The Impact of Transferable Fishing Quotas on Cost, Price, and Season Length

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ABSTRACT

Individual fishing quotas give fishers incentives to reduce costs (or increase productivity), lengthen the harvest season and increase price by improving catch quality. To what extent each of these three effects will be present when the management system is changed in a specific fishery depends on the characteristics of the fishery and on the markets and supply chains served. This paper uses a difference-in-differences approach to investigate the impact on all three outcomes of a regulatory change that introduced individual fishing quotas with some transferability for a group of coastal vessels in the Norwegian whitefish fisheries. The results indicate higher ex-vessel prices after the regulatory change, which imply higher quality of the fish landed, but show no significant extension of the fishing season or reduction of the average cost.

Key words: Cost, difference-in-differences, fisheries management, IFQs, price, season length.
JEL codes: Q01, Q22, Q28.

INTRODUCTION

Individual fishing quotas (IFQs) provide harvesting rights that alter fishers' incentives toward maximizing profits for their quota instead of maximizing their share of the catch (Grafton et al. 2006). The benefits of removing the competitive race to fish can appear in at least three dimensions: cost can be reduced (Grafton 1996), the harvest season can be extended (Homans and Wilen 1997), and generating higher-quality products can increase ex-vessel prices and possibly also harvesting costs (Homans and Wilen 2005). Moreover, when the IFQs are transferable, there are incentives to reduce overcapacity (Arnason 1990), although the incentives are limited when the transferability is restricted because of social considerations (Kroetz, Sanchirico, and Lew 2015).

In recent years, a literature investigating various effects associated with the introduction of individual fishing quotas has developed, usually focusing on one hypothesis at a time. Casey et al.

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(1995) and Homans and Wilen (1997) provide evidence of an extended fishing season. Birkenbach, Kaczan, and Smith (2017) show that the fishing season was extended in most US fisheries where IFQs were introduced, Hsueh (2017) provides similar results for Alaska fisheries, and Birkenbach et al. (2020) show that the extension of the season depends on the demand structure of the fleet, with empirical evidence from the Norwegian trawlers. Dupont et al. (2005), Dupont et al. (2002), Branch (2006), Scheld, Anderson, and Uchida (2012), Agar, Stephen, and Strelcheck (2014), Kroetz et al. (2017), and Ardini and Lee (2018) provide examples of fisheries where revenues or profits increased with IFQs. Kompas and Che (2005) provide evidence of reduced costs, while the results from Dupont et al. (2005), Dupont et al. (2002), Dresdner, Campos, and Chávez (2010), and Sólis, Agar, and del Corral (2015) suggest an increase in productivity, which also implies reduced costs. However, such benefits are not clear in all cases (Grafton, Squires, and Fox 2000; Asche, Bjørndal, and Gordon 2009; Chu 2009; Hamon et al. 2009; Walden et al. 2012). Various factors, such as availability of fish over the season, the markets being served, and the institutional design, may play a role in determining the effect of the IFQs, as well as the fact that it can take time for the full benefits of an individual fishing quota program to materialize (Grafton, Squires, and Fox 2000; Asche, Bjørndal, and Bjørndal 2014).

This paper investigates the potential benefits of the introduction of an IFQ system with some transferability for one group of vessels in the Norwegian fleet, specifically the coastal vessels between 11 and 14.9 m. Norwegian fisheries regulation varies by fleet segment/vessel group because of social considerations, and changes in regulations are often sequential. Hence, a difference-in-differences (DiD) approach can be used to investigate the impact of regulatory changes by comparing vessel groups that operate with similar harvesting technologies and serve the same market (Asche, Gordon, and Hannesson 2004; Asche, Chen, and Smith 2015; Pettersen and Myrland 2016; Pettersen and Asche 2020), but that differ with respect to the regulatory structure over some periods. Our data allow us to test all three main economic hypotheses associated with the introduction of IFQs: (1) whether the fishing season is extended, (2) whether harvesting costs are reduced, and (3) whether a higher ex-vessel price is obtained for the landings.

The paper is organized as follows. First, a brief overview of the relevant vessel groups and their management scheme is provided. Then, the data used are described along with the methods applied. In the final sections, the empirical results are presented, followed by concluding remarks.

BACKGROUND

The Norwegian coastal fleet targets mainly cod, saithe, and haddock.[1] The vessels use a number of gear types, such as gill nets, various lines, and Danish seines, and are mostly active in fishing grounds along the coast of Northern Norway. The limited size of the vessels prevents longer offshore trips, and the main fisheries are tied to the seasonal migrations of the fish stocks with the Lofoten cod fishery as the best known (Hannesson, Salvanes, and Squires 2010). The coastal fleet is important because it takes about 50% of the cod landings, the most valuable fishery in Norway (Cojocaru et al. 2019; Asche et al. 2020). In Norway, it is a political goal to maintain coastal communities and traditional small-scale coastal fisheries. Hence, in addition to preventing overfishing, the management system is designed to protect this vessel group relative to the oceangoing vessels in order to support

1. By definition, the coastal fleet comprises vessels under 500 m^3 storage capacity or less than 28 m in length (Ministry of Trade and Industry 2016).

coastal communities (Standal, Sønvisen, and Asche 2016; Iversen et al. 2020). The coastal fleet is divided into several vessel groups with the intention to avoid an unfair direct competition between vessels of different sizes.[2] During the period relevant to our study, the coastal vessels were segmented into four groups, by size: (1) 8–9.9 m, (2) 10–14.9 m, (3) 15–20.9 m, and (4) 21–27.9 m up to a storage capacity of 500 m^3, until 2007. In 2007, a revision took place and the first two size groups were rearranged to (1) <10.9 m, and (2) 11–14.9 m, respectively. According to the Fisheries Directorate (2021a), in 2004, there were 6,395 vessels under 11 m, 841 vessels between 11 and 14.9 m, 413 vessels between 15 and 20.9 m, and 267 vessels between 21 and 27.9 m. By 2010, the vessel counts in these four groups had been reduced to 4,905, 740, 203, and 175, respectively.

The total allowable catch (TAC) for the main species (cod, saithe, and haddock) is set species by species, and the total Norwegian TAC is divided between the different vessel groups using a prescribed formula, so that each vessel group has its own TAC. Cod comprises on average around 50% of the landings, followed by 24% of saithe and haddock. Other species include halibut, redfish, ling, tusk, blue whiting, shrimp, some small pelagic species, and small quantities of more than 20 other species.

Economic efficiency is also a consideration in the Norwegian management system, particularly as the opportunity cost of labor is increasing, and the political will to provide subsidies and other support has been eroded (Standal, Sønvisen, and Asche 2016).[3] IFQs with no transferability were introduced in the oceangoing fleets in the late 1970s, and regulators only started to experiment with limited degrees of transferability in the 1990s in this part of the fleet (Standal, Sønvisen, and Asche 2016).

For the coastal fleet, what was labeled (in Norwegian) as individual fishing quotas were introduced in 1990 (Standal, Sønvisen, and Asche 2016). However, this system is in the fisheries economic literature classified as a maximum quota scheme, as the sum of the individual quotas was substantially higher than the vessel group's TAC. In the Norwegian fisheries management system, this feature is known as "overregulation." Under this maximum quota system, once the group quota is caught, the fishery is closed. Any individual vessel must stop fishing once its quota limit is reached, or once the group TAC is reached, whichever comes first. As such, there is an incentive for the vessels to compete within the same group, akin to a race to fish. However, the race incentives have been weakened over time as the degree of overregulation has been reduced and limited transferability introduced. This essentially transformed the system to an IFQ for the oceangoing fleet in the 1990s and for coastal vessels larger than 15 m in 2004 (Hannesson 2013). Transferability is limited because, for the quota to be transferred, the vessel originally owning the quota has to be removed from the fishery, and the quota can then be transferred to one or a group of vessels. Moreover, only 80% of the purchased quota is transferred to the buyer(s) for an ownership duration of 25 years (Ministry of Trade and Industry 2016), while the remaining 20% is redistributed to the pool of vessels in that particular vessel group.[4]

This system was perceived to work well, and from January 1, 2008, it was introduced to the group of vessels between 11 and 14.9 m. After the introduction of transferable quotas in 2008, the

2. Guttormsen and Roll (2011) provide a detailed description of the Norwegian fisheries management system.

3. Up until the 1990s, buyback programs were used to try to address overcapacity, but transferability of rights has gradually become the preferred tool.

4. Short-run leasing is in general not an option, although there was a trial period when restricted leases for vessels between 15 and 28 m were allowed.

number of quota transactions rapidly picked up. Around 25% of the vessels in this group bought additional quotas in 2008, and this number increased to around 32% in 2010. During the same period, the number of vessels in the 11–14.9 m group dropped by about 20%. Hence, at least some fishers found the prospect of purchasing additional quota interesting. If any of the hypotheses relevant to the impacts of IFQs hold (e.g., longer season or higher revenue), this can be interpreted as evidence that the changes in the management system have improved economic efficiency.

EMPIRICAL STRATEGY

The consequences of policy changes can be evaluated by comparing outcomes of interest not only before and after the implementation of IFQs with transferability, but also between similar and, ideally, randomly assigned groups, that are impacted by the change at different levels.[5] In particular, the benefits of the introduction of individual transferable fishing quotas can be empirically tested by analyzing the changes in (1) fishing season, (2) costs, and (3) ex-vessel prices for the main target species, cod, using a DiD identification strategy. This approach assumes that, in the absence of the policy treatment, the relative change in the outcome of interest would be the same for both groups over time (Wooldridge 2010). Then, any observable deviation from this common trend in the treatment group after the policy has been implemented would have been caused by the policy. Thus, the DiD regression model for each hypothesis can be specified as the following:

$$\ln Y_{i,y} = a_i + b \times T + c \times D + d \times (D \times T) + e_{i,y},$$

where Y represents the outcome of interest (fishing season, cost, and price), for vessel i at year y. Individual time-invariant fixed effects are captured by a_i. The time dummy, T, controls for time-related characteristics, such as quota changes before and after the policy came into effect (T is 1 from 2008). By using the time dummy for the years before and after the event, the autocorrelation issue is minimized (Bertrand, Duflo, and Mullainathan 2004). The dummy, D, is 1 for the treatment group. Two groups of vessels were included in the analysis, namely the vessel group for which IFQs with transferability were implemented in 2008 (the treatment group), and the group continuing under regulated open access unaffected by this policy (the comparison group). The treatment group comprised the vessels participating in the size group 11–14.9 m, while the comparison group comprised the vessels in the size group under 11 m. These two groups are comparable because of their similarities. Both vessel groups operate with similar harvesting technologies (Cojocaru et al. 2019) and serve the same market (Asche, Gordon, and Hannesson 2004; Asche, Chen, and Smith 2015; Pettersen and Myrland 2016; Pettersen and Asche 2020). In addition, as shown in table 1 the two vessel groups have a similar average cost and season length, and receive similar prices for cod as well as on average.

The policy effect relates to the interaction term, $D \times T$, that captures, through the DiD estimator, d, the average effect on the treatment group after the policy introduction in 2008. Finally, the error term, e, is allowed to be correlated among vessels within the same group and period (i.e., robust standard errors). To account for the multiple comparisons, we use Bonferroni adjusted p-values. The Bonferroni correction is calculated by dividing the significance level of interest by the number of comparisons (four, in our case). For instance, when considering the regular

5. By not assuming a behavioral model that is invariant to the regulatory change, we avoid misleading results linked to using ex ante production data alone, as highlighted by Reimer, Abbott, and Haynie (2017).

Table 1. Summary Statistics by Coastal Vessel Group for Outcomes of Interest and Some Vessel Characteristics (before and after the policy change, 2008)

		Before		After	
Variable	Group	Mean	Std. Dev.	Mean	Std. Dev.
Average cost (NOK/kg)	Control group: <11 m vessels	7.98	1.97	8.50	2.33
	Treatment group: 11–15 m vessels (*D*)	7.85	2.09	8.52	2.61
Season length (days)	Control group: <11 m vessels	202.30	54.42	189.30	62.44
	Treatment group: 11–15 m vessels (*D*)	212.50	53.31	203.20	56.53
Total landings price (NOK/kg)	Control group: <11 m vessels	11.05	2.52	11.43	2.70
	Treatment group: 11–15 m vessels (*D*)	11.36	2.82	12.30	3.40
Cod price (NOK/kg)	Control group: <11 m vessels	13.15	1.88	13.36	3.38
	Treatment group: 11–15 m vessels (*D*)	13.06	1.67	14.99	3.26
Vessel length (m)	Control group: <11 m vessels	10.38	1.43	10.47	0.91
	Treatment group: 11–15 m vessels (*D*)	12.47	1.92	13.39	1.56
Cod (% landings)	Control group: <11 m vessels	0.52	0.18	0.56	0.19
	Treatment group: 11–15 m vessels (*D*)	0.49	0.18	0.48	0.19
Saithe (% landings)	Control group: <11m vessels	0.12	0.15	0.11	0.13
	Treatment group: 11–15m vessels (*D*)	0.15	0.15	0.14	0.15
Haddock (% landings)	Control group: <11 m vessels	0.12	0.15	0.09	0.13
	Treatment group: 11–15 m vessels (*D*)	0.09	0.11	0.09	0.13
Other (% landings)	Control group: <11 m vessels	0.24	0.23	0.24	0.21
	Treatment group: 11–15 m vessels (*D*)	0.28	0.19	0.30	0.19

1% significance level and comparing four different hypotheses, the Bonferroni-adjusted level for rejecting the hypothesis at 1% becomes 0.25%.

A key assumption in the DiD strategy is that in the absence of a policy change, the relative change in the outcome of interest would be the same for both groups over time (i.e., they present parallel trends). To investigate whether this key assumption holds, falsification tests and a more specific parallel trend test were applied. The falsification tests consist of regressing the outcomes of interest over the pretreatment period, using a different year than the year of the policy introduction. Thus, all posttreatment data after 2007 were dropped and the policy introduction redefined as (1) from 2005, and (2) from 2006. If no statistically significant effect is observed for these years, the identifying assumption holds. By allowing a false policy treatment time before the actual policy implementation, we test potential issues in our identification strategy with respect to anticipation and, if we can rule out anticipation, the common trend assumption holds (Lechner 2010). Anticipation implies that the vessel owners would change their behavior by anticipating the change in policy. Given the "race-to-fish" environment experienced by the coastal groups before the policy change, fishers' behavior in relation to cost, season length, and price is expected to change just from the time when the policy is introduced.

To specifically test for the parallel trends, an interaction term between year-specific fixed effects and the treatment group dummy is applied to the period before the policy change. Then, the null hypothesis that the interaction terms for each year are jointly equal to 0 is tested using a Wald test. If the null is not rejected, then the parallel trend assumption holds.

Another assumption in this identification strategy is with respect to the control contamination. We assume that the control group is neither directly nor indirectly impacted by the policy. In our case, whether the IFQs were introduced or not in the treated group is unlikely to have a substantial impact on cost, season length, and price outcomes for the control group. Each group has its own TAC, and the race to fish incentives are not changed for the control group. Thus, there is no reason to believe that the costs and season length for the control group would be indirectly affected by the policy. Given that both groups supply the same market, we cannot rule out that there would be some indirect benefits from an increase in prices received by the treated group. However, this is highly unlikely, as this potential market benefit was made available to all these vessels when the IFQs were introduced in 2004, for vessels longer than 15 m.

DATA

The data used in the analysis were collected by the Norwegian Directorate of Fisheries as part of their annual fisheries profitability survey, from 2004 to 2010. Every year, the Norwegian Directorate of Fisheries randomly selects a subset of vessels from each vessel group under the coastal fleet to participate in the mandatory survey. Therefore, some vessels might appear in consecutive years, while others might not (Fisheries Directorate 2021b), resulting in an unbalanced panel. The vessel owners report annual-level information on their vessel's characteristics (e.g., vessel length), species groups landings and revenues, days of operation, and costs. From 2004 to 2010, there are on average 2.7 observations per vessel, with a minimum of 2 and a maximum of 5 observations per vessel. The control group has a total of 198 observations for the studied period, while the treatment group has 658. Using the annual vessel-level data, three variables of interest were defined. Average cost was defined as the average variable cost calculated as the fraction between variable cost and quantity landed. Cost includes labor cost, expenses related to provisions, ice, preservation, packaging, fuel, fees, and other costs. Season length was expressed as the total number of days the vessels operated (i.e., preparations, forced harbor, days at sea, and completion of fishing). Finally, the unit price for the total landings was computed as total revenue to fisher divided by total quantity landed, while the unit price for cod, the main target species, was computed as the fraction between revenue and quantity landed of cod.[6]

EMPIRICAL RESULTS

The estimated parameters from the three regression models are reported in table 2. Most parameter estimates are statistically significant at the 5% level, and in most models the R^2 is above 0.5. For the policy effects, which are the parameters of interest, there are some important variations. There is a statistically significant increase in average cost, average price, and cod price. However, the effect on season length is statistically insignificant, suggesting that there was no extension of the fishing season. All models passed the falsification test (tables 3 and 4), and the parallel trend test (table 5). This indicates that there have been no anticipation effects and that the parallel trend hypothesis holds, as does the identification strategy.

Overall, the results indicate that the introduction of IFQs had beneficial consequences for the vessels between 11 and 15 m. The IFQ scheme seems to have contributed to an increase in prices for the treatment group by as much as 13%, and an even higher increase for the cod prices (19%). The positive effect on revenue after IFQ implementation is in line with other studies (Scheld, Anderson, and Uchida 2012; Ardini and Lee 2018). We would expect the revenue increase to result

6. Using a trip-level landings dataset (quantities) containing the vessels surveyed by the Fisheries Directorate, the Gini index was also tested as a proxy for season length extension (considering both species landed together as well as species groups—e.g., cod, saithe, haddock, tusk and ling, and others), as proposed by Birkenbach, Kaczan, and Smith (2017), with no significant difference identified in the results.

Table 2. Estimated Parameters from the DiD Regressions

	Average Cost (NOK/kg)	Season Length (days)	Total Landings Price (NOK/kg)	Cod Price (NOK/kg)
Policy effect: 2008 ($D \times T$)	0.136*	0.027	0.135**	0.188***
	[0.055]	[0.068]	[0.049]	[0.048]
Treatment group: 11–15 m vessels (D)	–0.124*	–0.016	–0.172***	–0.220***
	[0.049]	[0.065]	[0.045]	[0.036]
Time: After 2008 (T)	–0.029	–0.069	–0.061	–0.101*
	[0.049]	[0.062]	[0.043]	[0.041]
Constant	2.127***	5.322***	2.533***	2.744***
	[0.041]	[0.054]	[0.037]	[0.030]
Observations	856	856	856	856
Vessels	323	323	323	323
R^2	0.690	0.593	0.687	0.407

Note: Robust standard errors are in brackets. *** p-value < 0.0025, ** p-value < 0.0125, and * p-value < 0.025.

from changes in harvesting strategy, leading to more advantageous market timing (Scheld and Anderson 2014), or it may be due to improved quality of landings allowing targeting of higher-value markets (Casey et al. 1995). Quality can be increased, for instance, by better handling of the fish, by using more quality-friendly gears, by taking shorter trips, or by targeting larger fish. Although the data cannot explicitly reveal the underlying reasons for the revenue gains, improvements in quality and better market timing seem most plausible. The role of bargaining power documented in other fisheries (Guldin and Anderson 2018; Peña-Torres et al. 2019) is unlikely to play a role in the Norwegian setting. In Norway, all ex-vessel sales are conducted by a fisher-owned sales association that sets the transaction rules, collects payments on behalf of the fishers, and guarantees a minimum price to the fishers. This sales association has been in operation since 1939 and has not changed with the IFQs.

The null hypothesis of no impact on season length cannot be rejected. The absence of such an effect on season length is not too surprising as the coastal vessels operate mostly in coastal fishing

Table 3. Falsification Test for the Outcomes of Interest (policy treatment from 2005)

	Average Cost (NOK/kg)	Season Length (days)	Total Landings Price (NOK/kg)	Cod Price (NOK/kg)
Policy effect: 2005 ($D \times T$)	–0.024	–0.044	–0.037	0.005
	[0.032]	[0.057]	[0.030]	[0.018]
Treatment group: 11–15 m vessels (D)	–0.064	–0.057	–0.090	–0.159***
	[0.075]	[0.095]	[0.063]	[0.031]
Time: From 2005 (T)	0.164***	0.173***	0.175***	0.154***
	[0.026]	[0.051]	[0.025]	[0.017]
Constant	1.969***	5.267***	2.355***	2.563***
	[0.061]	[0.082]	[0.052]	[0.026]
Observations	590	590	590	590
Vessels	243	243	243	243
R^2	0.783	0.677	0.816	0.764

Note: Robust standard errors are in brackets. *** p-value < 0.0025.

Table 4. Falsification Test for the Outcomes of Interest (policy treatment from 2006)

	Average Cost (NOK/kg)	Season Length (days)	Total Landings Price (NOK/kg)	Cod Price (NOK/kg)
Policy effect: 2006 ($D \times T$)	–0.024	–0.045	–0.020	–0.013
	[0.034]	[0.046]	[0.028]	[0.014]
Treatment group: 11–15 m vessels (D)	–0.051	–0.086	–0.085	–0.117***
	[0.071]	[0.094]	[0.059]	[0.024]
Time: From 2006 (T)	0.143***	0.099*	0.150***	0.160***
	[0.030]	[0.041]	[0.024]	[0.013]
Constant	2.016***	5.366***	2.405***	2.587***
	[0.059]	[0.078]	[0.049]	[0.020]
Observations	590	590	590	590
Vessels	243	243	243	243
R^2	0.776	0.646	0.816	0.779

Note: Robust standard errors are in brackets. *** p-value < 0.0025, * p-value < 0.025.

Table 5. Parallel Test for the Outcomes of Interest

H_0: $G \times 2005 = G \times 2006 = G \times 2007$	Average Cost	Season Length	Total Landings Price	Cod Price
$F(3, 340)$	0.380	0.540	0.520	1.980
Prob. > F	0.765	0.652	0.672	0.116

grounds during winter and spring months, when spawning aggregation occurs (Kvamsdal 2016). Hence, the geographical and gear constraints may limit the extension of the fishing season because of these vessels being too small to follow the cod into the Barents Sea. Even though this outcome has been observed for many US IFQ programs, it is not present in all fisheries (Birkenbach, Kaczan, and Smith 2017). The fact that IFQs were introduced for the trawlers in the 1990s and for the larger coastal vessels in 2004 also limits market incentives for expanding the season as these, to a large extent, have already been exploited by those vessel groups.

With respect to the final hypothesis, the results show that the IFQs increased average costs. This indicates that a more careful handling of the catch or improved timing, although necessary for obtaining higher prices, also leads to higher costs. Improved handling of the fish to increase quality includes measures such as bringing in smaller rolls or hauls, leaving the gear in the sea for shorter periods of time, and taking shorter trips. These behavioral changes increase harvest costs (Asche, Chen, and Smith 2015; Bertheussen and Dreyer 2019). However, given that there are no changes with respect to the main gear types used during this period, there is potential to increase the fish quality even further by switching to quality-enhancing gears and developing the high-value markets (Bertheussen and Dreyer 2019; Bertheussen, Dreyer, and Reiertsen 2020).

CONCLUDING REMARKS

IFQs have proven to be a good tool for reducing incentives to race to fish. Profits can be increased by extending the fishing season, increasing productivity/reducing costs, and/or obtaining higher prices by supplying higher-quality fish. A mounting empirical literature indicates that the extent to which the different effects will be present in any specific case depends on the characteristics of the fishery, as well as the supply chains and markets it is serving. This is most evident in Birkenbach, Kaczan, and Smith (2017), the only study to date that investigates the impact of the introduction of IFQs for a large number of fisheries and finds substantial variation in the extent to which the length of harvest season is changed. Most other studies focus on specific cases and, primarily because of data limitations and empirical approach, most often on only one of the effects investigated here.

In this paper, a difference-in-differences approach is used to study how changes in the regulation influenced costs, season length, and prices obtained for a group of the Norwegian coastal fleet. Findings indicate that prices have increased, pointing to an improvement in quality. Costs have also increased, suggesting that more careful handling of the catch is costly. However, there was no significant effect on season length. This is possibly due to the nature of the fishery, considering that small coastal vessels get access to the fish stock only during the spawning run when it is closest to the coast. The results thus suggest that biological features of a fishery can preclude further gains from IFQs with respect to season length. In conclusion, the context and nuances of each fishery should be considered along each margin when evaluating the effects of IFQs.

REFERENCES

Agar, J. J., J. A. Stephen, and A. Strelcheck. 2014. "The Gulf of Mexico Red Snapper IFQ Program: The First Five Years." *Marine Resource Economics* 29 (2): 177–98.

Ardini, G., and M. L. Lee. 2018. "Do IFQs in the US Atlantic Sea Scallop Fishery Impact Price and Size?" *Marine Resource Economics* 33 (3): 263–88. https://doi.org/10.1086/698199.

Arnason, R. 1990. "Minimum Information Management in Fisheries." *Canadian Journal of Economics* 23 (3): 630–53. https://doi.org/10.2307/135652.

Asche, F., M. T. Bjørndal, and T. Bjørndal. 2014. "Development in Fleet Fishing Capacity in Rights Based Fisheries." *Marine Policy* 44:166–71. https://doi.org/10.1016/j.marpol.2013.08.018.

Asche, F., T. Bjørndal, and D. V. Gordon. 2009. "Resource Rent in Individual Quota Fisheries." *Land Economics* 85 (2): 279–91. https://doi.org/10.4256/mio.2010.0010.

Asche, F., Y. Chen, and M. D. Smith. 2015. "Economic Incentives to Target Species and Fish Size: Prices and Fine-Scale Product Attributes in Norwegian Fisheries." *ICES Journal of Marine Science* 72 (3): 733–40. https://doi.org/10.1093/icesjms/fst048.

Asche, F., A. L. Cojocaru, R. B. M. Pincinato, and K. H. Roll. 2020. "Production Risk in the Norwegian Fisheries." *Environmental and Resource Economics* 75 (1): 137–49.

Asche, F., D. V. Gordon, and R. Hannesson. 2004. "Tests for Market Integration and the Law of One Price: The Market for Whitefish in France." *Marine Resource Economics* 19 (2): 195–210. https://doi.org/10.1086/mre.19.2.42629428.

Bertheussen, B. A., and B. M. Dreyer. 2019. "Is the Norwegian Cod Industry Locked into a Value-Destructive Volume Logic?" *Marine Policy* 103:113–20. https://doi.org/10.1016/j.marpol.2019.02.023.

Bertheussen, B. A., B. M. Dreyer, and A. Reiertsen. 2020. "Economic Sustainability of Quality-Enhancing Business Models in the Norwegian Cod Industry." *Marine Policy* 113:103821. https://doi.org/10.1016/j.marpol.2020.103821.

Bertrand, M., E. Duflo, and S. Mullainathan. 2004. "How Much Should We Trust Differences-in-Differences Estimates?" *Quarterly Journal of Economics* 119 (1): 249–75.

Birkenbach, A. M., A. L. Cojocaru, F. Asche, A. G. Guttormsen, and M. D. Smith. 2020. "Seasonal Harvest Patterns in Multispecies Fisheries." *Environmental and Resource Economics* 75 (3): 631–55.

Birkenbach, A. M., D. Kaczan, and M. D. Smith. 2017. "Catch Shares Slow the Race to Fish." *Nature* 544 (7649): 223–26. https://doi.org/10.1038/nature21728.

Branch, T. A. 2006. “Discards and Revenues in Multispecies Groundfish Trawl Fisheries Managed by Trip Limits on the US West Coast and by ITQS in British Columbia.” *Bulletin of Marine Science* 78 (3): 669–89.

Casey, K. E., C. M. Dewees, B. R. Turris, and J. E. Wilen. 1995. “The Effects of Individual Vessel Quotas in the British Columbia Halibut Fishery.” *Marine Resource Economics* 10 (3): 211–30. https://doi.org/10.1086/mre.10.3.42629588.

Chu, C. 2009. “Thirty Years Later: The Global Growth of ITQs and Their Influence on Stock Status in Marine Fisheries.” *Fish and Fisheries* 10 (2): 217–30. https://doi.org/10.1111/j.1467-2979.2008.00313.x.

Cojocaru, A. L., F. Asche, R. B. M. Pincinato, and H.-M. Straume. 2019. “Where Are the Fish Landed? An Analysis of Landing Plants in Norway.” *Land Economics* 95 (2): 246–57.

Dresdner, J., N. Campos, and C. Chávez. 2010. “The Impact of Individual Quotas on Technical Efficiency: Does Quality Matter?” *Environment and Development Economics* 15 (5): 585–607. https://doi.org/10.1017/S1355770X10000215.

Dupont, D. P., K. J. Fox, D. V. Gordon, and R. Q. Grafton. 2005. “Profit and Price Effects of Multi-species Individual Transferable Quotas.” *Journal of Agricultural Economics* 56 (1): 31–57. https://doi.org/10.1111/j.1477-9552.2005.tb00121.x.

Dupont, D. P., R. Q. Grafton, J. Kirkley, and D. Squires. 2002. “Capacity Utilization Measures and Excess Capacity in Multi-product Privatized Fisheries.” *Resource and Energy Economics* 24 (3): 193–210. https://doi.org/10.1016/S0928-7655(01)00050-1.

Fisheries Directorate. 2021a. “Fiskeflåten.” Accessed June 1, 2021. https://www.fiskeridir.no/Yrkesfiske/Tall-og-analyse/Fiskere-fartoey-og-tillatelser/Fartoey-i-merkeregisteret/fiskeflaaten.

———. 2021b. “Om statistikken—Loennsomhet fiskeflaaten.” Accessed February 18, 2021. https://www.fiskeridir.no/Yrkesfiske/Tall-og-analyse/Loennsomhet/Om-statistikken-Loennsomhet-fiskeflaaten.

Grafton, R. Q. 1996. “Individual Transferable Quotas: Theory and Practice.” *Reviews in Fish Biology and Fisheries* 6:5–20. https://doi.org/10.1007/BF00058517.

Grafton, R. Q., R. Arnason, T. Bjørndal, D. Campbell, H. F. Campbell, C. W. Clark, R. Connor, et al. 2006. “Incentive-Based Approaches to Sustainable Fisheries.” *Canadian Journal of Fisheries and Aquatic Sciences* 63:699–710.

Grafton, R. Q., D. Squires, and K. J. Fox. 2000. “Private Property and Economic Efficiency: A Study of a Common-Pool Resource.” *Journal of Law and Economics* 43 (2): 679–713.

Guldin, M., and C. M. Anderson. 2018. “Catch Shares and Shoreside Processors: A Costs and Earnings Exploration into the Downstream Sector.” *Marine Resource Economics* 33 (3): 289–307.

Guttormsen, A. G., and K. H. Roll. 2011. “Technical Efficiency in a Heterogeneous Fishery: The Case of Norwegian Whitefish Fisheries.” *Marine Resource Economics* 26 (4): 293–307.

Hamon, K. G., O. Thébaud, S. Frusher, and L. R. Little. 2009. “A Retrospective Analysis of the Effects of Adopting Individual Transferable Quotas in the Tasmanian Red Rock Lobster, *Jasus edwardsii*, Fishery.” *Aquatic Living Resources* 22:549–58. https://doi.org/10.1051/alr/2009039.

Hannesson, R. 2013. “Norway’s Experience with ITQs.” *Marine Policy* 37:264–69. https://doi.org/10.1016/j.marpol.2012.05.008.

Hannesson, R., K. G. Salvanes, and D. Squires. 2010. “Technological Change and the Tragedy of the Commons: The Lofoten Fishery over 130 Years.” *Land Economics* 86 (4): 746–65.

Homans, F. R., and J. E. Wilen. 1997. “A Model of Regulated Open Access Resource Use.” *Journal of Environmental Economics and Management* 32 (1): 1–21. https://doi.org/10.1006/jeem.1996.0947.

———. 2005. “Market Rent Dissipation in Regulated Open Access Fisheries.” *Journal of Environmental Economics* 49 (2): 381–404. https://doi.org/10.1016/j.jeem.2003.12.008.

Hsueh, L. 2017. “Quasi-Experimental Evidence on the “Rights to Fish”: The Effects of Catch Shares on Fishermen’s Days at Sea.” *Journal of the Association of Environmental and Resource Economists* 4 (2): 407–45.

Iversen, A., F. Asche, M. Buck, E. Henriksen, J. Stein, and S. Svalestuen. 2020. "The Growth and Decline of Fisheries Communities: Explaining Relative Population Growth at MUNICIPALITY LEVEL." *Marine Policy* 112:103776. doi.org/10.1016/j.marpol.2019.103776.

Kompas, T., and T. N. Che. 2005. "Efficiency Gains and Cost Reductions from Individual Transferable Quotas: A Stochastic Cost Frontier for the Australian South East Fishery." *Journal of Productivity Analysis* 23 (3): 285–307. https://doi.org/10.1007/s11123-005-2210-1.

Kroetz, K., J. N. Sanchirico, and D. K. Lew. 2015. "Efficiency Costs of Social Objectives in Tradable Permit Programs." *Journal of the Association of Environmental and Resource Economists* 2 (3): 339–66. https://doi.org/10.1086/681646.

Kroetz, K., J. N. Sanchirico, J. Peña-Torres, and D. C. Novoa. 2017. "Evaluation of the Chilean Jack Mackerel ITQ System." *Marine Resource Economics* 32 (2): 217–41.

Kvamsdal, S. 2016. "Technical Change as a Stochastic Trend in a Fisheries Model." *Marine Resource Economics* 31 (4): 403–19.

Lechner, M. 2010. "The Estimation of Causal Effects by Difference-in-Difference Methods." *Foundations and Trends in Econometrics* 4 (3): 165–224. https://doi.org/10.1561/0800000014.

Ministry of Trade and Industry. 2016. *Et fremtidsrettet kvotesystem*. NOU 2016: 26. Oslo: Fisheries Department.

Peña-Torres, J., J. Dresdner, F. Quezada, and I. Luzardo. 2019. "Collective Share Quotas and the Role of Fishermen's Organizations in Ex-Vessel Price Determination." *Marine Resource Economics* 34 (4): 361–85. https://doi.org/10.1086/705788.

Pettersen, I. K., and F. Asche. 2020. "Hedonic Price Analysis of Ex-Vessel Cod in Norway." *Marine Resource Economics* 35 (4): 343–59.

Pettersen, I. K., and Ø. Myrland. 2016. "A Cod Is a Cod, but Is It a Commodity?" *Journal of Commodity Markets* 3 (1): 70–75. https://doi.org/10.1016/j.jcomm.2016.07.003.

Reimer, M. N., J. K. Abbott, and A. C. Haynie. 2017. "Empirical Models of Fisheries Production: Conflating Technology with Incentives?" *Marine Resource Economics* 32 (2): 169–90.

Scheld, A. M., and C. M. Anderson. 2014. "Market Effects of Catch Share Management: The Case of New England Multispecies Groundfish." *ICES Journal of Marine Science* 71 (7): 1835–45.

Scheld, A. M., C. M. Anderson, and H. Uchida, 2012. "The Economic Effects of Catch Share Management: The Rhode Island Fluke Sector Pilot Program." *Marine Resource Economics* 27 (3): 203–28.

Solís, D., J. J. Agar, and J. del Corral. 2015. "IFQs and Total Factor Productivity Changes: The Case of the Gulf of Mexico Red Snapper Fishery." *Marine Policy* 62:347–57. https://doi.org/10.1016/j.marpol.2015.06.001.

Standal, D., S. A. Sønvisen, and F. Asche. 2016. "Fishing in Deep Waters: The Development of a Deep-Sea Fishing Coastal Fleet in Norway." *Marine Policy* 63:1–7. https://doi.org/10.1016/j.marpol.2015.09.017.

Walden, J. B., J. E. Kirkley, R. Färe, and P. Logan. 2012. "Productivity Change under an Individual Transferable Quota Management System." *American Journal of Agricultural Economics* 94 (4): 913–28. https://doi.org/10.1093/ajae/aas025.

Wooldridge, J. M. 2010. *Econometric Analysis of Cross Section and Panel Data*. 2nd ed. Cambridge, MA: MIT Press.