed to this development. Nevertheless, there were substantial reductions in fleet overcapacity and employment, while profit gains increased for the entire fleet.

3 Methodology

Logit regression, with the two options ‘stay’ or ‘leave’ as the dependent variables, is used to investigate which factors

Table 1. Key numbers for the Danish fishing fleet, 2002 and 2012, nominal values[1].

	Total			Average per vessel		
	2002	2012	Change (%)	2002	2012	Change (%)
Number of active commercial vessels	1409	641	−55			
<18 m[2]	930	428	−54			
18–24 m	202	74	−63			
>24 m	189	65	−66			
Special fisheries	88	74	−16			
All active commercial vessels						
Days at sea	226 849	85 253	−62	161	133	−17
Turnover (DKK Million)	3738	2867	−23	2.653	4.472	+69
Profit (DKK Million)	104	276	+165	0.074	0.431	+482
Rate of return (% of fishing assets)	2.0	7.4	+270			
Full-time employment	3087	1023	−67	2.2	1.6	−27
Annual average income (DKK)	371 000	418 000	+13			
Active commercial vessels below 18 m						
Days at sea	130 899	53 265	−59	141	124	−12
Turnover (DKK Million)	978	625	−36	1.1	1.5	+39
Profit (DKK Million)	−135	−64	+53	−0.145	−0.150	−3
Rate of return (% of fishing assets)	−11.7	−7.5	+36			
Full-time employment	1326	490	−63	1.4	1.1	−20

Note: 1. The number of vessels includes all vessels registered in Denmark. All other numbers are only for active commercial vessels, with an active commercial vessel in 2012 having an annual turnover of more than DKK 250,000, with this limit being corrected for inflation. Special fisheries include vessels specialized in mussels and horse shrimp. Profit is after interest and remuneration to working owners but before taxes. Rate of return is profit in percentage of assets, excluding the value of fishing rights. FT employment is the number of working days on commercial active vessels divided by 220 days per person. Annual income is known from tax authorities and includes the full income (fishing and other income) of fishermen employed on a Danish fishing vessel for whom more than 60% of their total income comes from fishing.
2. In the published Account Statistics for Fishery, the 18-m length reported is used as the statistical limit between vessel groups. In the empirical analysis performed below, however, 17 m is used as the limit because legally, only vessels below 17 m can participate in the voluntary coastal fishermen arrangement.
Sources: The Danish AgriFish Agency, Yearbook of Fishery Statistics, Statistics Denmark, Account Statistics for Fisheries and special data extraction of tax authorities' registrations of individual persons taxable income employed at Danish fishing vessels. Data are specifically extracted for this article by merging the income statistics of Statistics Denmark with the vessel and landing statistics of the Danish Agri-Fish Agency.

influenced the decision of small-scale fishers to exit the fishing industry. This analysis was performed on a year-to-year basis for the period 2004–2009. For each year, an individual logit regression model was set up and solved. A person is included in the analysis in a given year if that person was a full-time small-scale fisher for the year analysed and for the two preceding years.

A full-time small-scale fisher is defined as a person who is at least 18 years old for whom more than 60% of his total income derives from fishing and for whom more than 50% of his income is earned on a vessel less than 17 m long, regardless of whether he/she owns the vessel or simply works on it as an employee. Moreover, a person is defined as having *left* the small-scale fishery in a given year if he/she *does not* fulfil the requirements for being a full-time small-scale fisher for that year and the two following years, i.e., if his/her income from small-scale fishery is less than 50% of total fishery income for the year in question and the two subsequent years. In contrast, a person is defined as *staying* in the small-scale fishery in a given year if his/her income from the small-scale fishery is larger than 50% of total fishery income for at least one of the 3 years consisting of the year in question and the two subsequent years.

Based on the general reduction of employment in the Danish fishery from 2949 to 961 people (Merayo et al., 2018) between 2002 and 2012 and the corresponding reduction in the number of fishing vessels, which was 63% for the large-scale fleet and 54% for the small-scale fleet, the chance of finding a new job as a fisher was generally poor in the period investigated. Therefore, in the case of a fisher not having worked full-time in the small-scale fishery for two consecutive years, it is assumed that the fisher has left the fishery.

As noted above, the dependent variable in the analysis is a binary choice, either to *stay* (=*0*) or to *leave* (=*1*) the fishery. The probability π_{Leave} of leaving is assessed by logit analysis, where the probability π of leaving the fishery is modelled using the logistic function via several explanatory variables $\overline{x} = (x_1, x_2, x_3, \ldots, x_N)$:

$$\pi_{\text{Leave}}(\overline{x}) = \frac{\exp\left(\alpha + \sum_{i=1}^{N} \beta_i \cdot x_i\right)}{1 + \exp\left(\alpha + \sum_{i=1}^{N} \beta_i \cdot x_i\right)} \tag{1}$$

where α and $\overline{\beta} = (\beta_1, \beta_2, \beta_3, \ldots, \beta_N)$ are parameters of the logistic regression model.

Correspondingly, the odds of leaving, i.e., the fraction between the probability of leaving and the probability of staying, is given by:

$$\Pi(\bar{x}) = \frac{\pi_{\text{leave}}(\bar{x})}{1-\pi_{\text{leave}}(\bar{x})} = \exp\left(\alpha + \sum_{i=1}^{N} \beta_i \cdot x_1\right) \quad (2)$$

The odds may be seen as the number of coastal fishermen leaving for each person staying. In the present context, the continuous variables are included in the model in logarithmic form, i.e., as $\tilde{x} = \log(x)$. In this case, the model given in equation (2) takes the following form:

$$\log(\Pi(\bar{x})) = \alpha + \sum_i \beta_i \cdot log(x_i) \quad (3)$$

Therefore, if x_i is changed by 1%, Π will change by $(1.01^{\beta}-1)\cdot 100\%$. Thus, the larger (or smaller) the coefficient β is, the larger (or smaller) the percentage increase in the odds given a 1% change in the income variables.

The explanatory variables are presented in the Data section below, including the overall (i.e., biased) capacity utilisation of the vessel on which the individual fishers work. Vessel capacity utilisation is estimated using data envelopment analysis (DEA) on a year-to-year basis, as is also the case for the logit analyses. DEA was performed for all included vessels and all gear and length groups. This is done to reflect that quotas can be traded between all vessels, independent of gear type or vessel length, i.e., that the capacity utilisation of one vessel will depend on the performance of the entire fleet, not only on the performance of similar vessels. The vessels that utilize their capacity best would have been able to purchase quotas from all other vessels in the fleet. Biased capacity utilisation is calculated (instead of unbiased capacity utilisation or technical efficiency), i.e., the ranking of the vessels according to observed relative performance each year, given their historically observed inputs and outputs. This is done because the output from the DEA (the biased capacity utilisation) is then used as an exogeneous input to the logit analysis. Moreover, performing the DEA on a yearly basis and assuming that all inputs are fixed (as is the case when estimating capacity utilisation) ensures that the yearly quota restrictions are complied with.

DEA has previously been applied to estimate capacity utilisation and technical efficiency and relate this to fishers' behaviour (Pascoe et al., 2013) and optimal fleet structure (Andersen and Bogetoft, 2007; Tsitsika et al., 2008; Lindebo et al., 2007). A general introduction to DEA can be found in Cooper et al. (2000) and Coelli et al. (2005). In the present case, an output-oriented DEA model, using the yearly aggregate vessel landing value as the output, is applied in accordance with Färe et al. (2000), estimating the overall capacity utilisation score ϵ for each year for each individual vessel:

$$\varepsilon \cdot y_i \leq \sum_{j=1}^{N} \lambda_{i,j} \cdot y_j; \quad i \in \{1, \ldots, N\} \quad (4)$$

$$x_{k,i} \geq \sum_{j=1}^{N} \lambda_{i,j} \cdot x_{k,j}; \quad i \in \{1, \ldots, N\} \quad (5)$$

$$1 = \sum_{j=1}^{N} \lambda_{i,j}; \quad i \in \{1, \ldots, N\} \quad (6)$$

Here, y_i is the output for vessel i (i=f, where N is the number of vessels) and $x_{k,i}$ is the k'th input for vessel i. Equation (6) ensures variable returns to scale.

4 Data

The census data, obtained from Statistics Denmark, include individual and household income data and socio-demographic variables throughout the period 2002–2012 for everyone holding a Danish Civil Registration (CPR) number. The unique dataset covers individuals who have, at some point during the period, obtained income (wages or income from their own enterprise/vessel) from the Danish fishing sector.

The socio-economic data consist of individual information (age, gender, family status, family income, and location of residence) and income information (income from their own enterprise and wage incomes, both specified for branch codes, pension income, social benefit income, and income from stocks and interests). A person is included in the logit analysis in a given year if that person is a full-time small-scale fisher in that year and in the two previous years. Moreover, that person is defined as having left the small-scale fishery in a given year if he/she is not a small-scale fisher in that and the two subsequent years.

The socio-economic dataset has been combined with two other statistical sources. First, the Danish fishing vessel register makes it possible to obtain information on landings and first sales from each vessel. Second, the account statistics for fisheries contain economic information on costs and earnings for the commercial Danish fishing fleet. The account statistic for fisheries only covers vessels with an annual sale of fish of approximately DKK 250 000, which is considered to be operating commercially in contrast to recreational fishers, for which it is difficult to obtain valid economic information. With this threshold, the statistics include more than 98% of landings in Denmark. Thus, in the current context, only persons working on such commercially active vessels are included in the analysis. Therefore, for each year, persons working on commercially active vessels from the socio-economic dataset are coupled with the specific fishing vessels where the income originates. The coupling has been made possible using anonymized Danish Central Personal Register (CPR) numbers for the individuals in the socio-economic dataset, which can be coupled with the origin of their fishery income, i.e., the vessel IDs from the Danish fishing vessel register. Thus, it is possible to identify persons working on different vessels, the fishing pattern of the vessel, the home port of the vessel and where it operates, landings data, and economic account data for the vessel. Moreover, as discussed above, the capacity utilisation, evaluated with DEA, of the vessel on which the person is working can be identified.

Given these definitions, Table 2 shows the number of persons in the final dataset who are in small-scale fisheries in a given year and who leave small-scale fisheries during the following year. For example, in 2004, 540 full-time small-scale fishers were included; of these, 17 left the small-scale

Table 2. Number of full-time small-scale fishermen in each of the years (t) 2004–2009 and the number leaving the fishery in year $t+1$ in each year.

Year (t)	Full-time small-scale fishermen in year = t	Number leaving the small-scale fishery in year = t + 1
2004	540	17 (3.1%)
2005	511	27 (5.3%)
2006	487	36 (7.4%)
2007	384	24 (6.3%)
2008	304	13 (4.3%)
2009	255	10 (3.9%)

Table 3. Descriptive statistics over the period 2004–2009 for the explanatory variables applied in the logit analysis of factors that affect small-scale fishermen's decision to leave the fishery.

Variable	Explanation	Average[1]	Standard deviation[1]	Minimum	Maximum
Occupational status in year t	Classification variable[2] (2 levels), dividing the fishermen into (i) hired fishermen (Occupational status = 1), and (ii) fishermen who do not receive wages but have their own firm (fishing boat) and fishermen who both have their own enterprise and receive wages, where at least one of these (own enterprise and/ or wages) originates from the fishery (Occupational status = 2).	1.78	0.41	1.00	2.00
Log (Wages Fishery$_t$)	The logarithm of the fisher's total income (above the minimum wage) from fisheries in the year, t, before leaving the fishery.	330 763	270 741	−623 241	4 698 329
Log (Wages Fishery$_{t-1}$)	The logarithm of the fisher's total income (above the minimum wage) from fisheries in the year, $t-1$, i.e., 2 years before leaving the fishery.	318 698	219 887	−674724	4 038 740
Log (Wages Other$_t$)	The logarithm of the fisher's total income (above the minimum wage) from other sources than fisheries in the year, t, before leaving the fishery.	4242	18 163	0	294 915
Log (Social Benefit$_t$ + Pensions$_t$)	The logarithm of the income from public services and from pensions in the year, t, before leaving the fishery.	4467	15 441	0	171 949
Log (Family Income$_t$)	The logarithm of the income of the rest of the fisher's family (i.e., excluding his own income) in the year, t, before leaving the fishery (above the minimum income).	194 473	161 634	−617067	1 486 382
Log (Capacity utilisation score in year t)	The DEA capacity utilisation score of the vessel on which the fisher is working in the analysed year.	–	–	–	–

Notes: [1]Averages of the income variables are of the absolute values and not of the logarithm of the variables.
[2]Occupational status is used as a classification variable in the SAS Proc logistic analysis, with the reference level being fishermen having their own firm (level 1). Classification variables need not be established as dummies when using this option in Proc Logistic.
[1+2]Averages and standard deviations are over the total period and thus comprise 2481 observations, cf. Table 2.

Table 4. Vessel averages and standard deviations (in parentheses) of the input (OAL, BT, KwCrew) and output (Val, DKK 1000) variables to the DEA analyses and of the resulting DEA capacity utilisation scores.

		Overall length (OAL (m))	Brutto tonnage (BT)	Engine power * Crew members (KwCrew)	Total value of landings Val (DKK 1000)	DEA capacity utilisation score
2004	All	17.2 (9.5)	79.6 (148.4)	1354.1 (3747.7)	2099.2 (465.9)	0.37 (0.20)
	OAL<17 m	12.0 (2.6)	16.9 (12.2)	296.3 (250.3)	937.7 (89.8)	0.33 (0.19)
2005	All	16.7 (9.4)	76.6 (163.7)	1449.4 (5878.2)	2422.3 (682.9)	0.40 (0.19)
	OAL<17 m	11.9 (2.7)	16.5 (12.5)	271.5 (235.8)	1077.2 (108.4)	0.33 (0.17)
2006	All	16.3 (9.3)	74.1 (177.4)	1386.1 (6010.4)	2781.8 (809.1)	0.37 (0.20)
	OAL<17 m	11.9 (2.7)	16.5 (12.5)	271.5 (235.8)	1077.2 (108.4)	0.33 (0.17)
2007	All	16.5 (9.7)	81.4 (201.4)	1547.1 (6906.7)	2963.1 (819.2)	0.39 (0.22)
	OAL<17 m	11.6 (2.7)	16.3 (12.4)	257.3 (211.3)	1237.6 (130.2)	0.37 (0.20)
2008	All	16.1 (9.3)	76.7 (197.3)	1367.8 (6662.7)	2971.3 (905.8)	0.38 (0.21)
	OAL<17 m	11.9 (2.6)	16.8 (12.6)	251.5 (192.8)	1066.0 (113.4)	0.33 (0.19)
2009	All	16.6 (9.5)	83.9 (225.8)	1483.8 (7189.9)	2839.3 (853.1)	0.43 (0.22)
	OAL<17 m	12.2 (2.6)	18.3 (14.3)	262.2 (191.3)	954.1 (94.4)	0.38 (0.20)

fishery in 2005. It must be noted that a person is considered to be leaving the fishery only if he/she has low activity in the fishery in three consecutive years, as described above.

Table 2 shows a general decline in the number of included full-time small-scale fishers. It is further observed that the fraction leaving the fishery increases towards 2007 and then decreases again. This trend is believed to be caused by the introduction of the ITQ system in the Danish fishery in 2007, which provided an incentive for small-scale fishers to sell their quotas (Merayo et al., 2018).

The explanatory variables included in the logit model and descriptive statistics for these variables over the period 2004–2009 are outlined in Table 3. One variable is a classification variable (‘Occupational status’), which is treated as a dummy variable in the logit analysis. The base case in the logit analysis is a person who owns a fishing vessel and does not receive wages from other sources. The remaining variables are continuous. It must be noted that most explanatory variables are income related and that no demographic variables (e.g., fisher’s age) are included. In earlier versions of the model, demographic variables were included, but all proved to have insignificant parameter values, which is why they have been left out in the present context.

For all continuous variables (i.e., all income variables and the DEA score), the natural logarithm of the variable is used. Moreover, wages from fishing, wages from other sources, and family income have been normalized with regards to the absolute value of the overall minimum (over all persons and years) of the variable plus 1, thus avoiding taking the logarithm of negative numbers (as these income variables can become negative due to a negative surplus from their own enterprises). Thus, ‘WagesFishery’ in Table 3 is calculated as

(Fishery income for the person in question)+|Minimum (Fishery income over all small-scale fishers in all years)|+1.

Two separate logit models were analysed: one with fishery income in year *t* included and one with fishery income in year *t–1* included. Both models include the remaining variables in Table 3. This inclusion was done to analyse the effects of the quota trade between vessels in the years leading to the introduction of ITQ management in 2007.

Moreover, Table 3 displays descriptive statistics of the absolute values (DKK) of the income variables and not of the logarithm of the variables. It is first observed that the sample includes a larger fraction of fishers who have their own firm compared to fishers receiving wages, given that the average occupational status is 1.78. Moreover, the fishers, on average, receive their largest income from the fishery compared with both income from other sources and income from social benefits and pensions. Furthermore, it is observed that a fisher is the family member with the highest income, which is 70% higher on average than the income of the rest of the family. The average of the capacity utilisation scores is not included in Table 3 because several fishers can work on the same vessel, which will bias the average. Unbiased averages of the capacity utilisation scores of the included vessels are displayed in Table 4.

The data used to estimate the capacity utilisation scores are obtained from the Danish fishing vessel register and the statistics on landings. The input variables included in the DEA analysis are the overall length of the vessel (OAL), the vessel size in tonnage (BT), and engine power in Kwh multiplied by the number of crew members (KwCrew) as a measure of effort.

The output in the DEA is the total value of vessel landings within the year (Val), i.e., the market value of the first sale (at harbour auctions) of the landings. First, the landing value was chosen because the individual vessels catch many different species, and including weight measures of each in the DEA would reduce the precision of the estimates. Second, the landings value as output reflects the degree to which an individual vessel can maximize its landings value per used input unit, given the overall quota restrictions and landings prices. The latter may differ from vessel to vessel given that they may land different combinations of fish qualities. Using landings value as output in the DEA reflects this fact as well as to what degree each vessel can target its catch composition towards producing maximum value at minimum costs.

Table 5. Parameter estimates from the logit regression including fishery wages in year *t*, regressing the probability of leaving against the variables indicated in Table 3 (and Eq. (1)). Standard errors of the parameters and variance inflation factors (VIFs) are included. Furthermore, the table displays the % change in probability of leaving the fishery when the explanatory variable changes by 1%.

		2004	2005	2006	2007	2008	2009
Number of observations		540	511	487	384	304	255
Intercept	Estimate	−157.5	−86.53	-207.4^{***}	132.5^{***}	−33.56	-240.1^{**}
	St. error	114.0	63.86	43.29	33.79	129.3	130.1
	VIF	–	–	–	–	–	–
Hired	Estimate	−0.28	0.42	0.04	1.58^{***}	1.76^{**}	−0.21
	St. error	0.76	0.53	0.50	0.49	0.70	1.03
	VIF	1.52	1.30	1.16	1.15	1.32	1.26
Log (Wages-Fishery$_t$)	Estimate	−0.14	−5.85	8.43^{***}	4.64^{***}	2.20	1.19
	St. error	4.42	4.31	1.57	1.68	2.59	6.82
	VIF	1.25	1.13	1.08	1.10	1.14	1.11
	% odds change	−0.14	−5.65	8.75	4.73	2.21	1.19
Log (Wages-Other$_t$)	Estimate	15.46^{**}	13.95	10.56^{***}	7.28^{***}	−0.36	19.84^{***}
	St. error	7.65	4.57	3.31	2.58	11.01	7.27
	VIF	1.01	1.02	1.02	1.05	1.03	1.04
	% odds change	16.63	14.89	11.08	7.51	−0.36	21.82
Log (Social-Benefit$_t$ + Pension$_t$)	Estimate	0.25^{***}	0.21	0.04	0.01	−0.05	0.17
	St. error	0.09	0.06	0.06	0.07	0.11	0.11
	VIF	1.51	1.26	1.18	1.13	1.33	1.18
	% odds change	0.25	0.21	0.04	0.01	−0.05	0.17
Log (Family-Income$_t$)	Estimate	−1.53	0.17	-1.92^{*}	−1.05	0.30	−0.09
	St. error	1.60	1.22	1.16	1.16	0.73	1.63
	VIF	1.01	1.03	1.05	1.02	1.06	1.02
	% odds change	−1.51	0.17	−1.89	−1.04	0.30	−0.09
Log (DEA score)	Estimate	-1.10^{**}	−1.01	-0.99^{***}	-0.60^{*}	-1.74^{***}	-1.81^{**}
	St. error	0.52	0.46	0.37	0.35	0.58	0.91
	VIF	1.27	1.16	1.07	1.08	1.17	1.11
	% odds change	−1.09	−1.00	−0.98	−0.60	−1.72	−1.78

Note: '***'=Significant at the 1% level, '**'=Significant at the 5% level, '*'=Significant at the 10% level.

Lindebo et al. (2007) likewise applied aggregated landings value, albeit for species groups, as output in capacity utilisation measurements and showed that the full (biased) capacity utilisation scores were closely correlated with the scores obtained using landings weights as outputs.

Table 4 displays the averages and standard deviations per vessel of these variables and of the resulting DEA scores. These findings are displayed for the total Danish fleet in each of the analysed years and for the vessels on which the small-scale fishers work, i.e., vessels less than 17 m. Table 4 first shows that the average capacity utilisation scores for the total sample of Danish vessels lie between 0.37 and 0.43. The reason for this relatively low average is that DEA is performed for the entire fleet and not for sub-divisions of the fleet. Thus, given the size difference and the specialization of the vessels, there is a small sub-sample of vessels with high capacity utilisation; however, most of the vessels had considerably lower capacity utilisation. Table 4 shows that this finding applies to the total fleet and to vessels less than 17 m. It should be highlighted that, given that the analysis performed in the present context considers relative capacity utilisation scores, i.e., the relationship between the fleet capacity utilisation and the probability of leaving the fishery, under a system with a free exchange of quotas between all types of vessels, all vessels in the fleet must be included in one DEA. Table 4 also shows that the average landed value per vessel for those under 17 m is approximately 40% of the average landed value per vessel for the full fleet. Similarly, the average length, tonnage and effort (KwCrew) are considerably lower for the sample of small-scale vessels than they are for the full sample.

5 Results

Table 5 displays the results of the logit analysis using the fishery income in year *t*. The table displays the estimated parameters of the logit analysis, the standard error of the parameter, the variance inflation factor (VIF) indicating how much possible collinearity affects the standard error, and finally the percentage change in the odds of leaving, given a percentage change in the explanatory variable. The latter is only displayed for the continuous explanatory variables.

Table 6. Parameter estimates from the logit regression including fishery wages in year *t−1*. Standard errors of the parameters and variance inflation factors (VIFs) are included. Furthermore, the table displays the % change in probability of leaving the fishery when the explanatory variable changes by 1%.

		2004	2005	2006	2007	2008	2009
Number of observations		540	511	487	384	304	255
Intercept	Estimate	411.1	−110.1	461.9	−278.5	−119.5	2584.2***
	St. error	811.6	565.1	569.8	528.2	606.5	972.2
	VIF	–	–	–	–	–	–
Hired	Estimate	−0.24	0.44	−0.56	1.26***	1.75**	0.09
	St. error	0.77	0.51	0.50	0.48	0.70	1.05
	VIF	1.52	1.30	1.16	1.16	1.32	1.25
Log (Wages-Fishery$_{t-1}$)	Estimate	−36.97	−2.12	−38.19	12.42	8.05	−186.9***
	St. error	52.33	37.10	37.62	34.71	39.93	64.98
	VIF	1.23	1.14	1.12	1.15	1.05	1.03
	% odds change	−30.78	−2.09	−31.61	13.15	8.34	−84.43
Log (Wages-Other$_t$)	Estimate	14.46*	12.44***	11.58***	8.62***	−1.02	21.83**
	St. error	7.60	4.55	3.09	2.56	11.19	9.17
	VIF	1.01	1.01	1.01	1.02	1.03	1.01
	% odds change	15.47	13.18	12.21	8.96	−1.01	24.26
Log (Social-Benefit$_t$ + Pension$_t$)	Estimate	0.25***	0.20***	0.15***	0.03	−0.04	0.23*
	St. error	0.09	0.06	0.06	0.07	0.11	0.12
	VIF	1.51	1.25	1.14	1.12	1.33	1.18
	% odds change	0.25	0.20	0.15	0.03	−0.04	0.23
Log (Family-income$_t$)	Estimate	−1.37	−0.05	−1.25	−0.84	0.25	0.28
	St. error	1.58	1.21	1.07	1.14	0.77	1.69
	VIF	1.01	1.02	1.05	1.02	1.05	1.02
	% odds change	−1.35	−0.05	−1.24	−0.83	0.25	0.28
Log (DEA score)	Estimate	−1.37*	−1.11**	−0.64*	−0.53	−1.64***	−1.71*
	St. error	−0.98	0.48	0.38	0.36	0.56	1.01
	VIF	1.24	1.18	1.14	1.13	1.07	1.08
	% odds change	−1.35	−1.10	−0.63	−0.53	−1.62	−1.69

Note: '***'=Significant at the 1% level, '**'=Significant at the 5% level, '*'=Significant at the 10% level.

Table 6 displays similar results but uses the fishery income in year *t–1*, with the remaining parameters being the same as in the analysis displayed in Table 5.

Table 5 first shows that the fisheries income parameter in year *t* is negative in 2005 and changes to positive over the remainder of the period, being significant in 2006 and 2007. Thus, particularly in 2006 and 2007, the probability of leaving the small-scale fishery in 2007 and 2008 is strongly correlated with income from fisheries. In 2006, a 1% increase in fishery income led to an 8.75% increase in the odds of leaving the fishery, while the odds of leaving the fishery increased by 4.73% in 2007 if the income from fisheries increased by 1%. These results suggest that when new opportunities for buying and selling quotas were introduced with the new regulation, fishers increased their income by selling their quota shares when they left the fishery.

Table 6 first shows that with the remaining parameters left unchanged, the effect of fishery income in year *t–1* is negative, except in 2007 and 2008, where it is positive, but not significantly so. Only in 2009 was the parameter negative and significant. Thus, in most years, there is an insignificant correlation between the probability of leaving the fishery in year *t+1* and the wages from the fishery in year *t−1*; in the case where this effect is significant (2009), the probability of leaving the fishery in year *t−1* decreases with the magnitude of the fishery wage in year *t−1*, as would be expected.

The effects of the remaining parameters change to only a small degree between Table 5 and Table 6 and only with regards to the degree of significance and not with regards to the sign or the order of magnitude. Thus, it is first observed from the two tables that the income from other sources is positively and, in most years, significantly correlated with the probability of leaving the fishery in 2004–2007 and in 2009. Thus, the higher the income from other sources in the year before leaving, the higher the probability of leaving in most years, suggesting that the fishers who are leaving may previously have established other working possibilities before leaving. In the years where this effect is significant, it is seen that the odds of leaving increase between 8% and 25% when the wages from other sources increase by 1%.

Income from social benefits and pensions in the year before leaving is positively correlated with the probability of leaving in the years leading to the introduction of ITQs in 2007, indicating that some fishers may have planned to retire after the introduction of the ITQ system when they were able to cash in their quota share and leave the fishery. However, this effect is small compared with the effects from fisheries and other wages and is significant only in some cases. In contrast, family income has no significant influence on the probability of leaving the fishery.

Tables 5 and 6 further show that, compared with small-scale fishers who have their own enterprise, hired fishers have a higher probability of leaving small-scale fisheries in 2007 and 2008. However, as this effect is not significant in all years, this is not viewed as a general tendency.

Finally, the two tables show that the capacity utilisation of the vessel on which the fishers work has a negative and, in most years, significant influence on the probability of leaving the fishery; it is seen that when the capacity utilisation increases by 1%, the odds of leaving the fishery decrease by approximately 1%. This tendency seems logical since Danish fishers are paid using a crew share system and better-performing vessels (having higher capacity utilisation) may therefore be able to pay out higher wages than poorer performing vessels, increasing the possibility of leaving the fisheries if employed on a vessel with low capacity utilisation.

It could be argued that the two effects – the influence of wages and capacity utilisation on the probability that a fisher will leave the fishery – are correlated, given that wages may to some degree be correlated with capacity utilisation. However, this possibility has been ruled out by, in all cases, regressing the dependent 'leave' variable against the explanatory variables using ordinary least squares regression. Furthermore, in connection with this applying collinearity analysis, analysis of tolerance, variance inflation factors (VIF) and condition index were included, none of which displayed signs of severe collinearity between any of the included dependent variables. The VIF factors are displayed in Tables 5 and 6.

6 Discussion conclusions

A multinomial logit model was estimated to explain the stay versus leave decision of individual Danish small-scale fishers during the ITQ implementation period. The probability that a fisher leaves the fishery decreases with increasing capacity utilisation of the vessel on which the fisher is employed; a 1% increase in capacity utilisation leads to an approximately 1% decrease in the odds of leaving the fishery. Thus, the result suggests that fishers working on the best-performing vessels (in terms of capacity utilisation) remain active during the ITQ implementation period. In contrast, there is a positive correlation between the probability of leaving the fishery and income from other branches, pensions, and social benefits. In particular, income from other sources of employment significantly influences the probability of leaving the fishery, given that the odds of leaving increases between 8% and 25% when the wages from other sources increase by 1%, suggesting that even fishers working on efficient vessels may leave the trade for other occupations if this is profitable enough. Moreover, income from the fishery in the year before leaving is strongly positively correlated with the probability of leaving in 2006 and 2007, possibly reflecting a high rate of quota trade around the time of implementation of ITQs in the Danish fishery regulation. As such, it seems that even though the performance of the vessel on which the fisher works has some influence on whether the choice is made to stay or exit the fishery, other factors, especially income from other employment sources, have a higher effect on the decision to stay or leave.

However, the result still indicates that labour has not formed a substantial barrier for achieving efficiency of the Danish ITQ reform for small-scale fishing, given that the lower the capacity utilisation of a vessel is, the more likely it is that fishers working on the vessel will exit the fishery, and the vessel must thus be expected to stop operating. Whether this result can be generalized to other countries or fisheries remains a question, and the answer might differ from case to case, depending on alternative employment and income opportunities, the age composition of fishers and the size of the fishing sector relative to other sectors. Moreover, quota transfer restrictions within the ITQ system may influence the path towards optimal adjustment of an ITQ-regulated fishery (e.g., Hoshino et al., 2020).

However, consolidation and concentration of capital and quotas accompanied by a decline in overall employment, as has been observed in the Danish case, have been seen in several other fisheries managed with ITQs, e.g., in the Atlantic Halibut and Sablefish fishery, in the Australian Southern bluefish tuna fishery, and the U.S. Ocean Quahog and Surf clam fishery (Olson, 2011). In these cases, it can be expected, based on the findings in this paper, that vessel efficiency has been an influential factor in the reduction of employment and thus that the most efficient vessels have remained in operation. In contrast, the Icelandic and New Zealand fisheries governed by ITQs have likewise seen the consolidation and concentration of capital and quotas, accompanied by an increase in employment (Olsen, 2011). In Iceland, increased employment was observed for the total fishing industry and believed to be caused by an increase in labour-intensive vessels outside the ITQ regulations. Thus, in Iceland, a move to other fisheries was observed as the ITQ fleet aggregated, still supporting the theory that fishers on less efficient vessels will leave these if possible. In New Zealand, increased employment was first seen because of the privatization leading to the added value of harvests and second because of governmental efforts to develop and strengthen small-scale inshore fisheries. Again, this is not in conflict with labour staying on the most efficient vessels.

The findings in this paper also reveal important information for evaluating the special arrangement of the Danish coastal fishery. The arrangement is voluntary, where extra annual quotas on cod, sole and plaice are given to vessels under 17 m entering this arrangement. However, the vessels are also bound to stay in the arrangement for three years without being able to sell their quota shares. The purpose is to sustain the Danish small-scale fishery, i.e., the same purpose as for bans on quota trade between small and large vessels in other ITQ-regulated fisheries, such as in Iceland. Since the Danish coastal arrangement allows small-scale fishers to leave the arrangement after three years, they can plan their exit and sell their quota shares to the vessels that can pay the most, whether inside or outside the arrangement. Our findings in this paper indicate that fishers on small-scale vessels with high capacity utilisation remain active, as opposed to an arrangement that does not allow quota trade between all vessel groups and sizes, where fishers on vessels with low capacity utilisation may remain active simply because they cannot sell their quotas.

The study has several limitations. First, it is only performed for a subset of the Danish fishery, i.e., for fishers working on coastal fishing vessels. Thus, generalization to the total Danish fishing industry, or to other fisheries, is not straightforward; nevertheless, it adds to the discussion of which factors affect a fisher's decision to stay in or leave a fishery. An interesting extension of the study would be to broaden it to comprise fishers in the total Danish fishery around the time of implementation of the ITQ reforms in Denmark. Moreover, the study only includes measurable quantitative factors in the analysis of factors that influence a fisher's decision to leave the fishery, i.e., monetary indicators and capacity utilisation of the vessel on which the fisher works. For a more holistic approach, qualitative factors could be included, e.g., (i) the tradition of staying in the trade, which, as has been highlighted in the introduction, is often prevalent especially for small-scale fishers, (ii) the years of experience both of the fisher and of his/her predecessors, and (iii) the possibility of acquiring alternative employment in small fishing communities. In particular, the experience of fishers working on a vessel may be correlated with the efficiency of a vessel and may be an underlying explanatory factor for staying in the fishery, especially for vessel owners. Thus, future research into factors influencing fishers' decision to stay in the trade would benefit from quantifying and including such factors.

However, despite these limitations and although the reduction in fisheries employment in Denmark during the study period may be correlated with both ITQ implementation and other drivers (especially the possibility of similar or higher income in other areas of employment), the findings that the fishers on the best performing vessels stay in business prevail, adding to the understanding of the factors influencing the restructuring of fisheries given the introduction of ITQ management schemes.

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