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Challenging spatial and seasonal distribution of fish landings—Experiences from vertically integrated trawlers and delivery obligations in Norway

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ABSTRACT

The highly seasonal Norwegian cod fisheries give rise to problems downstream in the value chain and the authorities have introduced several schemes to counter the strong incentives for seasonal harvesting. This paper studies how the trawler delivery obligation (TDO) regime influences aspects of the harvesting pattern, focusing on the temporal and geographic distribution of landings. The analysis shows that the trawlers as a group have far less seasonal variations in their cod landings compared to the coastal fleet. While the Norwegian fleet lands about 75% during the first half-year, the corresponding share for trawlers is about 50%. Contrary to the initial hypothesis, the independent trawlers fished the most off-season; about 57% of their total landings. Trawlers controlled by vertically integrated firms landed considerably less (about 45%) and independently owned trawlers with landing obligations fell between these two strategic groups (about 50%). Vertically integrated vessels have a higher fulfilment of their landing obligations than the independently owned. The differences between the strategic groups are relatively high, at 68% vs. 38%. These results indicate that delivery obligations alone are not sufficient to provide control over the geographic distribution.

1. Introduction

In the DuPont model, profitability is split in two components; profit margin and asset turnover. Providing food commodities, fish processing firms in general are not likely to command very high margins. Thus, profitable production requires a reasonable turnover on capital. However, fish resources are often in conflict with this aim. Through a number of factors, among them biology and weather, landings of fish often show strong seasonal fluctuations. These give discontinuities in supply of essential raw materials for the processing industry and hamper efficient capital utilization.

The problem with seasonal variations in supply is also market dependent. Some markets have demand fluctuations that are synchronous with the fisheries. Here, the impact is likely to be small. In other markets demand peaks in other seasons than landings, and others again show stable demand throughout the year. In such cases the problems related to seasonal fisheries are likely to be worse [1,2]. The cost structure and flexibility of the processing firms are also important. Firms with low capacity costs or high flexibility in terms of raw materials and production output will be less influenced [3,4].

Seasonal variation not only poses problems for the businesses involved, but also gives discontinuities in labor demand that is not highly compatible with workers' needs in an industrialized economy. With processing plants often placed in rural communities, this exacerbates the problems related to work opportunities and decreasing population.

The reduction in value added as a result of the fishing fleet's seasonal harvest will in turn also result in reduced revenues for the vessels. However, there is a trade-off involved, particularly for the fishermen and a seasonal fishing pattern can also be economically efficient. This becomes evident when taking into account the harvesting costs. A key cost driver is catch rates, often measured as catch per unit effort (CPUE). With high CPUE costs are low and vice versa. Fishermen therefore prefer to follow the seasonal pattern when the cost savings in the fleet exceed the loss in the processing industry.

In this study, focus is on the harvest of Northeast-Arctic cod (*Gadus morhua*). This is one of the most important species in Norwegian fisheries, particularly for employment in rural areas. Harvest is strongly seasonal, as about 75% is landed during the first four months of the year. This is clearly positively linked to systematic variations in catch rates, as the CPUE of stern trawlers in the low season only reaches 1/3 of the high season [5]. This pattern is even more pronounced for the coastal fleet, consisting of smaller, more weather-dependent and less mobile vessels [6].

To moderate the negative impacts of seasonality, several managerial schemes have been introduced by the authorities, mainly addressing the fishing fleet. These include period quotas, rural community quotas [7] and bonus schemes. Here the politically driven development of the Norwegian trawler fleet in the cod fisheries and the introduction of another season-moderating

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scheme—vessel delivery obligations, hereafter called the TDO regime, are addressed. More thoroughly described in the following section, the principal idea was that a trawler fleet could supply the processing industry with fish year-round, not only during the high season like the smaller coastal fleet vessels. At first, the trawlers had strong linkages to individual processing plants. Structural and ownership changes reduced or removed these bindings, prompting the authorities to restrict the landings of the individual trawlers to specified locations in order to maintain the supply to the beneficiary processing plants.

1.1. Outline

The paper continues as follows: the next sections presents the research questions, data and research method employed in this paper. Hypotheses for testing are also developed here. Then, descriptions of the development of the trawler fleet and the delivery obligation scheme follow. The model proposed by Hermansen and Dreyer [7] is expanded for explaining the degree of seasonality in harvesting from wild fish. In doing so the harvesting pattern of Northeast-Arctic cod (*Gadus morhua L.*) in Norway that has prevailed for centuries is described. The results of the empirical tests of the proposed hypotheses are then reported. The paper is concluded with a discussion of the results and managerial implications of our findings.

1.2. Research questions and implications

A key requirement for the TDO regime to be successful is that landings from trawlers – and those subject to delivery obligations – are able to alter the traditional seasonal pattern of landings, both in terms of time and geography. In a setting where high-season fishing is the preferred harvesting pattern from the fishermen's viewpoint, one cannot simply assume that this will be the case. The purpose of this paper is thus to investigate how the TDO regime has performed in moderating the highly seasonal harvesting strategy of Northeast-Arctic cod.

Landing patterns can be depicted along many dimensions. In accordance with our problem description, the study is limited to the geographic and temporal ones. The TDO regime has existed for more than 50 years, a period of pronounced changes in terms of structure, technology and management regimes. The study focuses on a modern context and the analysis is restricted to the period after the latest change in the delivery obligation scheme—from 2005 to 2009.

The knowledge obtained may prove helpful for changing or refining the TDO system in terms of its existence or improved efficiency. In a wider context the results may be significant in the design of management instruments that facilitate an economically and socially sound utilization of seasonally varying resources. For cod, this translates to the trade-off between low harvesting costs in the high season and the losses borne by the processing industry, local communities and consumer markets related to discontinuity of supply of fish.

2. Research method and data

This section presents the data employed in this study, develops the research hypotheses and describes how the testing of these is carried out. The success of the TDO regime is measured by how well it is able to moderate the concentration of cod landings in time and space. The hypotheses are based on how well different actors and vessels included in the TDO regime perform, i.e. land cod in periods out of the main season, compared to vessels and actors outside the TDO regime. The Hermansen and Dreyer model [7] is applied to predict how these strategic groups will act in their selections of harvesting strategies.

The trawler vessels in Norwegian fisheries may be divided in three groups, based on ownership and landing obligations:

(1) Independent—no processor ownership and no landing obligations.
(2) Landing obligations—no processor ownership but landing obligations.
(3) Controlled—both processor ownership and landing obligations.

First, the effects on the temporal landing pattern are investigated. The TDO regime is based on the assumption that trawlers are able to catch cod outside the high season. Further, delivery obligations and processor ownership are intended to guarantee that the vessels will actually choose a harvesting pattern favorable for the processing industry—in most cases this implies off-season fishing. The TDO regime has given the firms another portfolio of internal resources than other firms. According to Williamson [8] internal firm resources may be divided into four groups; site specificity, physical assets, dedicated assets and human assets. The TDO regime is based both physical and dedicated assets. The physical assets, i.e. size of the vessel and equipment, give the firm capability to catch cod in high seas in the summer and autumn. The dedicated assets, i.e. the ownership of the vessel, the quota and the obligation, give the processing plants a unique option to moderate the seasonal harvesting pattern from the traditional pattern. According to the Hermansen and Dreyer model, this moderation will impose costs on the vessels in form of reduced catch value and higher catching costs. However, according to the intension of the TDO regime these costs will be compensated by the increased gains achieved in the market and in improved capacity utilization in the processing plants. Based on these arguments the main hypothesis can be stated as follows:

H_1. The proportion of cod quota caught outside the high season will follow a ranking such that "Controlled" > "Obligations" > "Independent".

The data employed in this study are information on individual vessel's landings of fish and fishing licenses. The landings data include information on date, location, quantity, species and value. The data on landings of fish at vessel level and individual landing obligations were provided by the Norwegian Directorate of Fisheries. Based on the landing data a variable is generated to measure the share of landings out of season. Here "out of season" is defined as the period from May through December and landings as the quantity of cod. The vessels are grouped in the respective strategic groups, i.e. "Independent", "Obligations" and "Controlled". Conventional statistical tests are employed to determine if there are differences between the groups.

The second part of our study concerns the geographic component of the landing pattern. The intention of the TDO regime was partly to direct landings to a defined geographic location in order to secure the supply of raw materials for the processing plants there. In general, the group of independent trawlers fish and land to maximize their profits independently, while the other two groups are influenced by the landing obligations and ownership. Ownership is assumed to represent a stronger influence than landing obligations, and the following hypothesis regarding the fulfilment of specific delivery obligations is proposed:

H_2. The degree of upholding the landing obligations will follow a ranking such that "Controlled" > "Obligations".

While operationalizing the first hypothesis was fairly straightforward, more difficulties arise in evaluating H_2. Data on the vessel-specific landing obligations and the actual landing sites are available. However, there are considerable difficulties relating to the former. In some instances a specified processing plant, municipality or region is to be the beneficiary of landings. This may no longer be relevant, since plant(s) in this area may have been closed down or gone bankrupt. A variable is developed, measuring to what degree the individual vessels within each of the two relevant groups have upheld their landing obligations, and statistical tests are employed to determine if there are differences between the groups. This analysis is undertaken with individual vessel observations for each year in the period 2005 to and including 2009.

3. Trawlers and landing obligations

Today, trawlers are important in the Norwegian cod fisheries, catching about one third of the cod and even more of saithe and haddock. The emergence of this fleet, however, came far later than comparable fishing nations, and accompanied with much greater dispute. Due to a ban on trawling in Norwegian waters (Acts on Trawling of 1908, 1925, 1936 and 1939) there were only 11 Norwegian trawlers [9] until the onset of WWII. By comparison, Great Britain, France and Germany had fleets of trawler vessels counting about 1300, 400 and 300, respectively, in the late 1930s. Partly explaining this difference is the high abundance of fish near the coast, facilitating an effective small-vessel fishery. However, political and social factors were decisive [10–12].

While cities like Grimsby and Hull saw the development of a trawl shipowner cluster and a proletariat of fishermen, the Norwegian fishing fleet was dominated by self-employed fishermen combining fishing with owning and operating small-scale farms in rural areas. In the early 20th century some steam trawlers were introduced in the open access Norwegian fisheries. As a result, several conflicts between coastal vessels and these trawlers emerged. With the coastal fishermen's enjoying legitimacy in the Parliament, these conflicts led to the original trawler ban in 1908 [11]. However, with rich fishing banks, a fishing limit of only four nautical miles and no coast guard for surveillance, foreign trawlers were unavoidable. In 1934, about 300 trawlers operated on the fishing banks close to Andøya, an area earlier used by coastal fishermen solely, causing harsh confrontations between the two vessel groups. A preliminary law against trawl fishing in 1936 banned fish deliveries from trawlers in Norway and fixed the limit of Norwegian trawlers to the 11 existing licenses in order to avoid a domestic trawl fleet [10,11].

During WWII, the German occupants were eager to industrialize the fisheries. In fear of cutting off an important food supply, they did not challenge the sentiment in the population on organization of the fishing fleet [9,13]. However, during the war large fish filleting and freezing processing plants were constructed [12].

After WWII the industrialization strategy was prolonged, and the fish processing industry had an important role in the development plans for North-Norway. Industrialization meant centralization and large filleting plants that could supply West-European markets with fish. A prerequisite for the industry was a more continuous flow of raw material (fish) in order to ensure profitability and stable employment—something the coastal fishing fleet with their highly seasonal activity was poorly suited for.

On this background, 24 new trawl licenses were assigned in 1950, and the Trawler Act was amended the following year, removing the limit on number of trawlers. Still, the act clearly stated that trawlers were a supplement to supply from the coastal fleet. Throughout the 1950s the number of trawler licenses increased, and the processing industry was permitted to own trawlers. This was by exemption from the principal rule that fishing vessels should be owned by active fishermen. In the period 1968–74, six to seven new trawl licenses were granted annually to serve the fillet freezing industry. In 1978 their numbers reached a peak with 89 licenses. In addition 13 factory trawler licenses and 27 small trawler licenses were granted.

The fresh fish trawler licenses were granted to shipowners strongly tied to fillet processors or to the processors themselves. In the early 1980s both the trawling companies and the fish processing firms experienced economic difficulties, resulting in bankruptcies and sales of trawlers. In many cases the links between trawler licenses and processing firms were weakened or removed by such transactions. The authorities' response was to impose specific requirements on each vessel's landings, thus bringing about the delivery obligations. The vessel was required to land all or a specified share of its catch to specific fish processing plants or geographic areas, defined by the authorities based on the original bindings between vessel and processing plants.

The contents of the delivery obligations imposed on the license have been disputed several times. Most often when vessel owners and the favoured processing plants had conflicting interests. The contents have also been changed to reflect changes in processor structure when plants are closed down. Several capacity reduction measures, ITQs in particular, have reduced the fleet and the delivery obligations have been transferred along with the quotas. In 1999, 40 cod trawlers were subject to landing obligations [14]. Five years later the number was 36 [15] and by 2008 they were reduced to 26. Today the majority of these licenses are controlled by two large vertically integrated companies. In addition to the licenses with landing obligations, there were 11 "independent" trawlers in 2008, seven of which are factory trawlers.

During the break-up of the Soviet Union, several factors led to a large increase in landings from the Russian trawl fleet to the North-Norwegian processing industry. The Norwegian trawlers responded by selling their catch further south in Norway. In 1997, the 31 trawlers from Finnmark landed only 50% of their 55.000 tonnes quotas of cod and haddock in their home county [16]. Most of this fish were under delivery obligations to processors in the north, but with the large supply from foreign vessels, the processing firms did not claim this fish and did not dispute the change in landing pattern. However, the Russian fleet was gradually modernized and only a small share of its catches is now landed to the North-Norwegian filleting plants.

After a change in government and thorough review [14,17], the delivery obligation scheme was changed in 2004. The changes represented a weakening of the (sometimes) strict delivery conditions. The share of catches that were to be delivered was reduced from all fish to 80% of the cod and 60% of the haddock. The key change, however, stated that the vessels were required only to offer their catch to the processing plant. This was at a predetermined price, which detailed rules determined. These changes gave the vessels considerable opportunities to act so their catches were not interesting for the processors. The prices, being determined on the basis of sales from "free" trawlers were often higher than the filleting plants' willingness to pay. Both these factors have contributed to lower landings to the intended beneficiaries of the delivery obligation scheme.

4. Seasonal harvesting

Hermansen and Dreyer [7] propose a model for a better understanding of why fishermen concentrate their fishing effort both in time and space. The model rests on a general and reasonable assumption that firms seek to maximize their profit in order to survive and prosper. How to achieve this goal thus becomes a decision of where and when to apply the vessel, since in the short run, vessel size and gear type are given. I can often be observed that fishermen choose to concentrate their efforts in time and space. This is particularly prevalent in fishing for Northeast-Arctic cod. Fishing effort is concentrated to the winter season, from January to April, when the mature part of the stock migrates from the Barents Sea to primarily the Lofoten area to spawn. This pattern has prevailed for centuries, even though market knowledge, fish finding equipment, vessels and gear have developed considerably. Fig. 1 illustrates the seasonal catch profile of Northeast-Arctic cod.

How can such a seasonal harvesting pattern be explained? With relatively large investments in vessels and processing plants and the demand for fish being relatively stable, one could reasonably assume that high capacity utilization throughout the year would be the dominant strategy. Fisheries, however, differ from traditional putty–clay production processes, because key inputs, such as the fish stock, catchability and quality parameters, are exogenously given.

The expanded spatial and temporal allocation of fishing effort model is presented in Fig. 2. This allocation is the result of a complex utility maximizing problem where economic profit is an important component. Other utility components are spare-time, distance from family, work enjoyment and safety, among others. Maximizing profit means a trade-off between revenues and costs, both significantly influenced by seasonal variations. Catchability varies with the migration pattern of the fish stock, affecting both fishing costs and revenues. Fish quality varies seasonally, with implications for the price achieved. Variations in catchability and first-hand prices thus promote a more seasonal application of effort. Any positive correlation between these two factors will further strengthen the tendency to concentrate fishing effort.

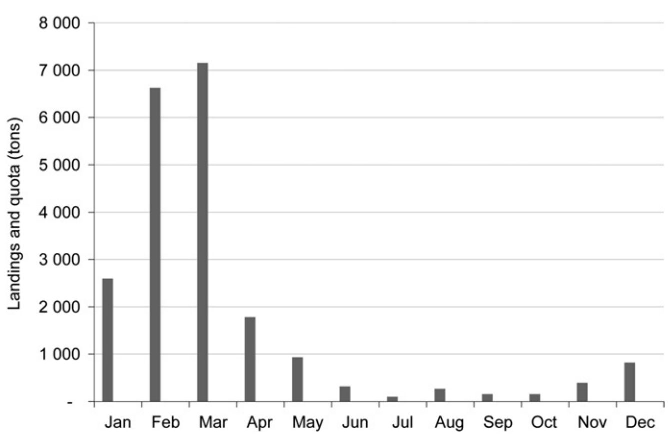

Fig. 1. Landings of cod (round weight) from vessels 15–21 m in length in 2007.

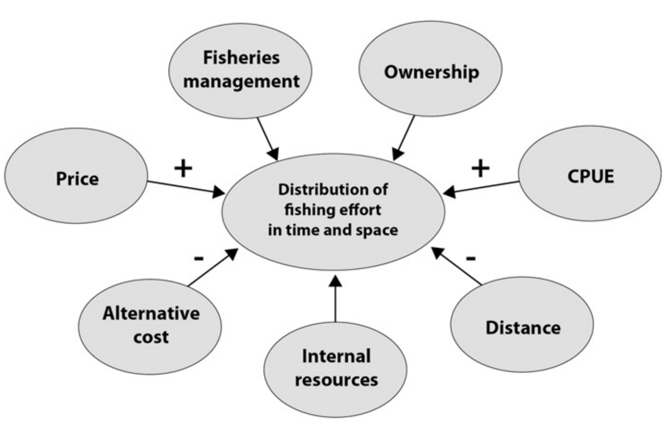

Fig. 2. Factors impacting spatial and temporal allocation of fishing effort.

Some fisheries will entail alternative costs as well, as the application of effort in a particular period or place may exclude or reduce the value of other fisheries or activities. The extreme example is when the peak seasons for two fisheries coincide in time, mutually excluding each other. Migration patterns influence the distance between the fishing grounds and landing sites, which through fuel use, investments and available time for fishing also directly affect profits. Large distances thus reduce the value of a particular season, whereas proximity to landing sites increase attractiveness.

In addition to these biologic and economic variables, the decision is also governed by the authorities through fisheries management. Almost all commercially interesting Norwegian fisheries have limited entry and are quota limited, placing restrictions on species and quantity. Operations are often restricted by gear and area regulations. Finally, landing area may be limited through the TDO system. The ownership of the vessel can have strong influence on the fishing pattern. A fisherman-owned vessel may maximize vessel profits alone, while a vertically integrated vessel may take on-shore considerations into account.

Based on our approach, as illustrated in Fig. 2, fishermen's adaptation can be predicted. However, there are stochastic elements to most of the variables; making uncertainty an important moderator for the harvesting pattern. Perhaps the best example is weather—a large part of the fleet consists of smaller vessels that are weather restricted and with limited operating radius.

According to Barney's resource-based view of firms (RBV), firms are heterogeneous, i.e. they control different portfolios of resources [18]. Based on this observation, Barney concludes that firms have different strategic options and will adapt differently, even in the same competitive context. In a fishing context, this implies that different harvesting patterns among vessels in the same fishery may be observed. For instance, the portfolio of licenses each vessel controls, gear type, home port and knowledge of fishing areas will impact which harvesting strategy the vessel adopts. The reasons for this variation in firm resources are complex. It may often be related to path dependency in investments in vessel and gear, fishing experience and where fishermen live. And, of course, it may also be a result of how the authorities manage the fisheries. This paper is particularly interested in how restrictions posed on a limited number of firms impact on the chosen harvesting strategy.

5. Findings

The following sections present and discuss the findings of the study. First, the actual fishery is described. Next, the effects on spatial and temporal distribution are evaluated. Finally, the hypotheses are tested with empirical data.

The trawler vessel group takes part in various fisheries, the majority being single- or two-species fisheries with a small share of other species in the catches. The economically most important species is cod, which is caught either alone or in a mixed fishery with haddock and/or saithe. These can also be caught in more single-species fisheries. Shrimp trawling has also been important, but less so the last years due to low product prices combined with high fuel prices. Vessels are allocated yearly quotas based on TAC and each vessel's quota share in the respective fisheries. As mentioned, the catchability varies systematically over the year and there is considerable uncertainty in both this and other in

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important variables such as prices. The choice of when to catch is to a large degree irreversible, meaning that the vessel owners are faced with a highly complex problem when planning the utilization of their quotas.

The temporal effects of the TDO regime are analyzed first. For each year between 2005 and 2009, the operating trawlers are divided in three groups—"Controlled", "Obligations" and "Independent". This categorization of vessels was not straightforward. Several capacity reduction programs and tradable quotas have resulted in vessels today holding licenses from a number of vessels. In some cases vessels have a combination of quotas both with and without delivery obligations attached. With the number of vessels being relatively small, it was decided to include these in the analysis. Information on quota shares was used for grouping; vessels where over 50% of their total quota were attached delivery obligations were grouped as controlled or obligations, depending on their ownership. Information on ownership was obtained through the Norwegian International Ship Registry (www.nis-nor.no). Data on vessel catches by month were gathered from a database provided by the Directorate of Fisheries. Further complicating the analysis is instability in the population of trawlers. Vessels are sold, capsize, suffer engine failures and other events that result in vessels not being operated for the whole year. These events may be planned or accidental, but having implications for the harvesting pattern in any case. To the best of our abilities, such outliers are excluded from the data material by visual inspection of the monthly landings. Long periods of no activity prompted closer analysis of whether this was an intended pattern or a response to an unforeseen event. For this, general knowledge of the vessels, data on quota validity dates from the Directorate of Fisheries and internet searches was utilized. This process yielded a number of vessel observations for analysis as shown in Table 1.

Monthly data on the vessels' temporal landing patterns of cod were analyzed to shed light on hypothesis 1. As mentioned, landings from and including May to December was considered off-season. The off-season percentage of annual cod landings for each vessel each year was calculated. Results were averaged within groups and are presented in Table 2.

The results in Table 2 show that all groups choose to land a relatively large share of their quota off-season. With the exception of one group one year, all observations fall between 43% and 67%. Among the individual vessels there are larger variations; there are vessels that catch all their cod during the high season and vessels that almost land all their cod off-season.

Comparing between groups, it is first noted that the independent vessels fish a larger share off-season than the controlled vessels every analyzed year. The obligations-group is generally on the same level as the independent, with a notable exemption in 2008, where they caught only one third off-season. The observations in this group are, however, very few, so these results have to interpreted with caution.

In order to statistically test the relationship between the three groups of vessels a dummy variable regression model shown in Eq. (1) was developed, assuming that fishing off-season is explained by vessel group and year. OBLIG, INDEP and all years represent dummy variables that take the value 1 when the observation falls within the vessel group or year in question and 0 otherwise.

$$\text{Codshare} = \beta_1 + \beta_1\text{OBLIG} + \beta_3\text{INDEP} + \beta_4 2006 + \beta_5 2007 + \beta_6 2008 + \beta_7 2009, \quad (1)$$

where Codshare is the share of annual cod catch in second half-year; OBLIG the dummy variable for vessels with delivery obligations; INDEP the dummy variable for independent vessels with no delivery obligations; 200*X* the dummy variable for the given year.

An ordinary least squares regression was run in the econometric software Shazam and the results are shown in Table 3. The chosen variables explain only a small share of the total variance. This was expected as the variation between individual vessels within groups was large, as shown by the standard deviation in Table 2, and our model has no variables that capture individual vessel aspects. Nevertheless, at a 10% level of significance we accept that both vessels with landing obligations (OBLIG) and independent vessels (INDEP) land a larger share of their cod off-season, with respectively, 7% and 12% points more than the controlled vessels at 45%. The results also show that the vessels caught 10% points more off-season in 2010.

These results are not supporting our initial hypothesis. Here it is assumed that the controlled vessels would fish the largest share off-season. Rather, the opposite is true; the independent vessels allocate most of their quota to off-season fishing.

Table 1
Vessel observations employed in analysis.

Year	Group			Total
	Controlled	Obligations	Independent	
2005	22	6	23	51
2006	20	6	22	48
2007	20	6	21	47
2008	19	4	14	37
2009	19	4	17	40

Table 3
Regression results from Eq. (1).

Variable	Coefficient	Std. error	*t*-stat	*p*-value
CONSTANT	0.45	0.03	15.80	0.00
OBLIG	0.07	0.04	1.73	0.09
INDEP	0.12	0.03	4.78	0.00
2006	−0.09	0.04	−0.24	0.81
2007	0.02	0.04	0.42	0.68
2008	−0.03	0.04	−0.76	0.44
2009	0.10	0.04	2.65	0.01

$R^2 = 0.14$.

Table 2
Average share of off-season cod landings.

Year	Average			Standard deviation		
	Controlled (%)	Obligations (%)	Independent (%)	Controlled (%)	Obligations (%)	Independent (%)
2005	45	56	56	17	19	14
2006	47	52	54	14	22	23
2007	44	56	58	15	21	25
2008	43	33	57	11	16	16
2009	54	67	67	22	13	20

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Turning to the geographical implications of the VTO regime; our second hypothesis was that the vessels controlled by a vertically integrated firm would show a higher compliance to their landing obligations. The independent vessels from the previous analysis were naturally left out, but else the same data set presented in Table 1 was employed in this analysis. Thus, the same process was employed for selecting vessels and screening for outliers. The data from the Directorate of Fisheries contain information on which municipality the fish was landed, and this was extracted for comparison with the individual vessel's landing obligation.

As mentioned, the landing obligations have been implemented on a vessel-by-vessel basis, hence there is no general format to them. Instead, the obligations are stated in writing and with large variation from vessel to vessel. This adds complexity to the analysis, and to illustrate this variation some examples of general obligations are provided below:

– Catch should be landed at a specified processing plant.
– Catch should be landed at a number of specified communities.
– The majority of the catch should be landed at a given municipality.

To further add complexity, the licenses containing the obligations have been traded between vessels. In many cases, one vessel may hold several licenses with landing obligations. In these cases, determining whether or to what degree it has upheld the landing obligation is often difficult. To statistically test the hypothesis, again a dummy variable model as shown in Eq. (2) is developed. This model explains the variation in compliance using the dummy variable OBLIG and dummy variables for each of the analyzed years.

$$\text{COMPL} = \beta_1 + \beta_1\text{CONTR} + \beta_4 2006 + \beta_5 2007 + \beta_6 2008 + \beta_7 2009, \quad (2)$$

where COMPL is the degree of compliance with landing obligation; CONTR the dummy for vessels controlled by a vertically integrated firm with delivery obligation.

The degree of compliance is a measure of to what extent the vessel has fulfilled its landing obligation(s). It is calculated as the amount delivered cod divided by the amount required by the obligation, thus it will take a value between 0 and 1. For vessels holding multiple obligations, a weighted average is calculated. For vessels catching less than their quota, the required amount is adjusted by the quota utilization ratio.

Table 4 shows the results from the ordinary least squares regression of Eq. (2). Again, the model explains only a small share of the variance. None of the years were found to influence the compliance, but both the constant and dummy for controlled vessels were significant below 1% level. The constant represents the compliance for vessels with delivery obligation only and adding the CONTR to this represents the controlled vessels. The results state that the first category fulfils only 32% of their obligations, while the controlled vessels fulfill 68% of theirs. These results therefore give strong support to the proposed hypothesis.

Table 4
Regression results for Eq. (2).

Variable	Coefficient	Std. error	*t*-stat	*p*-value
CONSTANT	0.32	0.01	3.57	0.00
CONTR	0.36	0.01	4.87	0.00
2006	0.03	0.10	0.29	0.78
2007	0.01	0.10	0.06	0.95
2008	−0.01	0.10	−0.08	0.93
2009	−0.04	0.10	−0.43	0.66

$R^2 = 0.16$.

6. Discussion

Although dating back to the early 20th century, the TDO regime is still active, but has been adjusted several times as a result of changes related to technology, industry structure and the overall management regime. Prime political objectives were to allow for a transition towards more industrial fish processing with a production less dependent on biological variations and uncertainty related to weather. This study investigated whether trawlers with landing obligations contribute towards this objective. For three groups of trawlers the temporal landing pattern and to what degree they fulfilled the geographic intentions in the landing obligations was analyzed. The results showed that vertically integrated trawlers with landing obligations landed the highest share of their catch during the high season, followed by independently owned trawlers with landing obligations. The independent trawlers landed the most off-season. This was opposite to the initial hypothesis. When looking at the geographical landing pattern the hypothesis was confirmed. Vertically integrated trawlers fulfilled their obligations to a much higher degree than the independently owned.

Several aspects deserve discussion in relation to these results. The models employed to analyze the two hypothesizes explained only a small portion of the total variance. This implies that there are a number of other factors determining both when and where the catch is landed. First and foremost these are likely to be related to variations between individual vessels, but it cannot be excluded that our model does not capture all elements that influence landing patterns on a group level.

Several sources have provided data for the analysis. The landings data are based on sales records between vessel and buyer. Vessels are required to keep logbooks on catch per haul. This assures that data on quantities and landing vessel are reliable. Information on landing date or site are also reliable. Site data may still be a source of uncertainty as the fish may be transported from a landing site to processing firms. This is particularly true for fish frozen onboard and landed at freezer storages that often are located at infrastructure hubs, being advantageous for resupply and crew rotation.

Grouping of vessels was done using data that coupled quota and vessel identifications along with ownership information from a separate database. These data showed that quotas were relatively often transferred between vessels. Whether to include data from both vessels or to omit the data altogether required attention. It was decided to include the data when there was less than a month gap before the new vessel resumed landings after such a transaction and the ownership was upheld. These criteria indicate that the vessel change did not lead to large changes from the planned landings pattern.

Several factors outside of our model may have influenced the results. Particularly the last decades have seen large structural changes in the cod processing industry. Most of the firms granted quotas with delivery obligations were filleting plants. Here, profits have proven low as a result of high labor costs and competition from frozen fillets from other countries and other species [19]. Plants have gone bankrupt and others have switched production from filleting to salting. This implies that some of the delivery obligations are impossible to fulfill, due to the plants being out of business. For this study information on which areas this applies for has not been collected. Among the firms that have switched production some may consider the raw material supplied from the trawler not suitable for their production and hence declined to buy it.

Technological changes onboard vessels may also influence attractiveness for processing plants. Trawlers are not allowed to install filleting equipment, but most have installed freezing equipment. This may render the fish unattractive for some processors, either due to not being equipped for thawing fish and using this in their production or not considering frozen fish suitable for their production.

The regulations governing the landing obligations were changed from an obligation to land to an obligation to offer. The formula defining the price of such fish has also been changed so it to a large extent reflects the willingness to pay of the most profitable processing industries. In effect, this fish has become significantly more expensive and beyond the break-even price of many processors.

A final source of uncertainty is related to many processing plants being owned by two large parent companies. With the liberalized regulations, the plant favoured in the delivery obligation may decline the offer and the fish can be sold to another plant owned by the same parent company.

The first hypothesis was rejected, as the independent trawlers were found to land the most off-season. To an extent this was unexpected, and it is difficult to explain this difference. The vessels are exposed to the same systematic variations in CPUE and fish prices, while the vertically integrated firms are likely to have strong economic incentives for stable supply. There are relatively small technical differences between the groups, apart from a significant share of the independent group being factory trawlers (have filleting and freezing plants onboard). These, however, do not contribute the most to the difference. All vessels have relatively similar quota portfolios. A trawl license gives quota for both haddock and saithe in addition to cod. These can be caught in mixed or single-specie fisheries. A vertically integrated firm that focuses on cod processing may be less interested in large catches of saithe, and may prefer a harvesting pattern that catches primarily cod or in combination with haddock. An independent trawler may deliver to several customers and achieve better utilization of its quotas and postpone cod harvesting. This has not been investigated in this study, but further exploration of the variation between these strategic groups is clearly warranted.

Vertically integrated vessels were found to have a higher fulfilment of their delivery obligations than the independent, thus confirming our second hypothesis. These firms are likely to take on-shore profit and social considerations into account, whereas the independent trawlers maximize only the vessel economic yield. As mentioned not only fish price incentives, but also crew and resupply give incentives towards landing in larger ports. This preference is evident in the data. The landing obligations have generally favoured the filleting segment. During the period in question, other processing segments such as salt and clipfish, have been price leading. With the offering prices in large part being determined by these segments willingness to pay it is reasonable to assume that many favoured processing plants have been forced to reject the offer. It is also known that, given the incentives, vessels have developed techniques to further discourage favoured plants' desire to buy this fish.

Relatively few studies have been dealing with the landing obligations, and in particular the geographic and temporal aspects of it. A study of individual trawlers fulfilment of their delivery obligations in the period 1999 to 2004 was published in the gray literature [20]. Although this does not quantify the degree of fulfilment or specifically analyses differences between vertically integrated and independent vessels, it concludes that the intentions in the obligations have not been met for the majority of the vessels. A study commissioned by the Ministry of Fisheries evaluated the scheme, focusing on data from 2004 [15]. Here, relatively small differences were found between the temporal landing pattern of trawlers with and without landing obligations. Finally, a study by Flaaten and Heen [21] investigated the profitability of the two groups, concluding that trawlers with landing obligations had significantly lower returns.

With one of our initial hypotheses being rejected through the analysis, revisiting the theoretical models that formed the basis for the hypotheses is warranted. These were the resource-based view of the firm [18] and the extended harvesting pattern model from [7]. Rejection of H_1 does not imply rejection of the models, but rather that some impacts are not fully understood. The vessel inputs are very comparable, with similar physical properties and quota portfolios, but they still employ considerably different harvesting patterns. This is evidence that there are other firm-specific resources that also play important roles. These inclusion of an "internal resources"-box in the harvesting model from Fig. 2 is clearly warranted. Unlike the factors such as CPUE and fish prices, we do not have explicit knowledge about the variables involved and impacts. The boxes "fisheries management" and "ownership" were assumed to capture the landing pattern effects of elements such as the delivery obligations and vertical integration. The rejection of H_1 shows that the initial assumption of the how these influenced the landing pattern was incorrect. Further studies of these elements of vessel behavior are therefore interesting.

7. Conclusions and management implications

This section summarizes our findings and discusses the implications for fisheries management. Norwegian cod fisheries are highly seasonal. Such a harvesting pattern is likely economically efficient for the fishing fleet, but give rise to problems downstream in the value chain, from processing firm to consumer. The authorities have introduced several schemes to counter the strong incentives for seasonal harvesting. This paper studies how the TDO regime influences aspects of the harvesting pattern, focusing on the temporal and geographic distribution of landings.

The analysis shows that the trawlers as a group have far less seasonal variations in their cod landings compared to the coastal fleet. While the Norwegian fleet lands about 75% during the first half-year, the corresponding share for trawlers is about 50%.

Contrary to the initial hypothesis, it was found that the independent trawlers fished the most off-season; about 57% of their total landings. Trawlers controlled by vertically integrated firms landed considerably less (about 45%) and independently owned trawlers with landing obligations fell between these two strategic groups (about 50%).

From a management viewpoint, with an aim to decrease the seasonality in cod landings, the introduction of trawlers in Norwegian fisheries clearly contributes positively. The results from the analysis, however, indicate that in this respect the delivery obligation scheme and vertically integrated vessels contribute less than independent vessels.

Turning to the geographic aspect, a landing obligation was issued when strong links between a trawler and a processing firm were weakened, often as a result of change in ownerships. The obligations intended to secure continued supply of raw materials to the processor from the trawler in question. Lately, the obligation has been weakened by legislative amendments, and has in the analyzed period been an obligation to offer the fish for sale.

The results show, as expected, that the vertically integrated vessels have a higher fulfilment of their landing obligations than the independently owned. The differences between the strategic groups are relatively high, at 68% vs. 38%. These results indicate that delivery obligations alone are not sufficient to provide control over the geographic distribution.

Several aspects that contribute to explaining the differences are discussed. For the vessel, as an independent economic actor, the liberty to land anywhere has clear economic benefits. Prices are likely higher, resupply and crew changes can be coordinated better with operations and at less cost. For the processor the willingness to pay is likely less than the market price constituting the basis for the offer, forcing them to decline.

Without externalities, economic theory predicts that optimal value adding is achieved when actors adapt without government interventions. The landing obligations represent an intervention that hampers the flow of raw material to the most efficient producer, thus reducing economic efficiency. The filleting industry, as the prime recipient of landing obligations, has shown prolonged poor profitability, while other sectors, such as clipfish production, have yielded far better results [22]. Not only does this reduce the immediate value of a limited resource such as cod, but also has longer-term negative consequences as productive structural changes in the on-shore processing is counteracted. The administration of the scheme also requires significant work from both public agencies and the shipowners, further reducing economic efficiency.

Comparing both objectives, temporal and geographic control, the results of our analysis are in conflict. The most even temporal distribution is obtained using independent trawlers, while to ensure a wanted geographic distribution, vertical integration is superior. Hence, in developing policy for this area of fisheries management the authorities have to prioritize between the two aims. However, both analyses and the transaction costs involved point toward landing obligations being a less effective instrument. Management should either investigate other schemes that are more effective or tighten the existing TDO regime.

The vertically integrated group is totally dominated by two large companies owning several trawlers and processing firms. In the Norwegian setting, it is likely that cancellation of landing obligations would lead to these two firms rationalizing their on-shore production considerably, leaving several fisheries-dependent communities without a processing plant and the negative consequences following from this.

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